Activity-Based Travel Model Estimation:

Coordinated Travel – Regional Activity Based Modeling Platform (CT-RAMP) for San Diego County

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Table of Contents

Table of Tables

Table of Figures

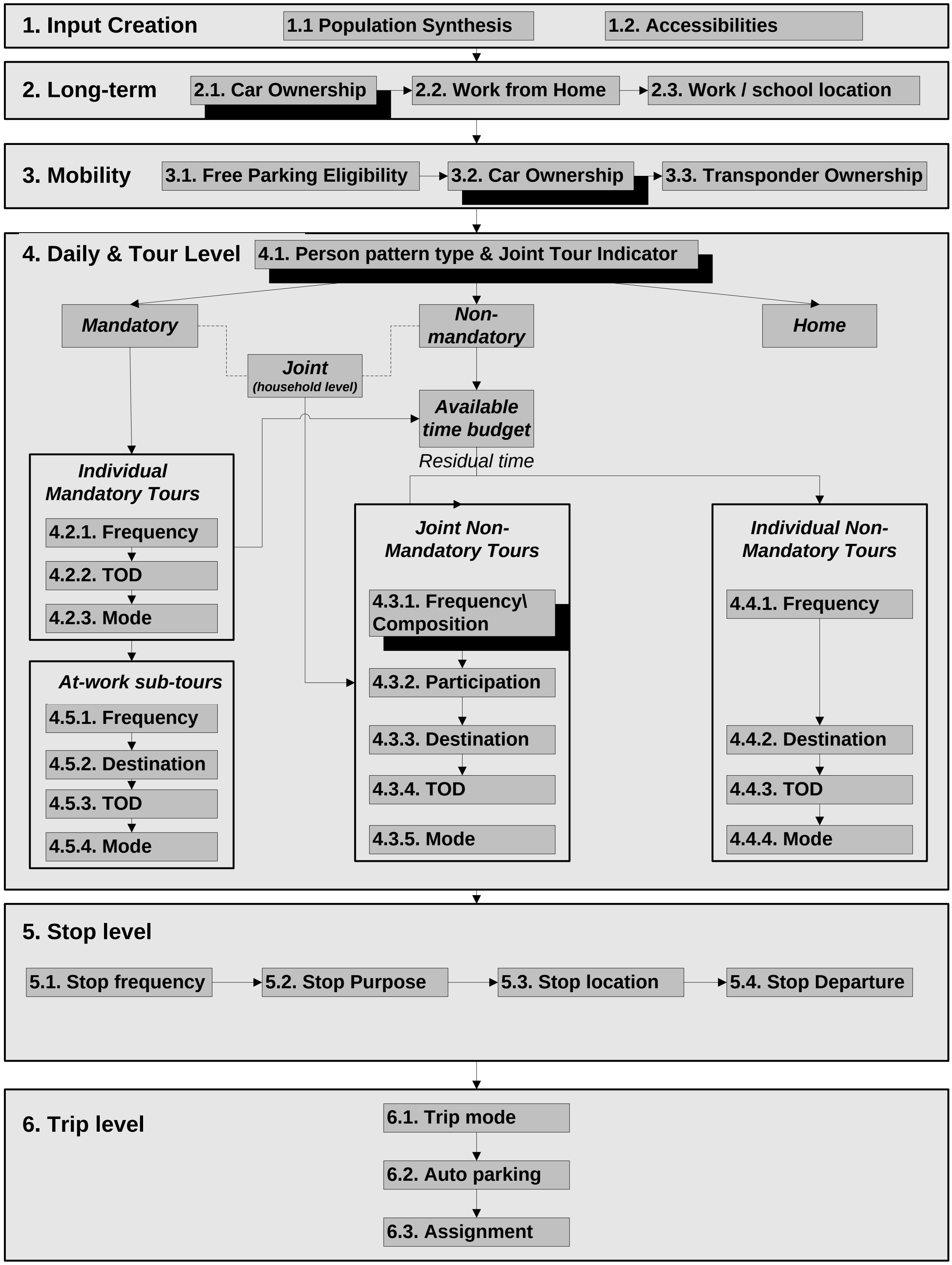
I. San Diego Resident Models

1.0 Introduction

This document describes the San Diego Association of Governments (SANDAG) Activity-Based Model (ABM) estimation. This ABM will serve as the major travel forecasting tool in the San Diego region for decades to come. This model ensures that the regional transportation planning process can rely on forecasting tools that will be adequate for new socioeconomic environments and emerging planning challenges. It is equally suitable for conventional highway projects, transit projects, and various policy studies such as highway pricing and HOV analysis.

The SANDAG model is based on the CT-RAMP (Coordinated Travel Regional Activity-Based Modeling Platform) family of Activity-Based Models. This model system is an advanced, but operational, AB model that fits the needs and planning processes of SANDAG. The CT-RAMP estimation is fully described in the following sections. The flow of the sub-models is shown in Figure 1. For more detailed information on the design of the models, refer to the document *SANDAG Activity Based Model Specifications*: *Coordinated Travel – Regional Activity Based Modeling Platform (CT-RAMP) for San Diego County.*

Figure 1: Basic Model Design and Linkage Between Sub-Models



2.0 Long Term Choice Models

This section describes the estimation of each model component including the estimation dataset, the coefficients and t-statistics of the main explanatory variables used, the utility structure if applicable, and a summary of the findings of the estimation results.

2.1 Auto Ownership

Auto ownership model estimation is described in Section 3.2.

2.2 Work from Home Choice

The work from home choice model predicts if a worker's (full-time or part-time) usual work place is home or if he/she works from home. The model was estimated as a binary multinomial logit using the ALOGIT software. This model is one of the first models applied in the model chain. It is applied before the usual out-of-home work destination choice model. The work from home choice model is applied to all workers and it includes general accessibilities to work locations, household characteristics and worker characteristics as explanatory variables.

Estimation Dataset

In the SANDAG 2006 Household Travel Behavior Survey, there are 4,151 observed worker records for both full-time and part-time workers. Table **1** below shows the workers in surveyed households by worker status, gender, age group, household income category and education level. Overall, the dataset shows that 11% of all workers work from home and 89% workers travel to work locations. The data shows that 19% of part-time workers work from home, whereas only 9% of full-time workers work from home. The percentage of working from home individuals increases from 6% for 35 years or younger individuals to 19% among 65 years or older workers.

Table 1: Frequencies of Working from Home

	Work from home				Total
	Yes		No		
Worker Status					
Full-time Worker	319	9%	3,064	91%	3,383
Part-time Worker	147	19%	621	81%	768
Total	**466**	**11%**	**3,685**	**89%**	**4,151**
Gender					
Male	256	11%	1,978	89%	2,234
Female	210	11%	1,705	89%	1,915
Unknown	0	0%	2	100%	2
Total	**466**	**11%**	**3,685**	**89%**	**4,151**
Age Group					
Less than 35 yrs	60	6%	946	94%	1,006
35 yrs to 45yrs	101	10%	871	90%	972
45 yrs to 55 yrs	137	12%	1,022	88%	1,159
55 yrs to 65 yrs	105	15%	575	85%	680
Older than 65 yrs	63	19%	271	81%	334
Total	**466**	**11%**	**3,685**	**89%**	**4,151**
Income Group					
Less than 30K	33	8%	396	92%	429
30K to 60K	92	12%	689	88%	781
60K to 100K	117	10%	1,006	90%	1,123
More than 100K	182	12%	1,297	88%	1,479
Unknown	42	12%	297	88%	339
Total	**466**	**11%**	**3,685**	**89%**	**4,151**
Education Level					
Bachelors or higher degree	293	13%	1,956	87%	2,249
Less than Bachelors	173	9%	1,729	91%	1,902
Total	**466**	**11%**	**3,685**	**89%**	**4,151**

The survey observations were joined with destination alternatives' MGRA based general accessibilities to create the estimation file.

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

Work accessibility:

Auto logsum to work (mandatory accessibility term 7)

Household income group:

Low income (less than $30,000)

Medium low income ($30,000-$60,000)

Medium income ($60,000-100,000)

Medium high income ($100,000-150,000)

High income ($150,000 and more)

Household composition:

Presence of non-working adults

Presence of preschool child

Person characteristics interacted with distance terms:

Work status – full-time vs part-time

Gender – female vs male

Education level –bachelor's degree or higher

Age group

Utility Structure

The utility (U_{in}) of choosing to work from home for an individual (n) in zone (i) is given by

$$U_{in} = \alpha + \delta \times A_i + \sum_k \beta_k \times N_{nk}$$

Where, α is the flat constant for choosing to work from home, A_i is the accessibility from zone (*i*), and N_{nk} represents various person or household characteristics for individual n.

Results

The work from home choice estimation results are summarized in Table 2. Since, this is a binary choice model, all utility components are added in the utility for work from home and the other utility is set to zero.

Table 2: SANDAG Work from Home Choice Model Estimation Results

Observations:	4151
Log likelihood with Constants only:	-1457.9094
Final log likelihood:	-1388.4521
Rho-Squared (0):	0.5174
Rho-Squared (constant):	0.0476

Utility Function Variables	Coeff	T-Stat
Constant	0.4384	0.2516
Total employment accessibility (Accessibility to workplaces from the home MGRA)	-0.1404	-1.1238
Full-time worker	-0.8119	-6.7365
Female worker	-0.3470	-3.0985
Education level		
Bachelors or higher	0.2847	2.6733
Age group		
Less than 35 years	-0.5735	-3.3244
35 years to 45 years	0.0000	0.0000
45 years to 55 years	0.2144	1.4910
55 years to 65 years	0.4517	2.9076
Older than 65 years	0.5835	2.9312
Household characteristics		
Income less than 30K	-0.3931	-1.9735
Female worker with a preschool child	0.5727	2.7676
Presence of non-working adults	-0.3725	-2.2044

Findings:

- Constant: The constant for work from home is positive, but it is offset by the negative coefficient on total accessibility.
- Coefficient on full-time worker: It is negative as expected. It means that part-time workers are more likely to work from home on a regular basis.
- Coefficients for females: There are two coefficients for females – one directly on female and another captures the affect when a preschool child is present in the household. The later coefficient is positive and fully offsets the effect of negative female coefficient. Females without preschool children are less likely to work from home and females with preschool children are more likely to work from home.
- Household income: Low income group (<=30K) workers are less likely to work from home.
- Age: There is a clear progression within age group which shows that older age workers are more likely to work from home as compared to younger workers.

- Education level: Workers with bachelor's or higher education are more likely to work from home. This probably is due to nature of work for individuals with bachelors or higher degree.
- Non-working adults at home: Workers with non-working adults at home are less likely to work from home.

2.3 Work and School Location Choices

2.3.1 Mandatory (Workplace) Location Choice

The work destination choice model predicts the usual out-of-home work location for full-time and part-time workers. The model was estimated in a multinomial logit form using the ALOGIT software. This model is one of the first models applied in the model chain. It is preceded by the binary work from home model which identifies individuals working from home. The work destination choice model is applied to all workers who do not work from home. The work destination choice model includes mode choice logsum, distance terms, zonal employment, household characteristics and worker characteristics as explanatory variables.

Estimation Dataset

In the SANDAG 2006 Household Travel Behavior Survey, there are 3,477 observed worker records including both full-time and part-time workers after excluding workers who work from home. Since, there are a large number of destination alternatives; it is not possible to include all alternatives in the estimation dataset. A sampling-by-importance approach was used to choose an alternatives set for each worker. Each worker record was duplicated 10 times and different choice sets with 40 alternatives were selected based on the size term and distance. This approach was statistically equivalent to selecting 400 alternatives for the choice set. Table 3 below shows the working adults in the surveyed households by worker status, gender and income group.

Table 3: Frequencies of Working Out-of-home Adults

	Count	Percentage
Worker status		
Full-time	2,534	72.88%
Part-time	943	27.12%
Gender		
Male	1,784	51.31%
Female	1,692	48.66%
Missing	1	0.03%
Income group		
Less than 30K	393	11.30%
30K to 60K	718	20.65%
60K to 100K	1,059	30.46%
100K to 150K	857	24.65%
More than 150K	450	12.94%
Total	**3,477**	**100%**

The survey observations were joined with destination alternatives' MGRA based mode choice logsum, distance from home and employment to create the estimation file.

Main Explanatory Variables

The following variables were examined and proved to be significant in the utility functions:

- Mode choice logsum
- Impedance between the home and potential work destinations:
  - Linear distance
  - Distance square root
  - Distance squared
  - Distance cubed
- Household income group interacted with distance terms:
  - Low income (less than $60,000)
  - Medium income ($60,000-100,000)
  - High income ($100,000 and more)
- Total employment
- Person Characteristics interacted with distance terms:
  - Work Status – Full-time vs. Part-time

- Gender – Female vs. Male

Utility Structure

The utility (U_{ijn}) of choosing a work destination (j) for an individual (n) in zone (i) is given by

$$U_{ijn} = S_j + \alpha \times L_{ij} + \sum \beta^k \times D_{ij}^k + \sum \beta^k \times D_{ij}^k N_n^k + C_{jn}$$

Where, S_j is the size variable for destination zone *j*, L_{ij} is the mode choice logsum between zone pair *ij*, D_{ij}^k represents the various distance terms (linear, log, squared, cubed and square root), N_n^k represent person or household characteristics for individual n and is used for creating interaction variable with distance terms, and C_{jn} is a correction term to compensate for the sampling bias in the model estimation (i.e. represent the difference between the sampling probability and final estimated probability for each alternative). The appendix explains how this correction factor is calculated.

A combination of distance terms is used in the utility such that the composite distance utility function is monotonically decreasing within the maximum chosen work distance (72 miles) range. Table 4 shows the frequency of distance to work location for 3,933 workers in the dataset.

Table 4: Frequency of Distance to Chosen Work Destinations

Bin (miles)	Frequency
5	1,543
10	852
15	622
20	409
25	240
30	111
35	70
40	44
45	21
50	10
55	2
60	5
65	3
70	0
75	1
Total	**3,933**

Results

The work destination choice estimation results are summarized in Table 5.

Table 5-a: SANDAG Out-of-Home Usual Work Location Choice Model Estimation Results

Observations:	3390(x10)
Final log likelihood:	-112604.2459
Rho-Squared (0):	0.0897
Rho-Squared (constant):	0.0847

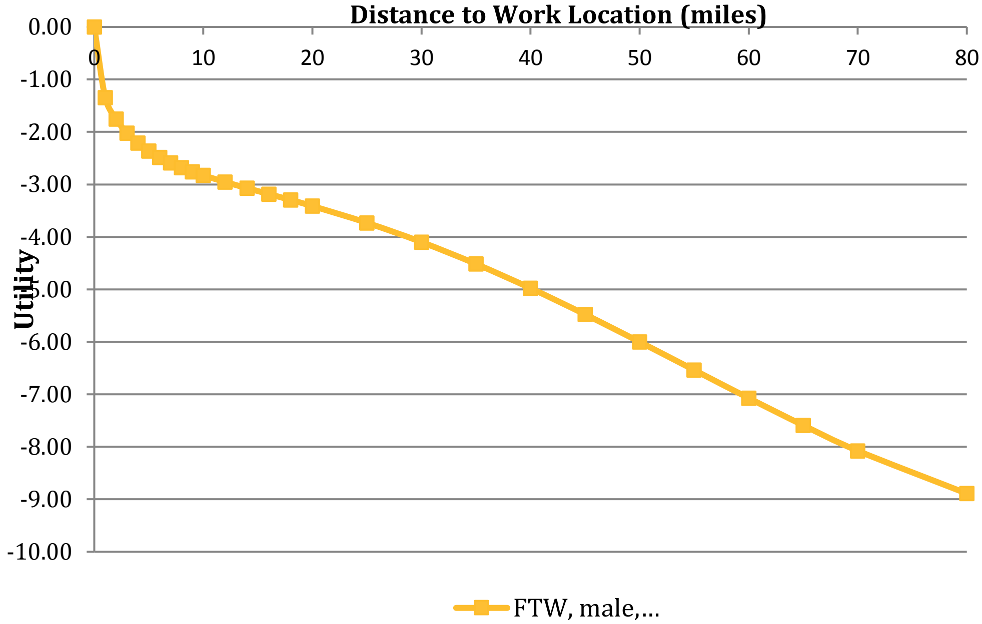
Utility Function Variables	Coeff	T-Stat
Sample of alternatives correction factor	1.000	
Mode Choice Logsum	0.547	16.08
Distance	0.266	14.00
Distance Square Root	-1.604	-22.95
Distance Squared	-0.004	-10.86
Distance Cubed	0.00002	6.04
Distance interact with Part-time worker		
Distance - part-time worker	-0.116	-23.37
Distance Squared – part-time worker	0.0004	2.34
Distance interact with Female		
Distance - female	-0.025	-15.68
Distance interact with Low Income Group (<=60K)		
Distance – low income	0.194	9.49
Distance Square Root – low income	-0.872	-10.03
Distance Squared – low income	-0.002	-9.24
Distance interact with High Income Group (>100K)		
Distance Squared – high income	0.0002	3.86
Distance – high income	0	
Size Variable		
Total Employment	1.0000	
No attractions if no employment in zone	-999.0	

Findings

- The coefficient on mode choice logsum is positive as expected.
- Composite distance function (or distance decay factor) has been defined as a combination of linear, square root, squared and cubed distance terms with different coefficients. This term should be analyzed as a composite term and the coefficient (positive or negative) of individual terms should not be looked at. For example, the coefficient on linear distance is positive but it does not mean that workers choose distant locations as work places. But, we should look at the combined effect of all terms. Figure 2shows the distance decay factor (or the composite distance term) for the reference case (i.e. full-time worker, male and medium

income group). This function is monotonously decreasing in within the maximum chosen work distance range.

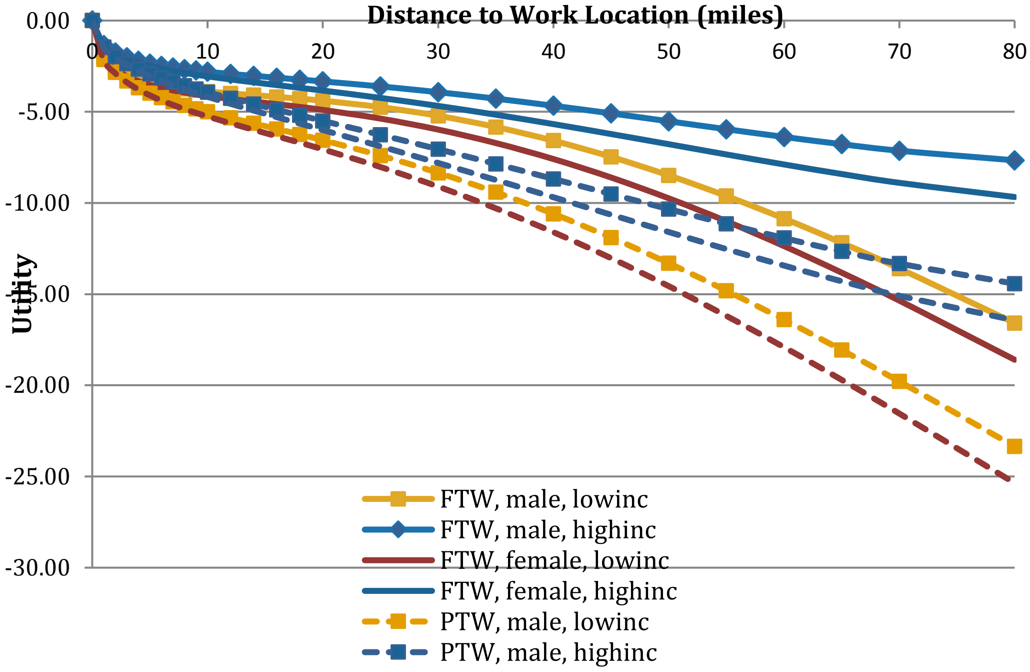
Figure 2: Distance Decay Factor



The effects of work status (full-time vs. part-time), gender (females vs. males) and household income was found siginificant on distance to work location. The findings are below:

- Part-time workers are most sensitive to longer commute than full-time workers. The sensitivity increases with longer distances.
- Females are less likely to travel longer distances as compared to males. This could be due to household responsibility and children at home.
- Income group: Low income workers are more sensitive to commuting longer distances. Longer distances would increase the cost of commuting and it could be the reason low income workers prefer to work close to their homes.
- Figure 3 shows the distance decay function for various segments based on work status, gender and income group. For income group, only low income and high income categories are shown. The medium income decay factor will fall between the low and high income groups.

Figure 3: Distance Decay Factor by Segments



FTW	Full-time worker
PTW	Part-time worker
Lowinc	Low income group (<=60K)
Highinc	High income group (>100K)

Size Terms: Total employment was used as the size term in the model estimation, since unfortunately the household survey did not collect worker occupation. However, in application, worker occupation is used to segment workers, and each occupation category has its own size term, reflecting differences in the attractiveness of specific types of employment for different worker occupations. These size terms are consistent with the labor participation rates of workers by worker occupation in employment categories, according to the PECAS land-use model. The size terms implemented are shown in Table5-b

Table 5-b: SANDAG Usual Work Location Choice Model Implemented Size Terms

	Management Business Science and Arts Labor	Services Labor	Sales and Office Labor	Natural Resources Construction and Maintenance Labor	Production Transportation and Material Moving Labor	Military Labor
Agriculture	0.2676	0.0800	0.0482	0.5408	0.0633	0.0000
Construction Production	0.0000	0.0087	0.0000	0.9151	0.0762	0.0000
Construction Support	0.6700	0.0000	0.3300	0.0000	0.0000	0.0000
Utilities Production	0.0000	0.0353	0.0000	0.5967	0.3680	0.0000
Utilities Office	0.6321	0.0000	0.3679	0.0000	0.0000	0.0000
Construction of Buildings production	0.0000	0.0096	0.0000	0.9378	0.0526	0.0000
Construction of Buildings office support	0.6919	0.0000	0.3081	0.0000	0.0000	0.0000
Manufacturing Production	0.0000	0.0229	0.0000	0.1348	0.8423	0.0000
Manufacturing Office	0.7155	0.0000	0.2845	0.0000	0.0000	0.0000
Wholesale and Warehousing	0.2103	0.0141	0.5339	0.0752	0.1665	0.0000
Transportation Activity	0.1080	0.0308	0.2632	0.0643	0.5338	0.0000
Retail Activity	0.1253	0.0304	0.6930	0.0484	0.1029	0.0000
Professional and Business Services	0.5841	0.0179	0.3478	0.0330	0.0171	0.0000
Professional and Business Building Maint	0.1591	0.4642	0.2437	0.0431	0.0898	0.0000
Private Education Elementary K-12	0.7769	0.1223	0.0795	0.0067	0.0146	0.0000
Private Education Post-Secondary	0.7381	0.0557	0.1708	0.0124	0.0229	0.0000
Health Services	0.5645	0.2241	0.1888	0.0061	0.0166	0.0000
Personal Services Office-Based	0.6074	0.1250	0.2094	0.0239	0.0343	0.0000

Amusement Services	0.3340	0.3760	0.2131	0.0355	0.0414	0.0000
Hotels and Motels	0.1776	0.5096	0.2446	0.0249	0.0432	0.0000
Restaurants and Bars	0.1215	0.7271	0.1086	0.0029	0.0399	0.0000
Personal Services Retail-Based	0.1504	0.4131	0.1217	0.1912	0.1236	0.0000
Religious Activity	0.6512	0.1276	0.1868	0.0223	0.0122	0.0000
Private Households	0.0110	0.9674	0.0126	0.0034	0.0056	0.0000
State and Local Government	0.2360	0.1708	0.1690	0.2014	0.2228	0.0000
Federal Non-Military	0.4078	0.1373	0.2810	0.0937	0.0802	0.0000
Federal Military Activity	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
State and Local Government Blue Collar	0.0000	0.8742	0.0000	0.0797	0.0461	0.0000
State and Local Government White Collar	0.5907	0.0000	0.4093	0.0000	0.0000	0.0000
Public Education (K-12)	0.7680	0.0917	0.1058	0.0125	0.0220	0.0000

2.3.2 Mandatory (University/School) Location Choice

The school destination choice model predicts the usual school location for all student types. The model was estimated as a multinomial logit with size variables using the ALOGIT software. This model is applied very early in the model chain with work destination choice model. This model is fully segmented by four student types – preschoolers, kindergarten to 6th grade, 7th to 12th grade and university students. The school destination choice model includes mode choice logsum, distance terms, enrollments, employment, population, household characteristics and student characteristics as explanatory variables.

Estimation Dataset

In the SANDAG 2006 household travel behavior survey, there are 2197 observed student records including 235 preschoolers, 737 kindergarten to 6th graders, 703 7th -12th graders and 522 university students. Table 6 below shows the student in the surveyed households by income group, person type and age categories.

Table 6: Frequencies on Students

	Preschool		K to 6th		7th to 12th		University	
	Count	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Age								
0 to 3 years	124	53%						
4 to 6 years	106	45%						
Driving Age Students					255	36%		
Under 25 years							234	45%
Person Type								
University Students (3)							255	49%
Workers (1,2)							235	45%
Non-Working Adults /Retirees (4,5)							32	6%
Income Group								
Less than 30K	35	15%	123	17%	104	15%	92	18%
30K to 60K	34	14%	138	19%	124	18%	136	26%
60K to 100K	61	26%	188	26%	160	23%	112	21%
100K to 150K	69	29%	164	22%	146	21%	98	19%
More than 150K	24	10%	73	10%	91	13%	45	9%
Missing	12	5%	51	7%	78	11%	39	7%
Total	**235**	**100%**	**737**	**100%**	**703**	**100%**	**522**	**100%**

Since there are a large number of destination alternatives; it is not possible to include all alternatives in the estimation dataset. A sampling-by-importance approach (similar to the approach used for work destination choice model) was used to choose alternatives set for each student. Each record was duplicated 20 times and different choice sets with 30 alternatives each were selected based on the size term and distance. This approach, statistically, is equivalent to selecting 20x30=600 alternatives for the choice set.

The survey observations were joined with destination alternatives' MGRA based mode choice logsum, distance, enrollments, population and employment to create the estimation file.

Main Explanatory Variables and Segmentation

The model is fully segmented by the four student types:

1. Preschoolers
2. Kindergarten to 8th grade
3. 9th grade to 12th grade
4. University students

The following variables were examined and proved to be significant in the utility functions:

Mode Choice Logsum

Impedance between the home and potential school destinations

- Linear distance
- Log of distance (defined as log(1+distance))
- Distance square root
- Distance squared
- Distance cubed

Household income group interacted with distance terms:

- Low income (less than $60,000)
- Medium income ($60,000-100,000)
- High income ($100,000 and more)

Size Variables

- School Enrollments- for kindergarten to 12th graders
- University, college and adult school enrollments- for university students with large enrollments
- Population - for preschoolers model
- Employment (for preschooler model) - consists of following categories - Professional and Business Services, Professional and Business Building Maintenance, Private Education Elementary K-12, Private Education Post-Secondary, Health Services, Religious Activity, State and Local Government, Federal Non-Military, Federal Military Activity, State and Local Government Blue Collar, State and Local Government White Collar and Public Education (K-12).

Person Characteristics interacted with distance terms:

- Age Category

- Person Type

Utility Structure

The utility (U_{ijn}^{k}) of choosing a school destination (*j*) for an individual (*n*) from segment (k) in zone (*i*) is given by

$$U_{ijn}^{k} = S_{j}^{k} + \alpha^{k} \times L_{ij} + \sum_{p} \beta^{pk} \times D_{ij}^{p} + \sum_{q} \beta^{qk} \times D_{ij} N_{n}^{q} + C_{jn}$$

Where, segment (*k)* represents the student types, S_{j}^{k} is the size function for destination zone *j* and segment *k*, L_{ij} is the mode choice logsum between zone pair *ij*, D_{ij}^{p} represents the various distance terms (*p = linear, log, squared, cubed and square root*), N_{n}^{q} represents the q[th] person's household characteristics (such as income, age group, person type) for individual n and are used for creating interaction variable with linear distance (D_{ij}), and C_{jn} is a correction term to compensate for the sampling error in the model estimation (i.e. represent the difference between the sampling probability and final estimated probability for each alternative). The appendix explains how this correction factor is calculated.

The size function (S_{j}^{k}) for destination j, segment k is a combination of different (*d*) size variables (S_{jd}^{k}) such as enrollments, employment, population and their interaction with person characteristics. It is included in the utility function as a log term. The coefficients (γ_{d}^{k}) on the size terms are constrained as positive in the estimation process.

$$S_{j}^{k} = \log(S_{j1}^{k} + \sum_{d>1} \gamma_{d}^{k} \times S_{jd}^{k})$$

A combination of distance terms is used in the utility such that the composite distance utility function is monotonically decreasing within the maximum chosen school distance range. Table 7 shows the frequency of distance to school location for each student type in the dataset.

Table 7: Frequency of observed distance to usual school location by student type

Bin(miles)	Preschooler(1)	K to 8th grader (2)	9th to 12th grader (3)	University(4)
2	89	462	267	52
4	55	106	213	50
6	39	61	77	66
8	14	17	42	72
10	9	20	29	48
15	16	51	45	96
20	8	10	16	75
25	4	4	3	24
30	0	4	6	14
35	1	2	0	9
40	0	0	5	5
45	0	0	0	7
50	0	0	0	2
55	0	0	0	0
60	0	0	0	0
65	0	0	0	2

Results: Pre-School Student Model:

Table 8 shows the estimation results for usual school destination choice model for pre-school children.

Findings:

- The coefficient on mode choice logsum is constrained to 1 as the unconstrained coefficient was greater than 1 and quite significant. The value of this logsum parameter should be between 0 and 1, because it is equivalent of nesting coefficient with mode choice at the lower level and destination choice at the upper level.
- Size Variable is a non-linear function of employment and population. The coefficient on employment is constrained to 1 and population coefficient is estimated relative to it. The coefficient on population is much weaker than the employment coefficient which shows that employment is the governing attraction for pre-school students.

Table 8: SANDAG Usual School Location Choice Model Estimation Results for Pre-School Children

Observations:	4400
Likelihood with Constants only:	-14685.08
Final log likelihood:	-8144.09
Rho-Squared (0):	0.4596
Rho-Squared (constant):	0.4454

Parameter	Coeff	T-Stat
Sample of alternatives correction factor	1.0000	
Ln Size Variables (Total Employment + 0.188*Population)	1.000	
Population	0.1888	-35.28
Employment		
Professional and Business Services	1.0000	
Professional and Business Building Maint	1.0000	
Private Education Elementary K-12	1.0000	
Private Education Post-Secondary	1.0000	
Health Services	1.0000	
Religious Activity	1.0000	
Federal Non-Military	1.0000	
Federal Military Activity	1.0000	
State and Local Government Blue Collar	1.0000	
State and Local Government White Collar	1.0000	
Public Education (K-12)	1.0000	
State and Local Government Enterprises Activity	1.0000	
Impedance		
Mode Choice Logsum	0.5	
Linear Distance	0.4333	1.27
Natural Log Distance Ln(1+ Distance)	4.3415	1.50
Square Root of Distance	-7.3800	-2.06
Distance Squared	0.0125	2.93
Distance Cubed	-0.0004	-4.79
Distance interacted with Income Groups		
Distance – low income (Household Income <=60K)	-0.0956	-8.14
Distance interacted with Age Group		
Distance - Age 0 to 3 years	-0.007	-0.98
No attractions if no employment or population in zone (Preschool Specific)	-999.0	

- Composite Distance Function (or Distance Decay factor) has been defined as a combination of linear, logged, square root, squared and cubed distance terms with different coefficients. Some of these terms are also interacted with income groups. Figure 4 shows the distance decay factor for the three income groups within the maximum observed home to school distance range. Figure 5 shows the same graph for up to 100 mile range and shows that the function is monotonously decreasing.
- Low income households are more sensitive to distance.
- Younger children (0 to 3 years) are slightly more sensitive to longer distances. It is possible that younger kids go to pre-schools closer to home.

Figure 4: Distance Decay Factor for Preschoolers

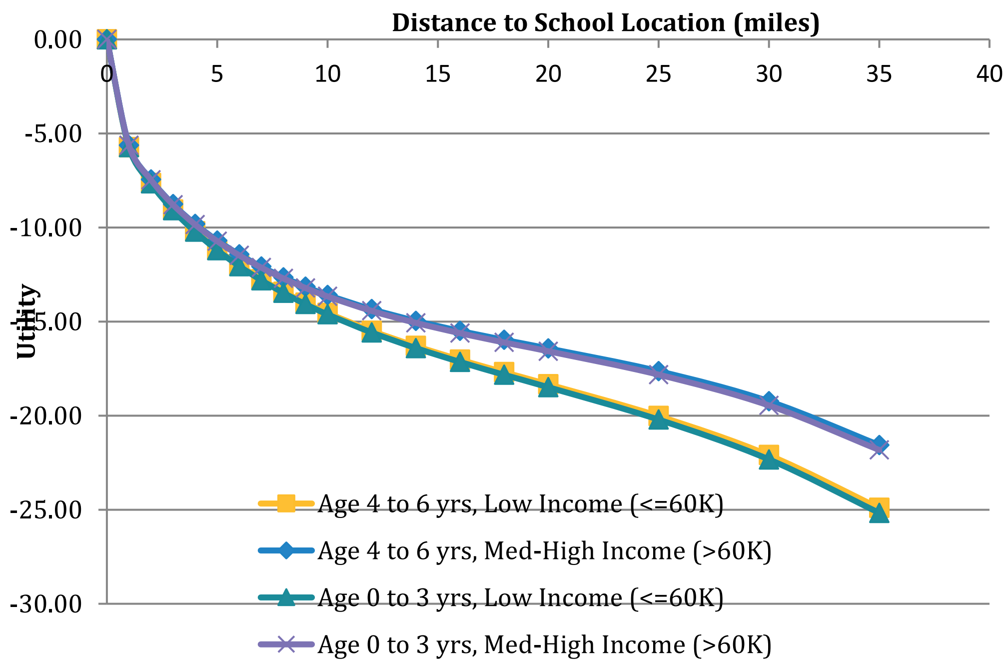
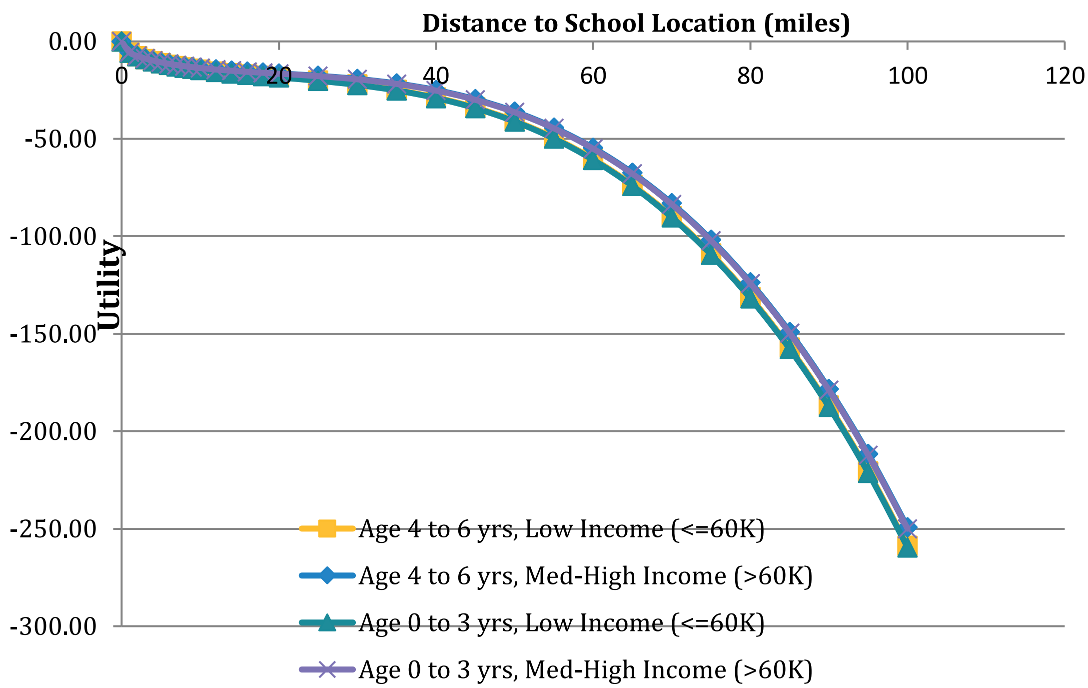


Figure 5: Distance Decay Factor for Preschoolers



Results: Kindergarten to 8th Grade (K8) Model

Table 9 below shows the estimation results for school destination model for kindergarten to 8th grade students. The explanatory power of this school location models is quite high –a rho-squared of 0.691. It could probably because school locations for kindergarten to 8th are close to home and also restricted by school district so there are few likely destinations.

Table 9: SANDAG Usual School Location Choice Model Estimation Results for Kindergarten to 8th grade students

Observations:	14720
Likelihood with Constants only:	-48568.68
Final log likelihood:	-15265.98
Rho-Squared (0):	0.691
Rho-Squared (constant):	0.6857

Parameter	Coeff	T-Stat
Sample of alternatives correction factor	1.000	
Ln Size Variables		
Elementary & Middle School Enrollment	1.000	
Impedance		
Mode Choice Logsum	0.3494	3.58
Linear Distance	1.4025	20.85
Square Root of Distance	-6.6929	-35.01
Distance Squared	-0.0245	-9.44
Distance Cubed	0.0002	3.58
no attractions if grade school enrollment is zero	-999	

Findings:

- The coefficient on mode choice logsum is positive as expected.
- The size variable only includes K-8 school enrollment and the coefficient on this term is constrained to 1.
- Composite Distance Function (or Distance Decay factor) has been defined as a combination of linear, square root, squared and cubed distance terms with different coefficients. Figure 6 shows the distance decay factor (or the composite distance term) for K-8 students. This function is monotonously decreasing in within the maximum observed home to school distance. Figure 7 shows that the distance decay factor is monotonously decreasing for longer distances and the utility steeply decreases after the maximum observes home to school distance.

Figure 6: Distance Decay Factor for K-8 students

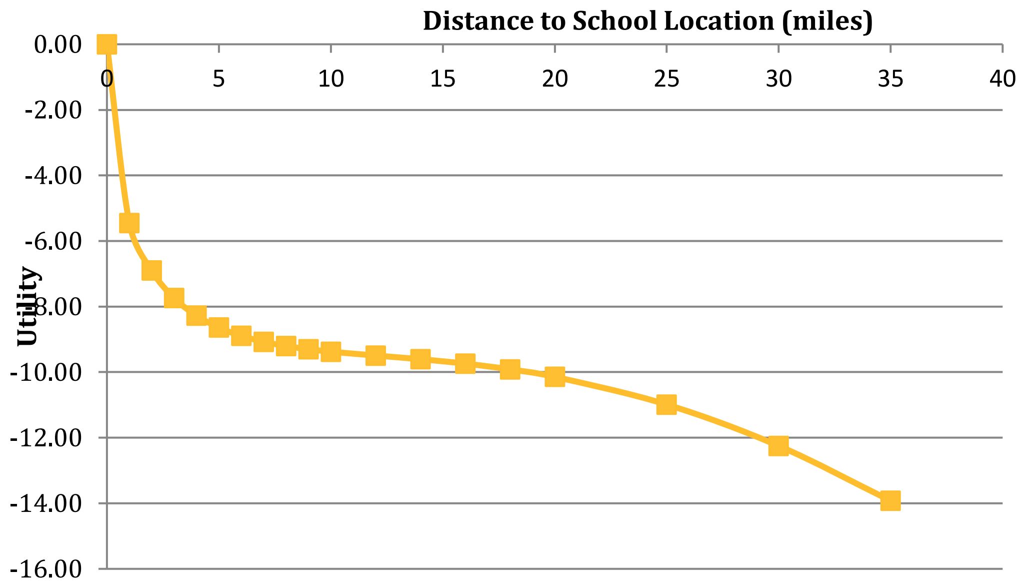
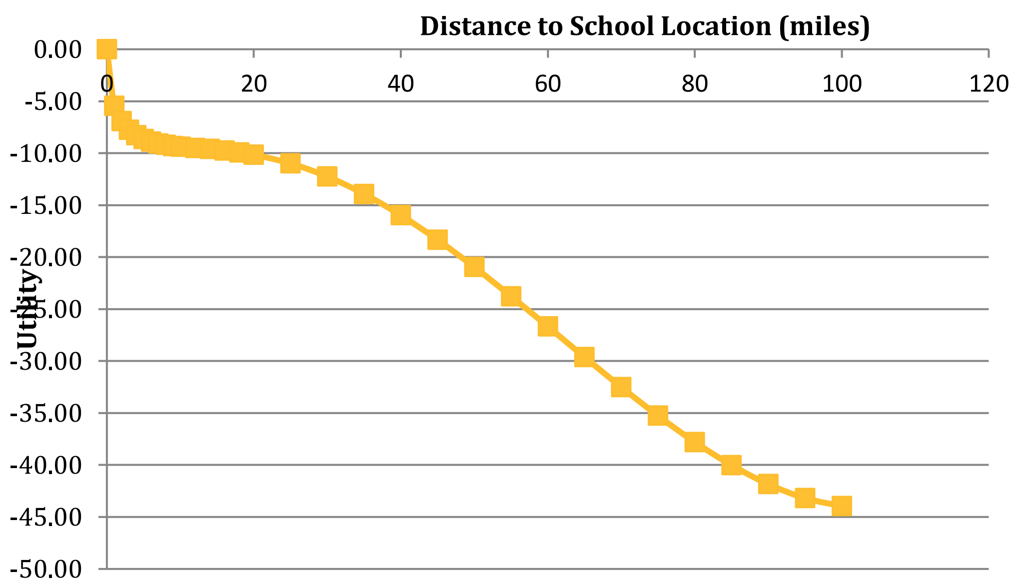


Figure 7: Distance Decay Factor for K-8 students



Results: Model for 9th to 12th Grade Students

The estimation results for school destination model for 9^{th} to 12^{th} grade students are shown in Table 10. The explanatory power of this school location models is also quite high (like the K-8 model) –a rho-squared of 0.62.

Table 10: SANDAG Usual School Location Choice Model Estimation Results for 9^{th} to 12^{th} grade students

Observations:	13880
Likelihood with Constants only:	-44443.12
Final log likelihood:	-17243.81
Rho-Squared (0):	0.62
Rho-Squared (constant):	0.612

Parameter	Coeff	T-Stat
Sample of alternatives correction factor		**1.000**
Ln Size Variables		
High School Enrollment	1.000	
Impedance		
Mode Choice Logsum	0.2500	
Linear Distance	0.0241	0.38
Square Root of Distance	-2.2566	-12.27
Distance Squared	0.0120	5.52
Distance Cubed	-0.0002	-6.61
no attractions if high school enrollment is zero	-999	

Findings:

- The mode choice logsum coefficient was affected significantly with addition of distance terms other than linear distance in the model. That is why the coefficient on mode choice logsum was constrained to 0.25.
- The size variable only includes high school enrollment and the coefficient on this term is constrained to 1.
- There were no cases where students go to school outside of home school district. So, the option of choosing a school outside of home school district was made unavailable.
- Composite Distance Function (or Distance Decay factor) has been defined as a combination of linear, square root, squared and cubed distance terms with different coefficients. Figure 8 shows the distance decay factor (or the composite distance term) for 9th to 12th grade students. This function is monotonously decreasing in within the maximum observed home to school distance. Figure 9 shows the distance decay function for longer distances and shows that the function is always decreasing and rapidly increases the disutility with distances longer than the observed maximum school distance.

Figure 8: Distance Decay Factor for 9th to 12th grade students

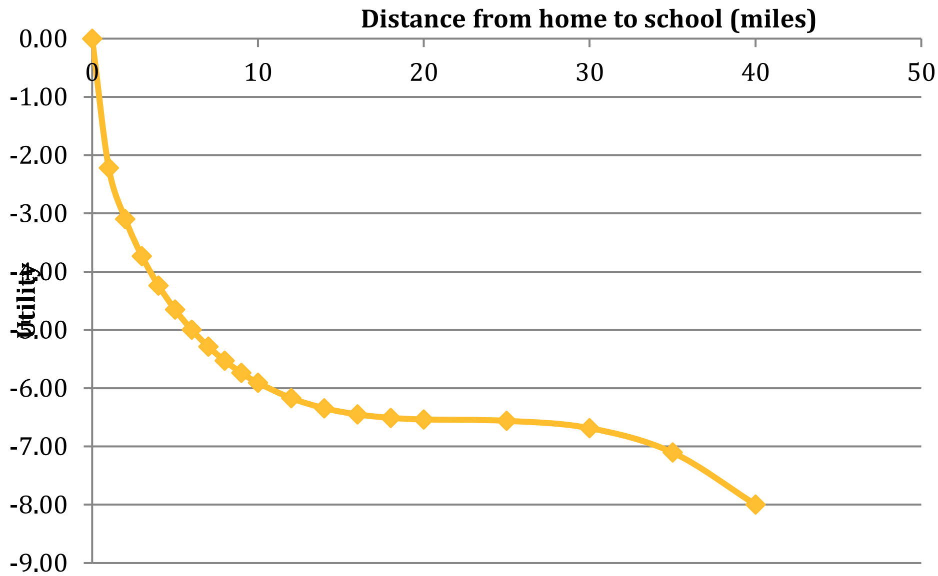
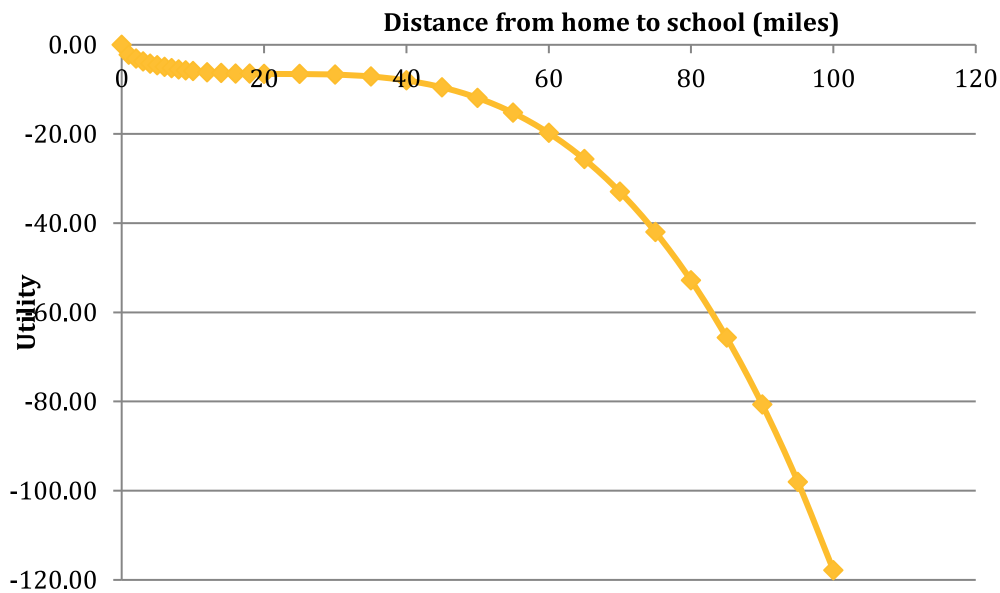


Figure 9: Distance Decay Factor for 9th to 12th grade students



Results: University Students Model

The estimation results for school destination model for university/college students are shown in Table 11.

Table 11: SANDAG Usual School Location Choice Model Estimation Results for University Students

Observations:	9420
Likelihood with Constants only:	-25556.92
Final log likelihood:	-18501.88
Rho-Squared (0):	0.2883
Rho-Squared (constant):	0.2761

Parameter	Coeff	T-Stat
Sample of alternatives correction factor	**1.000**	
Logged Size Variables		
University Enrollments	1.000	
Other College Enrollments - Typical Student	0.8590	11.29
Other College Enrollments - Non-Typical Student	0.4902	6.36
Adult School Enrollments - Typical Student	0.0304	0.19
Adult School Enrollments - Non-Typical Student	0.1499	2.20
Impedance		
Mode Choice Logsum	0.2500	
Linear Distance	1.279	4.13
Natural log Distance Ln(1+ Distance)	10.412	4.27
Square Root of Distance	-13.774	-4.44
Distance Squared	-0.011	-4.64
Distance Cubed	0.000	5.46
Linear Distance Interaction with		
Distance for Workers	0.013	4.54
Distance for Large University Enrollment	0.028	10.84
no attractions if university size is zero	-999	

Findings:

- The coefficient on mode choice logsum is constrained to 0.25 because of interaction between logsum and distance terms.
- The size variable is a non-linear function of university enrollments, other college enrollments and adult school enrollments. The coefficient on university enrollments is constrained to 1 and other coefficients are estimated relative to this. The impact of enrollments is further segmented by person type (university student or not) and age group (less than 30 years). A typical student was defined based on person type (university student, i.e. full time student) and age less than 30 years.
- Other colleges are found to be more attractive to a typical student as compared to other students.

- Overall, adult schools are not very attractive as compared to university or other colleges. And, even less attractive for a typical student.

- Composite Distance Function (or Distance Decay factor) has been defined as a combination of linear, logged, square root, squared and cubed distance terms with different coefficients. This function is monotonously decreasing in within the maximum observed home to school distance. The distance was further segmented by work status (worker or not) and destination university enrollment size (large university, i.e. more than 5000 enrollments). Figure 10 shows the distance decay factor (or the composite distance term) for each segment within the maximum observed home to school distance range. When this graph is extended for longer distances (as shown in Figure 11), it does not remain monotonously decreasing. Therefore, the utility is made constant after 60 miles as shown in the modified graph in Figure 11.

Figure 10: Distance Decay Factor for University Students

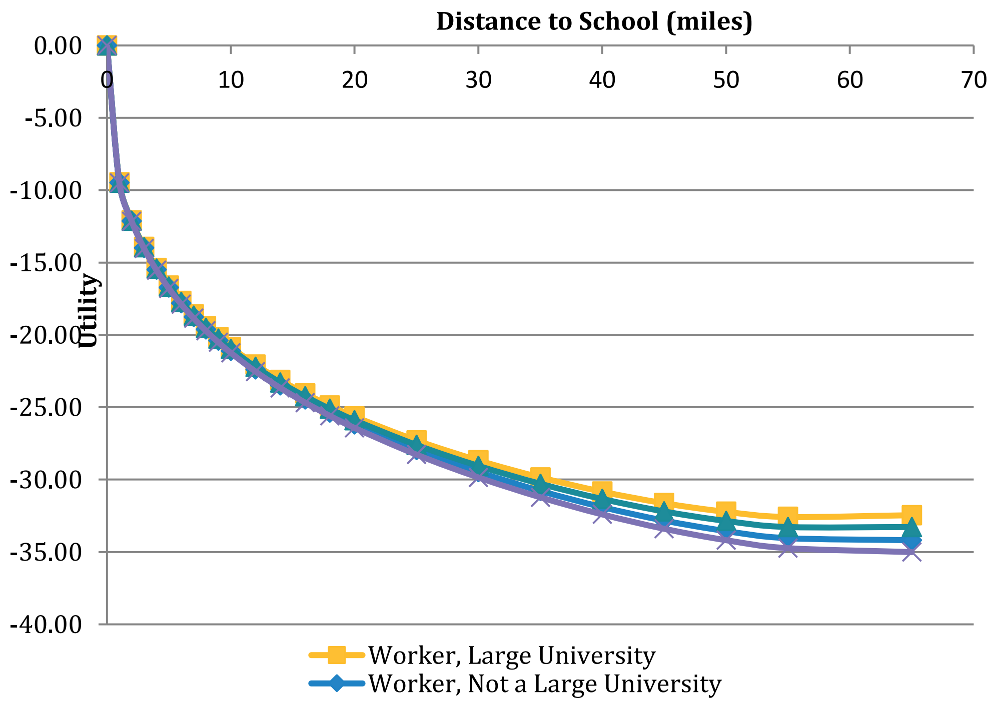
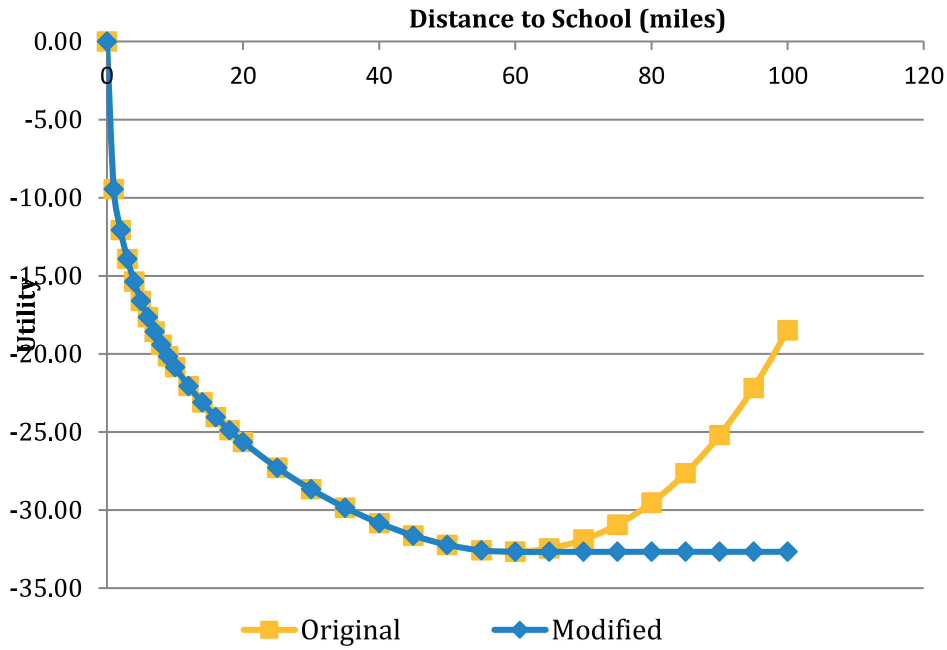


Figure 11: Modified Distance Decay Factor for University Students



3.0 Mobility Models

3.1 Employer Parking Provision Model

The *Employer Parking Provision Model* predicts which persons have on-site parking provided to them at their workplaces and which persons receive reimbursement for off-site parking costs. The provision model takes the form of a multinomial logit discrete choice between free on-site parking, parking reimbursement (including partial or full reimbursement of off-site parking and partial reimbursement of on-site parking) and no parking provision.

It should be noted that free-onsite parking is not the same as full reimbursement. Many of those with full reimbursement in the survey data could have chosen to park closer to their destinations and accepted partial reimbursement. Whether parking is fully reimbursed will be determined both by the reimbursement model and the location choice model.

Persons with workplaces outside of downtown San Diego area are assumed to receive free parking at their workplaces.

Estimation Dataset

The primary data sources that were used for the development of the parking choice models were the *2010-2011 Parking Behavior Survey* and the *2009-2010 Parking Inventory*. The parking behavior survey captured not only people's location decisions, but also the amount they were reimbursed by their employers. The parking inventory contains a tabulation of the parking stalls in every MGRA in the parking constrained area. The most detailed part of the inventory contains a listing of nearly every commercial lot and garage in areas with parking charges, obtained by request from the commercial operators. These records contain the number of stalls by a variety of classifications and the payment terms in effect at the time of the inventory.

In addition to the data on commercial lots, SANDAG obtained data on metered spaces from a spatial layer maintained by the City of San Diego and field visits to other areas. SANDAG also estimated the number of free-on-street spaces using formulas based on frontage length and driveway density. Finally, SANDAG extrapolated average parking ratios published in the CoStar commercial real estate database to buildings throughout the area to estimate the unobservable number of private parking stalls.

Table 12: Frequency of Parking Observations by Purpose and Payment Term

Payment Term	Purpose						Total	
	Work		School		Other			
	N	Percent	N	Percent	N	Percent	N	Percent
Free	5	1%	3	5%			8	1%
Hourly	14	4%	2	4%	21	15%	37	6%
Daily	148	43%	28	85%	116	81%	292	56%
Monthly	179	52%	2	6%	6	5%	187	37%
Total	**346**	**100%**	**35**	**100%**	**143**	**100%**	**524**	**100%**
Marginal Purpose Distribution		*66%*		*7%*		*27%*		*100%*

The frequency of parking behavior observations by payment term and activity duration is shown in Table 13. As monthly rates were used almost exclusively for work trips, almost all of the activity durations for monthly payments were from eight to eleven hours. Daily parking had a similar peak at nine hours, but there were several shorter trips that used daily rates. There are many instances where the daily rate is not much more than twice the hourly rate, so this is not necessarily out of the ordinary. Most hourly parking was for less than five hours.

Table 13: Frequency of Parking Observations by Payment Term and Activity Duration

	Payment Term								Total	
	Free		Hourly		Daily		Monthly			
Duration (h)	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
1			11	30%	10	3%			21	4%
2			7	22%	16	5%	1	1%	24	4%
3			3	7%	18	6%			21	4%
4			6	15%	21	7%			27	5%
5			1	3%	24	9%			25	5%
6			2	5%	12	4%	4	2%	18	4%
7					14	5%	5	3%	19	4%
8	2	30%	2	6%	24	9%	17	9%	45	9%
9	3	42%	2	5%	64	25%	76	40%	145	30%
10	1	14%	2	7%	40	16%	55	30%	98	21%
11	1	14%			16	7%	18	10%	35	8%
12					2	1%	7	4%	9	2%
13					1	0%	2	1%	3	1%
14					1	0%	2	1%	3	1%
15					2	1%			2	0%
16					1	0%			1	0%
17					1	0%			1	0%
Total	**7**	**100%**	**36**	**100%**	**267**	**100%**	**187**	**100%**	**497**	**100%**
Average Duration		*1%*		*7%*		*54%*		*38%*		*100%*

The frequency of parking observations by occupation and employment status for work trips appears in Table 14. The downtown sample was 69% composed of people in professional occupations. There were few part-time workers parking for work in the sample.

Table 14: Frequency of Parking Observations by Occupation and Employment Status, Work

	Employment Status				Total	
	Full Time		Part Time			
Occupation type	N	Percent	N	Percent	N	Percent
Management, professional, and related occupations	202	66%	20	56%	222	65%
Sales and office occupations	50	17%	10	27%	60	18%
Natural resources, construction, and maintenance	27	9%	1	3%	28	8%
Service occupations	12	3%	6	14%	18	5%
Production, transportation, and material moving	4	1%			4	1%
Military	2	0%			2	0%
Unknown	9	3%			9	3%
Total	**306**	**100%**	**37**	**100%**	**343**	**100%**
Marginal Employment Status Distribution		*89%*		*11%*		*100%*

The frequency of parking observations by income and level of reimbursement, on- and off-site, appears in Table 15. Each of the income quintiles was well-represented, except for the lowest, $0-30k. Not surprisingly, those with the lowest incomes were less likely to be fully reimbursed for parking. There are several observations for which the income is missing. See the section on the specification of the reimbursement model for options for dealing with missing data.

Table 15: Frequency of Parking Observations by Income and Payment, Location, and Reimbursement, Work

Payment, Location & Reimbursement	Household Income												Total	
	$0-30k		$0-60k		$60-100k		$100-150k		$150k+		Unknown			
	N	Pct.	N	Pct.	N	Pct.	N	Pct.	N	Pct.	N	Pct.	N	Pct.
Free, off-site		0%	2	2%	3	2%		0%		0%		0%	5	1%
Free, on-site	1	4%	5	8%	9	10%	7	9%	12	20%	7	16%	41	12%
Pay, full reimb.	6	26%	21	35%	31	36%	26	37%	13	22%	21	53%	118	35%
Pay, part reimb.	2	9%	9	15%	11	12%	9	12%	7	12%	1	3%	39	11%
Pay, no reimb.	14	61%	26	40%	34	40%	32	42%	25	46%	12	28%	143	41%
Total	23	100%	63	100%	88	100%	74	100%	57	100%	41	100%	346	100%
Marg. Inc. Dist.		*7%*		*18%*		*25%*		*21%*		*16%*		*12%*		*100%*

Main Explanatory Variables

To estimate the parking provision model, the data from the parking behavior survey was enriched with additional work trips to the downtown area from the transit on-board survey. This enrichment was necessary due to the bias in the parking behavior survey.

Workers who took transit downtown were assumed to not receive parking benefits, and treated the transit on-board survey as a choice-based sample.

The primary drivers of this decision could be broken down into three categories: *transportation system characteristics*, *workplace characteristics*, and *person characteristics*. The transportation system characteristics represent the ease with which an employer can attract workers without offering a parking reimbursement. Workplace characteristics represent the urban form and land uses at the workplace. The Person characteristics are demographic and geographic characteristics of the worker.

Transportation system characteristics

- Average daily equivalent of monthly parking costs in nearby MGRAs
- Accessibility to population of workplace MGRA by transit
- Walk distance from workplace MGRA to nearest rail station
- Shadow price of MGRA from the workplace location choice model

Workplace characteristics

- Density of parking stalls in workplace MGRA
- Employment density of workplace MGRA

- Share of workplace employment by industry
- College enrollment in workplace TAZ
- Workplace MGRA contains garage with attached office tower
- Land use zoning of workplace MGRA

Person characteristics

- Household income of person
- Occupation of person
- Driving distance from home to workplace
- Person is full-time worker
- Person is full-time student
- Person is part-time student
- Age of person
- Gender of person

Fixed effects

- Surveyed location is garage with attached office tower
- Surveyed location is garage without attached office tower
- Parking at surveyed location is free
- Daily cost of parking at surveyed location
- Percentage of records at surveyed location that were deleted

Utility Structure

The provision model takes the form of a multinomial logit discrete choice between free on-site parking, parking reimbursement (including partial or full reimbursement of off-site parking and partial reimbursement of on-site parking) and no parking provision. In the multinomial logit model, the decision-maker utility function is given by:

$$u_{ni} = \beta_i X_{ni}$$

Where β_i is a vector of parameters; X_{ni} is a vector of attributes of the person, workplace, and/or interactions between them.

It should be noted that free-onsite parking is not the same as full reimbursement. Many of those with full reimbursement in the survey data could have chosen to park closer to their destinations and accepted partial reimbursement. Whether parking is fully reimbursed will be determined both by the reimbursement model and the location choice model.

Results

The bias in the parking behavior survey and the need to enrich the sample with records from the transit on-board survey prevented the estimation of parameters for the majority of the variables mentioned above. The parameters in the estimated utility function appear in Table 16. Unreported incomes were handled with additional dummy variables.

Table 16: Parking Provision Utility Function Parameters

Variable	Alternative	Coef.	t-value
Very high income (Income > $100k)	Free on-site	1.870	4.010
High income (Income $60k to $100k)	Free on-site	0.858	1.650
Estimated alternative-specific constant	Free on-site	-4.370	-5.430
Correction for sample stratification	Free on-site	2.1686	
Calibration adjustment	Free on-site	-0.2537	
Very High Income (Income > $100k)	Reimbursement	0.612	3.210
Logsum-weighted daily equivalent of avg. monthly cost	Reimbursement	0.368	3.230
Percent blue collar employment	Reimbursement	-1.840	-2.040
Percent education and health employment	Reimbursement	2.260	4.200
Estimated alternative-specific constants	Reimbursement	-5.150	
Correction for sample stratification	Reimbursement	1.4754	
Calibration adjustment	Reimbursement	0.2282	

3.2 Car Ownership Model

The household car ownership model predicts the number of autos (including motorcycles, vans, and trucks for personal use) available to a household. The model was estimated in a nested logit form using the ALOGIT software. In this model, household car ownership is a dependent variable derived from the activity needs of the household based on household characteristics, and the characteristics of persons within the household. 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.

Estimation Dataset

The estimation dataset included 3,651 (including 115 transit over sample) observed households from the SANDAG 2006 household travel behavior survey. Table 17 shows surveyed households by number of owned cars and by San Diego County MSA. The survey observations were joined with MGRA-based mandatory and non-mandatory accessibilities as well as 4D measures to create the estimation file. Mandatory and non-mandatory activity accessibilities are the logsum/utility measures calculated using asserted mode and destination choice models. Mandatory accessibilities reflect the actual workplace and/or school location for each worker and student in the household, while non-mandatory accessibilities reflect the general accessibility of the household to all potential non-mandatory destinations.

Table 17: Household Vehicles

San Diego County MSA	N	Household Vehicles 0	1	2	3+	Total	Mean
Central	731	17.0%	47.1%	27.3%	8.5%	100.0%	1.32
North City	923	3.1%	31.4%	45.1%	20.4%	100.0%	1.91
South Suburban	370	13.0%	28.6%	37.5%	20.9%	100.0%	1.80
East Suburban	562	5.1%	34.1%	41.4%	19.4%	100.0%	1.87
North County West	469	3.9%	30.9%	46.2%	19.0%	100.0%	1.88
North County East	457	7.0%	31.4%	40.6%	21.1%	100.0%	1.85
East County	25	6.8%	33.3%	35.9%	23.9%	100.0%	1.94
Total	**3,536**	**8.0%**	**34.7%**	**39.5%**	**17.8%**	**100.0%**	**1.76**

Base: 3,536 households weighted (excluding 115 transit over sample)

Nested Logit Model Structure

The SANDAG car ownership model is a nested logit model with five choices: 0 cars, 1 car, 2 cars, 3 cars and 4 or more cars. The nested structure is illustrated in Figure 12. -At the first level of the nesting structure, the choices are split into 0 cars and 1 or more cars. A household's choice of having or not having cars represents the most significant car ownership decision and is placed at the highest level in the nested structure. At the next level of the model, the choice of 1 or more cars is further split into 1 car and 2 or more car choices. Finally, the 2 or more car choice is split into 2, 3 and 4 or more car choices. The nesting coefficient at 0 car and 1 plus car level is estimated as 0.668, and the nesting coefficient at 1 car and 2 plus cars level is set to 1.0, which essentially reduces the 3-level choice structure to a bi-level choice structure (Figure 13).

Figure 12: Nested Auto Ownership Model Structure

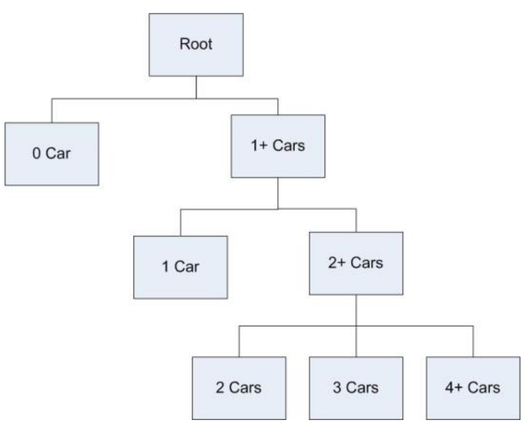
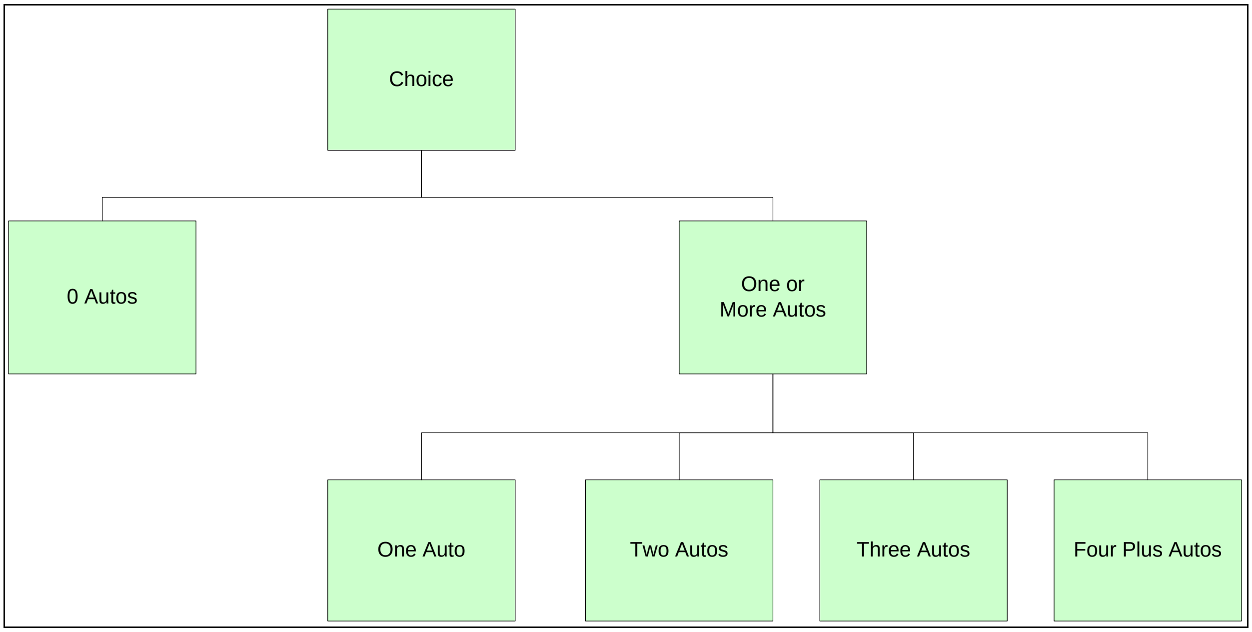


Figure 13: Auto Ownership Nesting Structure



Main Explanatory Variables and Utility Structure

The following variables have been examined and proved to be significant in the utility functions:

Household size:

- Number of driving age household members

Household composition:

- Ratio of workers (full time and part time) to driving age household members
- Ratio of young adults to driving age household members
- Ratio of school children to driving age household members
- Ratio of younger retirees (under age 80) to driving age household members
- Ratio of older retirees (age 80 and plus) to driving age household members

Household income group:

- Low income (less than $30,000)
- Low-Medium income ($30,000-60,000)
- High-Medium income ($60,000-100,000), used as reference income
- High income ($100,000 and more)

Education:

- Non high school graduate
- High school graduate

Zonal accessibility indices from residential zones to potential destinations:

- Non-motorized accessibility to non-mandatory activities in off peak period
- Difference between auto accessibility and transit accessibility to non-mandatory activities in off peak period.

Zonal density indices:

- Intersection density by MGRA.
- Population density by MGRA.
- Retail employment density by MGRA.

Household residence type:

- Detached dwelling unit.
- Non-detached dwelling unit.

Household mandatory activity auto dependency indices:

- Workers' mandatory activity auto dependency
- Students' mandatory activity auto dependency

Household mandatory activity rail mode indices:

- Workers' mandatory activity rail mode indices
- Students' mandatory activity rail mode indices

The zonal accessibility indices for non-mandatory activities take the form of destination choice logsums and represent a result of summation of attractions across all destinations. They are calculated across destination zone attractions by mode (auto, transit, and walk) and time-of-day period. Off-peak skims are used for creation of non-mandatory accessibilities.

The household mandatory activity auto dependency variable is calculated using the difference between the single-occupant vehicle (SOV) and the walk to transit mode choice logsum, stratified by person type (worker versus student). The logsums are computed based on the household MGRA and the work MGRA (for workers) or school MGRA (for students). The household auto dependency is obtained by aggregating individual auto dependencies of each person type (worker versus student) in the household.

The household mandatory activity rail mode index is calculated using the ratio of the rail mode in-vehicle time over the total transit in-vehicle time for trips that used rail as part of their transit path, stratified by person type (worker versus student). The household rail mode index is obtained by aggregating individual rail indices of worker/student members in the household. All mandatory mode choice logsums and accessibilities are calculated using AM peak skims.

Population and retail employment densities are calculated as the summation of the respective attribute of each MGRA that has a centroid that falls within a half mile halo divided by the area of the MGRA. Intersection density is calculated as the number of intersections within a 1/2 mile radius of each MGRA centroid.

Educational level variable is a dummy variable indicating if at least one household member has a high school or higher education.

Relative car sufficiency

Household composition and education variables are stratified using relative car sufficiency, which is calculated as the difference between number of cars in the alternative and the number of driving age members in a household. Car sufficiency is set to insufficient, sufficient, and over sufficient if the value is negative, zero, and positive respectively, for each alternative, depending on the number of driving age members in the household. The car sufficiency table is illustrated in Table 18.

Table 18: Relative car sufficiency

No. of Drivers	Car-ownership alternatives				
	0	1	2	3	4
0	sufficient	over sufficient	over sufficient	over sufficient	over sufficient
1	insufficient	sufficient	over sufficient	over sufficient	over sufficient
2	insufficient	insufficient	sufficient	over sufficient	over sufficient
3	insufficient	insufficient	insufficient	sufficient	over sufficient
4	insufficient	insufficient	insufficient	insufficient	sufficient

Results

The car ownership estimation results are summarized in Table 19.

Table 19: SANDAG Car Ownership Model Estimation Results

Observations: 3651
Final log likelihood: 3360.34
Rho-Squared (0): 0.4281
Rho-Squared (constant): 0.3334 theta1 =0.668, theta2 = 1.0

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
Alternative Specific Constant for HH size – #of driving age members	1 driver household	-1.920	-1.506	ref	ref	-0.935	-2.638	-1.905	-4.244	-2.488	-4.337
	2 drivers household	-3.471	-2.446	-2.203	-4.935	ref	ref	-0.829	-2.881	-1.778	-4.010
	3 drivers household	-3.330	-2.141	-2.473	-4.962	-0.317	-1.351	ref	ref	-0.534	-1.330
	4+ drivers household	-6.111	-3.249	-3.984	-5.618	-0.910	-2.005	-0.524	-0.974	ref	ref
HH compositions - Ratio of workers to driving age household members	1 driver household	-1.464	-3.234	ref	ref	0.475	3.023	0.475	3.023	0.475	3.023
	2 drivers household	-1.464	-3.234	-0.408	-1.580	ref	ref	0.475	3.023	0.475	3.023
	3 drivers household	-1.464	-3.234	-0.408	-1.580	-0.408	-1.580	ref	ref	0.475	3.023
	4+ drivers household	-1.464	-3.234	-0.408	-1.580	-0.408	-1.580	-0.408	-1.580	ref	ref
HH compositions - Ratio of young adults to driving age household members	1 driver household	-1.770	-2.649	ref	ref	0	--	0	--	0	--
	2 drivers household	-1.770	-2.649	-0.598	-1.917	ref	ref	0	--	0	--
	3 drivers household	-1.770	-2.649	-0.598	-1.917	-0.598	-1.917	ref	ref	0	--
	4+ drivers household	-1.770	-2.649	-0.598	-1.917	-0.598	-1.917	-0.598	-1.917	ref	ref

HH compositions - Ratio of pre-driving age school children to driving age household members	1 driver household	-0.346	-1.378	ref	ref	0.109	1.180	0.109	1.180	0.109	1.180
	2 drivers household	-0.346	-1.378	-0.019	-0.232	ref	ref	0.109	1.180	0.109	1.180
	3 drivers household	-0.346	-1.378	-0.019	-0.232	-0.019	-0.232	ref	ref	0.109	1.180
	4+ drivers household	-0.346	-1.378	-0.019	-0.232	-0.019	-0.232	-0.019	-0.232	ref	ref
HH compositions – Ratio of younger retirees (under age 80) to driving age household members	1 driver household	-0.382	-1.148	ref	ref	0.287	1.783	0.287	1.783	0.287	1.783
	2 drivers household	-0.382	-1.148	-0.199	-0.989	ref	ref	0.287	1.783	0.287	1.783
	3 drivers household	-0.382	-1.148	-0.199	-0.989	-0.199	-0.989	ref	ref	0.287	1.783
	4+ drivers household	-0.382	-1.148	-0.199	-0.989	-0.199	-0.989	-0.199	-0.989	ref	ref
HH compositions – Ratio of older retirees (age 80+) to driving age household members	1 driver household	0.609	0.994	ref	ref	-0.901	-3.824	-0.901	-3.824	-0.901	-3.824
	2 drivers household	0.609	0.994	0.233	0.354	ref	ref	-0.901	-3.824	-0.901	-3.824
	3 drivers household	0.609	0.994	0.233	0.354	0.233	0.354	ref	ref	-0.901	-3.824
	4+ drivers household	0.609	0.994	0.233	0.354	0.233	0.354	0.233	0.354	ref	ref
HH Income group	<30k	2.655	9.732	0.632	5.300	ref	ref	-0.601	-3.239	-0.936	-2.967
	30-60k	0.918	3.009	0.343	3.544	ref	ref	-0.306	-2.677	-0.272	-1.641
	100k+	-0.443	-3.801	-0.443	-3.801	ref	ref	0.087	1.080	0.144	1.258
Education - Non high school grads in household	1 driver household	0.768	1.642	ref	ref	ref	ref	-0.177	-1.017	-0.177	-1.017
	2 drivers household	0.768	1.642	0.432	1.188			-0.177	-1.017	-0.177	-1.017
	3 drivers household	0.768	1.642	0.432	1.188	ref	ref	ref	ref	-0.177	-1.017

	4+ drivers household	0.768	1.642	0.432	1.188	ref	ref	0.432	1.188	ref	ref
Zonal accessibility	Non-motorized Accessibility	0.061	0.441	0.040	0.790	ref	ref	-0.053	-1.878	-0.101	-2.546
	Auto Accessibility-transit Accessibility (difference)	-0.201	-4.379	-0.009	-1.170	ref	ref	0.000	--	0.000	--
Zonal density indices	Intersection density	0	--	0	--	ref	ref	-0.327	-1.641	-0.327	-1.641
	Population density	0.046	3.839	0.023	3.851	ref	ref	0	--	0	--
	Retail density	0.075	2.189	0.030	2.119	ref	ref	0	--	0	--
Household Residence Type	Detached single family house	-1.775	-8.034	-0.528	-6.498	ref	ref	0.427	4.109	0.540	3.231
Household mandatory activity auto dependency indices	worker	-0.165	-1.090	-0.165	-2.458	ref	ref	0.104	1.157	0.104	1.157
	student	-0.044	-2.235	-0.044	-0.924	ref	ref	0.000	--	0.000	--
Household mandatory activity rail mode indices	worker	0.171	0.152	0.171	0.233	ref	ref	-0.207	-1.667	-0.207	-1.667
	student	0.263	0.681	0.263	0.680	ref	ref	0.000	--	0.000	--
Alternative specific constant adjustment	for PRE-AO non-group quarter households			0.710		-0.229		-0.523		-0.719	
	for POST-AO non-group quarter			0.190		0.422		0.515		0.674	

	households										
	for POST-AO 0 WORKER households			-0.310		-0.368		-0.228		0.253	
	for POST-AO 1 WORKER households			-0.214		-0.835		-0.988		-0.959	
	for POST-AO 2 WORKER households			-0.064		-0.480		-0.846		-1.103	
	for POST-AO 3 WORKER households			-1.860		-2.642		-2.423		-3.076	
	for POST-AO 4+ WORKER households			-2.753		-4.285		-3.873		-4.100	

Red font: t-stat not significant

Ref: coefficient default to 0 for reference choice alternative

Findings

- The number of driving age household members has a strong impact on household car ownership. In this category, the reference choice is set for each household as the choice that corresponds to a sufficient number of autos for the total number of driving age adults. Insufficient and over sufficient car ownership alternatives both have negative coefficients, and the more over sufficient/insufficient the larger the negative coefficients. This finding is consistent with the expectation that people are more likely to have sufficient cars than to have either more or less sufficient cars than adults able to drive them.
- The workers to driving age household members ratio has negative coefficients for 0 and insufficient car ownership choices. This finding is consistent with the expectation that households tend to own sufficient cars so that workers in the household have enough cars to commute to work. The positive coefficients for over sufficient choices are probably caused by the higher income for households have more wage earning members.
- The young adults to driving age household members ratio has similar coefficient patterns as those of the workers to driving age household members ratio except that over-sufficient choices have zero coefficients. The insufficient car ownership choices have negative coefficient as others.
- The school children to driving age household members ratio has similar coefficient patterns as those of the workers to driving age household members ratio, but to a less degree for both insufficient and over sufficient choices. This shows that households with school children need sufficient cars to transport both parent and kids to work and school activities.
- The retirees are divided into two groups, under age 80 and 80 and above. The car ownership of these two groups shows opposite patterns. The younger retiree variable shares the same patterns as those of the workers and school children variables. For the older retirees, the trend is reversed. The older retirees to driving age household members ratio has positive coefficients for both 0 and insufficient car ownership choices and has negative coefficients for over sufficient car ownership choices. This shows that older retirees tend to be less mobile and therefore tend to own less cars compared with the younger groups.
- The high-medium income group is used as the reference group for the income category. Low income household are more likely to have 0 and 1 cars and less likely to have 3 and 4 plus cars. The large positive 0 car coefficient (2.6549) and the significant t statistic value 9.732 shows that there is a strong correlation between low household income and 0 car ownership. The low-medium income group shares the same pattern as the low income group, but to a lesser degree. The 0 car ownership coefficient is 0.9182, much less than the 2.655 value of the low income group. The high income households have an opposite pattern compared with the low income households. They are less likely to have 0 car (a negative coefficient -0.443) and more likely to have 3 and 4 plus cars (positive coefficients 0.087 and 0.1441 respectively).
- Compared with the reference educational level (high school graduate or higher), households with no high school graduates are more likely to have 0 car (positive coefficient (0.7678)) and insufficient cars (positive coefficient (0.4323)), but less likely to have over sufficient cars (negative coefficient - (-0.1767)).

- The non-motorized variable represents the zonal accessibility of non-motorized travel modes, such as walking and biking, or in other words the ease of travel by walking and biking. The positive coefficient 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 negative coefficient (-0.2008)) 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 car.
- The residence type variable has a strong impact on car ownership. Households that live in a detached dwelling unit have a large negative coefficient (-1.7747) for zero car ownership. This is probably because detached units are more likely to be in suburban areas and tend to have plenty of available parking.
- The mandatory tour auto dependency variable represents how much a household member's mandatory tours (work and school tours) are dependent on the auto mode. This variable has negative coefficients for 0 car ownership for both workers and students. This shows that a household is less likely to own zero cars if workers and students in the household have a strong dependency on using the auto mode for commuting to work and school.
- The mandatory rail mode variable represents how much workers and students depend on rail mode to commute to work and school. The positive coefficients of 0 car ownership shows that the higher use of rail for mandatory tours by workers and students indicates a greater likelihood for their household to own zero cars.

3. 3 Toll Transponder Ownership Model

This model predicts whether a household owns a toll transponder unit. It was estimated based on aggregate transponder ownership data using a quasi-binomial logit model to account for over-dispersion. It predicts the probability of owning a transponder unit for each household based on aggregate characteristics of the zone.

In the model base-year of 2007, the San Diego region contains one toll facility - the I-15 managed lanes - where a transponder is required for access. Another toll facility (SR-125) opened in November 2007, in which a transponder unit can be utilized to pay a lower toll than a cash toll. This model will be used for both toll facilities. The modeling of the choice to use the toll facility is more accurate if done in two stages: transponder ownership and mode choice. If a household does not own a transponder, and the toll path in the mode choice model requires a transponder, then transponder-only toll alternatives in the mode choice model should be unavailable.

Estimation Dataset

The data source that was used for the development of the transponder ownership model is a database of transponder account owners and a time series of their usage on the I-15 facility between 2008 and 2010. Because of the phasing of the facility construction, the transponder ownership model was estimated for a base year of 2010, since there was no segment opened during that year. To protect the transponder owners' confidentiality, SANDAG did not release disaggregated data regarding individual account holders to PB. Therefore, an aggregate model was estimated of the share of transponder ownership in each TAZ as a function of zonal averages. These zonal average variables came from four sources. Transit destination choice logsum accessibility values were taken from the calculations in the activity based-model. Auto travel times were taken from the level of service (LOS) matrix outputs from a 2010 run of the four-step model. Aggregate auto ownership and income distributions were taken at a tract level from the US Census American Community Survey (ACS) 2005-2009 estimates. Distance from the facility was calculated from the freeway multiline layer and TAZ centroids using GIS.

Main Explanatory Variables

In developing the model, the most relevant variables for transponder ownership was hypothesized to be auto ownership, income, and the degree to which owning a transponder could improve one's transportation options. This last characteristic of the benefits to transponder ownership was defined using three separate terms. The first term was the straight-line distance to the nearest managed lanes facility.

The second measure of the benefits of transponder ownership was the expected travel time savings to and from work that a transponder would bring. Since the model was estimated in an aggregate fashion, the travel time savings of any one individual household or worker was unknown, so a variable was calculated approximating the average travel savings of all households in each zone over all possible work destinations *d*. This average was calculated using an expected value with probabilities taken from a simplified destination choice model. The expected travel time savings of households in a zone *z* is

$$\frac{\sum_d (AutoTime_{zd} - TollTime_{zd}) \cdot Employment_d \cdot \exp\left(-0.01\; AutoTime_{zd}\right)}{\sum_d Employment_d \cdot \exp\left(-0.01\; AutoTime_{zd}\right)}.$$

The times are calculated in minutes and include both the AM peak travel time to the destination and the PM peak time returning from the destination. Even for locations where it is highly desirable to own a transponder, this expected travel time savings is quite low because it includes all possible destinations.

These two terms expressing the benefits of transponder ownership did not capture all of the benefits of ownership because the expected travel time savings variable did not differentiate between those whose non-toll paths were still on I-15 and those who had options other than I-15 entirely, perhaps because of differences in awareness of the facility. Those whose only good non-toll option is also on I-15 should be more likely to switch to owning a transponder because the alternative is more visible to them. Those who have a good non-toll option that does not use I-15 should be less likely to own a transponder even if the toll path would save time because they have more alternatives available to them.

Therefore, we also included a third term expressing the percent difference between the AM non-toll travel time to downtown zone 3781 and the AM non-toll travel time to downtown when the general purpose lanes parallel to all toll lanes requiring transponders were made unavailable in the path-finder. This variable is calculated as

$$\frac{Non\ Toll\ Time\ Avoiding\ Facility - Non\ Toll\ Time}{Non\ Toll\ Time}.$$

Those who use I-15 even for non-toll paths have much greater percent increase in travel time from detouring, while those with other options have lower increases in travel time.

Utility Structure

The transponder ownership model is applied in the activity-based model system after the auto ownership model in order to limit transponder ownership to auto-owning households. Each household makes a discrete choice to own or not to own a transponder based on a binary logit random utility model. Under this specification, the probability P_i that a household i will own a transponder is defined in terms of a linear-in-parameters utility function u_i by

$$P_i = \frac{\exp{(u_i)}}{1 + \exp{(u_i)}}.$$

Because of the aggregate nature of the estimation dataset, the variables in the utility function must be the same, and the probability for each household in a given TAZ must be identical to one zonal probability P_z, with one exception. In application, zero-auto households do not have the transponder choice available to them.

The model estimation was based on the assumption that the total number of households in each TAZ owning transponders arose by individual households making choices according to the above probability model. If the choices were independent, this specification would result in a number of transponders with a binomial distribution according with probability P and number of trials n equal to the number of households. The log-likelihood $L(k|P)$ of observing k_z transponders in a series of zones z with n_z households each would be

$$L(k_z|P_z) = \sum_z k_z P_z + (n_z - k_z)(1 - P_z).$$

Because the utility function cannot explain the choice probabilities perfectly, and the households tend to be similar to households in the same zone and dissimilar to households in other zones, the probabilities of the households are not quite independent, and the therefore, the variance in the number of transponders is greater than would be expected from a binomial distribution. This condition is known as *overdispersion*, and the distribution is known as *quasi-binomial* with a variance equal to the binomial variance multiplied by a dispersion parameter.

Although L is not the actual log-likelihood in the quasi-binomial model, using the quasi-likelihood method, we can still maximize L and obtain estimates of the utility function parameters that are consistent and asymptotically normal. These estimates are the same as those that result from the binomial assumption, except the variance of the estimates is greater by a factor of the dispersion parameter. We estimated these parameters using the method of iteratively re-weighted least squares. For more on this method and the quasi-binomial specification see McCullagh and Nelder (1983).

The quasi-binomial specification does not have any bearing on the disaggregate application of the model. Either a binomial or quasi-binomial model can be applied to individual households in the manner described above.

Results

The estimated transponder ownership utility function appears in Table 20. As the share of households with multiple autos in the zone increases, the average rate of transponder ownership in the zone increases. It is likely that an increased rate of ownership among multiple-auto households is responsible for most of the effect, but the disaggregate nature of the relationship cannot be determined from the data.

As the expected travel time savings increases, the probability of transponder ownership increases, up to a saturation point. Above 0.3 minutes, the probability does not increase when controlling for the other variables. As the zones move away from the facility, beginning at 2 miles, increased distance results in lower rates of transponder ownership. The lack of a non-toll option which is completely separate from the general purpose lanes on the tolled portion of the facility that results in an increase in travel time of less than 10% is associated with an increase in transponder ownership, up to a saturation point. Detours with an additional travel time above 20% are not associated with more transponder ownership, all else equal.

Finally, greater transit accessibility is associated with lower rates of transponder ownership for the same level of auto ownership because of the greater availability of the transit option to the household. Where zones were completely transit inaccessible, the transit accessibility logsum was undefined, and set to a default of zero. The coefficient for no transit accessibility indicates that these zones have lower levels of transponder ownership than would be expected from a linear extrapolation of the relationship between accessibility and transponder ownership in transit-accessible zones.

Table 20: Estimated Transponder Ownership Utility Function Parameters

Variable	Coef.	t-value
Proportion of households in zone with multiple autos	2.225	4.246
Expected travel time savings up to 0.3 minutes	6.800	13.138
Straight-line distance from facility above 2 miles	-0.087	-11.929
Percent increase above 10% in non-toll time from avoiding facility entirely, (10% to 20%)	10.514	12.007
Average transit accessibility of MGRAs in zone	-0.115	-10.417
No transit accessibility (default zero)	-0.317	-3.305
Constant	-6.438	-15.826
Ownership unavailable for zero auto households	-999	
Correction for non-geocoded records	1	
Correction for zero-auto households	1	

The quasi-binomial dispersion parameter was estimated to be 7.314. (1.0 corresponds to the binomial case.)

Because the third travel time and distance variable (the percent increase in non-toll time from avoiding the transponder facility) would require the creation of an additional skim, we also estimated a version of the model that did not require it. The parameters of this utility function are shown in Table 21.

Table 21: Alternate Transponder Ownership Utility Function Parameters

Variable	Coef.	t-value
Proportion of households in zone with multiple autos	2.135	3.955
Expected travel time savings up to 0.3 minutes	10.888	26.837
Straight-line distance from facility above 2 miles	-0.082	-10.447
Average transit accessibility of MGRAs in zone	-0.116	-10.313
No transit accessibility (default zero)	-0.487	-5.057
Constant	-6.613	-15.785

The quasi-binomial dispersion parameter was estimated to be 7.633. (1.0 corresponds to the binomial case.) The alternate model has a slightly poorer fit, as indicated by the increase in the dispersion parameter. In the alternate model, too many transponders are predicted to be to the southwest of the facility. However, the fit of the model is still good, and the alternate model should be considered for final implementation if complexity introduced by the creation of extra skims and calculation of multiple travel time variables is not desired.

4.0 Daily & Tour Level Models

4.1 Coordinated Daily Activity Pattern (CDAP) Model

The Coordinated Daily Activity Pattern (CDAP) model predicts the activity pattern types at an entire day level 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).

The independent variables in the model include person and household characteristics, including person-type, and accessibility terms. The most important aspects of this approach is to capture the role of person-type and other household, person, and accessibility variables on the propensity to travel to work or other activities and the effects of intra-household interactions on travel and the propensity to engage in joint activities. This model is applied after a work-at-home model, work and school location choices, and auto ownership, and therefore includes explicit accessibilities to mandatory activities (at a person level) and general accessibilities to non-mandatory activities (at a household level) as explanatory variables.

Estimation Dataset

The estimation dataset included 3,651 observed households from the SANDAG 2006 Household Travel Behavior Survey. Table 22 below shows the observed frequency of individual DAP types by person type. The survey observations were joined with MGRA-based mandatory and non-mandatory accessibilities to create the estimation file. Mandatory and non-mandatory activity accessibilities are the logsum/utility measures calculated using asserted mode and destination choice models. Mandatory accessibilities reflect the actual workplace and/or school location for each worker and student in the household, while non-mandatory accessibilities reflect the general accessibility of the household to all potential non-mandatory destinations.

Table 22: Observed frequency of DAP types

Person Type	Total	Absolute Frequency			Relative Frequency		
		Mandatory	Non-Mandatory	At Home	Mandatory	Non-Mandatory	At Home
Full Time Worker	3,383	2,775	405	203	82.0%	12.0%	6.0%
Part Time Worker	768	475	236	57	61.8%	30.7%	7.4%
University Student	247	171	55	21	69.2%	22.3%	8.5%
Non-Worker	767	8	574	185	1.0%	74.8%	24.1%
Retiree	1,515	9	1,132	374	0.6%	74.7%	24.7%
Driving Age School Child	300	270	15	15	90.0%	5.0%	5.0%
Pre-driving Age School Child	1,123	1058	44	21	94.2%	3.9%	1.9%
Pre- School Child	666	296	273	97	44.4%	41.0%	14.6%
Total	**8,769**	**5,062**	**2,734**	**973**	**57.7%**	**31.2%**	**11.1%**

Choice and Model Structure

The SANDAG CDAP model is a multinomial logit model with a total of 691 alternatives across different household sizes. For each household size, the set of choices are defined as a combination of individual DAP types for all household members and joint travel patterns. Individual DAP is classified by three main types which are mutually exclusive and collectively exhaustive:

1. Mandatory pattern (M) – includes daily patterns where at least one mandatory tour (away from home) is implemented. The mandatory activity could be any one of these -work, university or school. It may also include non-mandatory activities in addition to mandatory activities.
2. Non-Mandatory pattern (N) – involves only maintenance and discretionary activities out of home where travel is associated.
3. At-home pattern (H) – includes staying at home.

The choice structure includes all possible combinations by individual DAP types for up to five household members in an explicit way. For larger households with six or more members, five members are explicitly considered based on their person-type, and the remaining (which constitute less than 1.4% of the observed cases) are sequentially modeled conditional upon the choices made by the five representative members. The rules for inclusion are:

- The household members are prioritized (highest to lowest) based on person type
    - Full-time worker
    - Part-time worker
    - Pre-school Child
    - Pre-Driving Age School Child
    - Driving Age School Child

    - Non-Working Adult
    - Retiree
    - University Student
- Younger children get priority when choosing between 2 or more children from same person type group

The choice structure includes 363 alternatives with no joint travel and 328 alternatives with joint travel, totaling to 691 alternatives as shown in Table 23. Note that the choices are available based on household size.

Table 23: Formulation of Alternatives

Household Size	Alternatives – no Joint Travel	Alternatives with Joint Travel	All Alternatives
1	3	0	3
2	3x3=9	3x3-(3x2-1)=4	13
3	3x3x3=27	3x3x3-(3x3-2)=20	47
4	3x3x3x3=81	3x3x3x3-(3x4-3) =72	153
5 or more	3x3x3x3x3=243	3x3x3x3x3-(3x5-4)=232	475
Total	**363**	**328**	**691**

Availability of Alternatives

Since the alternatives are dependent on the number of household members, not all choices are available for every household. The choices available to a household are dependent on household size.

Main Explanatory Variables and Utility Structure

The following variables have been examined and proved to be significant in the utility functions:

- Person type
- Household size
- Household income group:
    - Low income (less than $30,000)
    - Low-medium income ($30,000-60,000)
    - High-medium income ($60,000-100,000)
    - High income ($100,000 and more)
- Car sufficiency with respect to workers
    - No cars
    - Cars less than workers
    - Cars equal to workers
    - Cars more than workers
- Age group
- Gender

- Zonal accessibility indices from residential zones to Non-Mandatory activity destinations
- Auto logsum to work (mandatory accessibility term 7) and school location (mandatory accessibility term 18)
- Household residence type
    - Detached dwelling unit
    - Non-detached dwelling unit
- Variables related to Usual Work Place
    - Usual work place is home
    - No usual work place
- Availability of household members for joint travel
    - Number of adults with mandatory pattern
    - Number of adults with non-mandatory pattern
    - Number of pre-driving age children with mandatory pattern
    - Number of pre-driving age children with non-mandatory pattern
    - Dummy for if all adults stay at home

The zonal accessibility indices for non-mandatory activities take the form of destination choice HOV logsums (destination accessibility terms 7-9) and represent a result of summation of attractions across all destinations. They are calculated across destination zone attractions by mode (auto, transit, and walk) and time-of-day period. Off-peak skims are used for creation of non-mandatory accessibilities.

The joint travel utility is dependent on combination of daily activity patterns for each alternative. Some of the utility variables are not pre-calculated but calculated "on-the–fly" for each alternative. Example below shows how these variables are calculated for a 5 person household based on daily activity pattern for three different alternatives.

#	Person Type	Daily Activity Pattern		
		Alt 1	Alt 2	Alt3
1	Full-time worker	1	2	3
2	Pre-school child	2	2	1
3	Pre-driving age school child	1	3	1
4	Pre-driving age school child	1	3	1
5	Non-working adult	2	3	3
On-the-fly variables				
Number of adults with mandatory pattern		1	0	0
Number of adults with non-mandatory pattern		1	1	0
Number of children with mandatory pattern		2	0	3
Number of children with non-mandatory pattern		1	1	0
If all adults are at home		0	0	1

Results and Findings

The CDAP estimation results are summarized in Table 24 and Table 25.

Here are the findings from the estimation results:

- *Person type*: The person type specific constants indicate that, all else being equal, full-time workers and school children are most likely to have mandatory patterns; and, non-workers and retirees are least likely to carry out mandatory activities.
- *Gender:* The interaction of person type with females shows that among workers and university students, females are less likely to stay at home, while among retirees they are more likely to stay at home.
- *Age*: Among very young children (under age 6), the chances of going to school increases with age. Among children of age 6 to 15 yrs, the likelihood of going to school for children 13-15 yrs old is less than children under 13 yrs. This may reflect an increasing likelihood of participation in other activities that conflict with school as age increases.
- *Car ownership/sufficiency:* Non-workers and retirees are more likely to travel for non-mandatory activities and full-time workers are less likely to travel for only non-mandatory activities if there are more cars than workers in the household. This shows that the travel pattern for non-workers and retirees is affected by the availability of a car. Full-time workers are less likely to have only non-mandatory pattern because non-workers or other family members are more likely to take care of maintenance activities if a car is available. In zero car households or less cars than workers households, very young children (under age 6) are more likely to stay at home.
- *Household income:* Full time workers in low-income households are more likely to engage in non-mandatory activities or stay at home as compared to carrying out mandatory activities. However, part-time workers and university students from low income households (less

than 30K) are more likely to attend mandatory activities. Pre-driving age school students from low income households are more likely to stay at home. Non-workers and retirees from high income households (more than 100k) are less likely to stay at home and pre-school children from high income households (more than 60k) are more likely to attend mandatory activities (e.g., day care or play schools).

- *Accessibility:* University students are more likely to travel to mandatory activities if accessibility to university location is high. University students have higher flexibility in terms of scheduling classes and may be able to schedule classes to minimize travel to school to avoid congestion. 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.
- *Usual work location:* Workers are much less likely to travel for mandatory activities if their usual work location is home. Also, they are more likely to stay at home and involve in non-mandatory activities due to flexible schedule and travel time savings. Workers who reported not having any usual work location are less likely to have mandatory travel.
- *Dwelling type:* Living in a detached home increases the likelihood of staying at home for retirees, pre-driving age school children and workers.
- *Two-way interactions:* The two-way interaction *terms* by person type combinations are estimated for same pattern types (MM, NN or HH). All possible interactions were tried in the estimation, except for mandatory patterns involving non-workers and retirees, and combinations with unobserved cases.
    - All estimated two-way interactions are positive
    - For mandatory (M) pattern, some of the largest interactions are found among school children (SD and SP). The interactions are also positive between workers (particularly, part-time workers) and children.
    - For non-mandatory (N) pattern, the largest positive interactions are among pairs of pre-driving-age school children. . For younger children (age less than 6), significant positive interactions are found with adults (particularly, part-time workers, non-workers and driving age school children) and other children.
    - For at home (H) pattern, largest interactions are between children of similar age group (i.e., pre-driving age child with pre-driving age child and driving age school child with driving age school child), and between non-worker and pre-driving age children.
- *Three –way interactions:* Three-way *interaction* terms (MMM, NNN or HHH) were considered for specific person type combinations because there are many possible three-way combinations.
    - Combination of three full time workers shows a positive interaction. If two full time workers go to work then the third one is also likely to go to work/school.
    - Combination of three children show negative for HHH pattern. Since, this works on top of the positive two-way interaction term, it reduces the strong positive impact of two-way interaction for three children at home.
- *Same pattern for all household members:* The estimates show all negatives for non-mandatory and at home patterns. The strength of the negative coefficient increases with

household size. However, for mandatory patterns, the coefficients are not very significant for household size 3 and 5, which could be dependent on household composition. There is a strong positive affect for four member households. These coefficients will offset the effect of two-way and three-way interaction terms for larger households. (Note: the number of two-way interaction terms increase significantly with household size - a three person household has 3 terms, a four person household has 6 terms and a five-person household has 10 terms)

- *Joint travel:* The CDAP model also predicts whether joint travel occurs at a household level.
    - Household members are less likely to have a joint tour given everything else is same.
    - For a household member with a mandatory pattern, the chances of participating in joint travel are higher with better accessibility to work location.
    - The probability of joint travel in a household is higher with a greater number of adults or children with non-mandatory pattern.
    - The likelihood of joint travel is reduced if all adults stay at home. In most cases, children are accompanied by adults for travel on a joint tour.
    - Low income (<30K) households are less likely to have joint travel whereas higher income (>60K) are more likely to have joint travel.
    - Members of a household with fewer cars than workers are more likely to have joint tours. Whereas in households with more cars, people tend to have more individual tours.

Table 24: SANDAG CDAP Model Estimation Results

Observations:	3651
Likelihood -Constants only:	-8023.635
Final Likelihood =	-5450.8943
Rho-Squared w.r.t. Zero =	0.4946
Rho-Squared w.r.t. Constants =	0.3206

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												

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
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											1.9783	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				
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

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
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	0.8762	4.55														

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
Place is Home																
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		
(ASCA) Alternative Specific Constant Adjustment																
ASCA for Mandatory	-0.2301		-0.4710		-0.3361		-999		-999		0.1434		0.4725		0.5554	
ASCA for Non-Mandatory	-0.1846		-0.4229		0.0325		0.0770		-0.0012		-0.8075		-0.1462		0.1340	
Two Person Interactions																
MM Pattern																
Interacted with Full Time Worker																
Interacted with Part Time Worker			0.0000													
Interacted with 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
Interacted with Non-Worker							-999									
Interacted with Retiree									-999							
Interacted with Driving School Child			0.0000								0.6854	0.86				
Interacted with Pre-Driving School Child	0.1434	1.41	0.4024	1.79	0.2755	1.09					0.3692	1.41	0.7729	2.59		
Interacted with Pre-School Child	0.3851	2.54	0.4453	1.49	0.4148	1.02					0.5467	0.85				
NN Pattern																
Interacted with Full Time Worker	0.1500	0.64														
Interacted with Part Time Worker																
Interacted with University Student																
Interacted with Non-Worker																
Interacted with Retiree					0.8526	2.22										
Interacted with	1.0053	2.24			0.9678	1.00	0.7134	1.26								

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
Driving School Child																
Interacted with Pre-Driving School Child	0.3041	0.90	0.3248	0.56			0.8509	2.54			1.8265	3.95	2.5719	5.09		
Interacted with Pre-School Child			0.9231	3.07	0.9241	2.31	1.1721	5.19			1.1744	1.00	0.7036	1.52	0.4338	1.22
HH Pattern																
Interacted with Full Time Worker	0.7511	2.04														
Interacted with Part Time Worker	0.0000		0.7897	1.07												
Interacted with University Student			1.6170	2.13												
Interacted with Non-Worker			1.1606	2.22	0.6370	0.80	1.2214	2.98								
Interacted with Retiree	0.6692	2.26	0.7915	2.02	0.1955	0.20	0.8544	2.97	1.0484	5.40						
Interacted with Driving School Child	1.3472	2.77			2.2375	3.40	1.1160	1.62			3.1920	2.20				
Interacted with Pre-Driving School Child			1.8203	1.80			1.9740	3.56					5.6222	7.75		
Interacted with 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

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
Three Person Interactions																
MMM Pattern																
Interacted with FWxFW	0.2980	2.03														
Interacted with FWxPW	0.2032	1.22														
Interacted with FWxKD*																
Interacted with PWxPW	-0.6279	-1.33														
Interacted with PWxKD	-0.0432	-0.31	-0.1524	-0.32												
Interacted with KDxKD	-0.1301	-1.17	-0.1259	-0.54									-0.0112	-0.06		
Interacted with RT x RT									-999							
Interacted with NW x NW							-999									
NNN Pattern																
Interacted with FWxFW																
Interacted with FWxPW																
Interacted with FWxNW																
Interacted with	-0.5454	-0.87														

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
FWxKD																
Interacted with PWxPW			1.8781	1.52												
Interacted with NWxNW	-0.9496	-0.88														
Interacted with PWxKD	-1.7459	-1.76														
Interacted with NWxKD	-0.1659	-0.65														
Interacted with KDxKD	0.4687	1.64	-0.6913	-1.12			-0.4894	-1.41					-0.0582	-0.11		
HHH Pattern																
Interacted with FWxFW																
Interacted with FWxPW																
Interacted with FWxNW	1.5072	1.5072														
Interacted with FWxKD	0.8382	0.8382														
Interacted with PWxPW																
Interacted with NWxNW																
Interacted with PWxKD	0.4246	0.42														
Interacted with	0.1548	0.26					-0.9024	-0.9024								

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
NWxKD																
Interacted with KDxKD	-0.7547	-0.98	-2.2535	-1.72			-1.3723	-2.27					-2.4703			

Note:

* KD:Pre-Driving School Child and Pre-School Child; RD:retired person;   NW:nonworking adult person

The interaction order is: The top raw field interacts with the left column field. For example: the -0.7547 is the coefficient of FWxKDxKD, for HHH pattern

Table 25: SANDAG CDAP Model Estimation Results for All Member Interaction and Joint Tour (continued)

Utility Terms	Mandatory		Non-Mandatory		At Home		Joint	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Same Pattern for All HH Members								
Three Person households	-0.1140	-0.73	-0.4673	-1.56	-0.1538	-0.31		
Four Person Households	0.4569	2.45	-0.4669	-0.80	-0.4645	-0.50		
Five Person Households	-0.2607	-0.88	-1.4859	-1.43	-9.0000			
Joint Travel								
Constant – Joint Tour							-3.1506	-1.92
Constant - joint tour for hhsize 2							0.3314	
Constant - joint tour for hhsize 3							0.3608	
Constant - joint tour for hhsize 4							-0.1186	
Constant - joint tour for hhsize 5+							-0.0535	
Accessibility to retail employment / to Non Mandatory destinations							0.0550	0.50
Work Accessibilities for Persons with Mandatory Dap							0.1722	2.13

Utility Terms	Mandatory		Non-Mandatory		At Home		Joint	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Number of Adults with Non-Mandatory DAP							1.2557	13.08
Number of Adults with Mandatory DAP							0.0080	0.10
Number of Pre-driving age Children with Non-Mandatory DAP							1.6898	12.20
Number of Pre-driving age Children with Mandatory DAP							0.1088	1.76
If All Adults stay at home / None of the Adults have Dap 1 or 2							-0.9888	-0.90
Income								
Less than 30K							-0.1925	-1.13
Between 60 and 100K							0.1043	0.85
More than 100K							0.1043	0.85
Car Ownership								
Fewer Cars than Workers							0.0884	0.36
More Cars than Workers							-0.0059	-0.05

4.2 Individual Mandatory Tour Modeling

4.2.1 Individual Mandatory Tour Frequency

The mandatory tour frequency choice model predicts the number of mandatory (work and school) tours for each person who chooses the mandatory daily activity pattern type (DAP) in the Coordinated Daily Activity Pattern (CDAP) Model. The mandatory tour frequency model is applied after the coordinated daily activity pattern (DAP) model at household level. All persons who choose a mandatory daily activity pattern type (M) in the CDAP model are subjected to the individual mandatory tour determined, and implement at least one mandatory tour. The model has five alternatives: one work tour, one school tour, two or more work tours, two or more school tours, one work tour plus one school tour. It was estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 4791 observations of work and school tours for the person types 1-7 after exclusion of preschool children from the SANDAG 2006 Household Travel Behavior Survey. In order to evaluate the potential impact of workplace and school location on the number of mandatory tours, the survey observations were appended with distance, travel time by auto and transit, and mode choice logsums to work and school locations. Non-motorized accessibilities at the work location (MGRA) and accessibilities for the escort purpose from the residence location (MGRA) were also included in the estimation dataset.

Observed Frequency of Mandatory Tours

Table 26 shows the frequency of mandatory tour patterns by person type and gender. Most of the persons have either 1 work tour or 1 school tour as mandatory tour. Only around 6% have two or more tours of same type or different types.

Table 26: Frequency of Mandatory Tour Patterns by Person type and Gender

	1 Work	2+ Work	1 School	2+ School	Work & School	Total
Person Type						
Full-time Worker	2,577	157	18	0	22	2,774
Part-time Worker	422	36	12	0	4	474
University Student	27	0	119	7	18	171
Non-Working Adult	0	0	7	0	0	7
Retiree	0	0	9	0	0	9
Driving Age School Child	3	0	242	13	12	270
Pre-driving Age School Child	0	0	1,045	13	0	1,058
Pre-school Child	0	0	290	0	0	290
Gender						
Male	1,680	102	880	26	20	2,708
Female	1,347	91	849	7	36	2,330
Missing	2	0	13	0	0	15
Total	**3,029**	**193**	**1,742**	**33**	**56**	**5,053**

Main Explanatory Variables

The following variables have been examined in the estimation process:

- **Personal characteristics stratified by *person* type**
- Female
  - Age 35 and younger for full time worker
  - Age greater than 35 for university student
- **Household composition stratified by person type**
  - Zero car
  - Car not sufficient for drivers, university student, and school age children
  - Number of preschool children for full and part time workers, and university student
  - Number of school age children not going to school for full and part time workers
  - Non-working adult for workers
  - Non-family household
  - Household income greater than $50k for full and part time workers, and university student
- **Mandatory tour destination location (model choice accessibility term 2)**
  - Workplace location within walking distance bins (0-0.5 and 0.5-3 miles)
  - School location within walking distance bin (0-0.5 and 0.5-2 miles)
  - Minimum travel time to or from workplace (non-motorized not included)

    - Non-motorized accessibility at workplace
- **Population accessibility to household**
    - Escorting accessibility by car ownership

The work location within distance of 3 miles distance turned out to be a very strong positive factor for double work tours. The comparison between numbers of observed and predicted choices for double work tours by distance band showed that the model over predicted tours in 0-0.5 mile distance band and compensated in the second distance band 0.5-1 miles by under prediction. To capture the non-linear distance effects, two sets of distance terms were tested: 0-0.5 and 0.5-3 miles, 0-1 and 1-3 miles. The test results showed the 0-0.5 and 0.5-3 miles distance terms better replicated the survey data.

A few variables do not have a logical or significant impact on the choice of mandatory tours, such as number of non-working adults in the household for workers making single school tour, or a combination of one work and one school tour; minimum travel time to or from school for students making double school tours; and middle and high income household workers making one school tour. These variables were either excluded or their coefficients were set to zero in the final estimation.

Results

The final estimation results are presented in Table 27 below for all person types 1-7. The entries for non-variable alternatives for the corresponding person type are labeled “N/A” in order to distinguish them from zero (i.e. statistically insignificant or reference-alternative coefficients.)

Table 27: Mandatory Tour Frequency Model Estimation Result

Observations:	4791
Likelihood – Constants only	-7668.75
Final log likelihood:	-1096.089
Rho-Squared (0):	0.8570
Rho-Squared (constant):	0.7344

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Constant	1=Full-time worker	0.000		-1.071	-0.406	-16.928	-2.150	N/A		-10.450	-1.279
	2=Part time worker	0.000		-1.778	-0.663	-16.156	-2.071	N/A		-10.241	-1.260
	3=University student	-0.935	-1.930	N/A		0.000		-2.329	-4.734	-0.898	-1.573
	4=Non-worker U65	0.000		N/A		0.000		N/A		N/A	
	5=Retiree 65+	0.000		N/A		0.000		N/A		N/A	
	6=School child 16-17	-2.810	-3.425	N/A		0.000		-2.230	-5.800	-3.449	-3.093
	7=School child 6-15	N/A		N/A		0.000		-3.838	-9.652	N/A	
Person is female (dummy)	1=Full-time worker	0.000		-0.172	-0.990	-0.372	-0.687	N/A		0.657	1.386
	2=Part time worker	0.000		0.726	1.552	0.634	0.823	N/A		0.000	
	3=University student	-0.186	-0.374	N/A		0.000		-1.207	-1.362	-0.627	-1.090
	4=Non-worker U65	N/A		N/A		N/A		N/A		N/A	
	5=Retiree 65+	N/A		N/A		N/A		N/A		N/A	
	6=School child 16-17	-0.845	-0.668	N/A		0.000		-1.566	-1.998	2.225	2.038
	7=School child 6-15	N/A		N/A		0.000		-1.124	-1.696	N/A	
Young adult (age <=35)	1=Full-time worker	0.000		0.000		0.337	0.776	N/A		0.000	

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Age older than 35	3=University student	1.374	1.029	N/A		0.000		0.000		N/A	
Workplace within distance band 1 (0-0.5 mile) (dummy)	1=Full-time worker			0.642	1.746						
	2=Part time worker			0.642	1.746						
Workplace within distance band 2 (0.5-3 miles) (dummy)	1=Full-time worker			1.217	6.139						
	2=Part time worker			1.217	6.139						
School within distance band 2 (0.5-2 miles) (dummy)	3=University student							0.492	1.293		
	6=School child 16-17							0.492	1.293		
	7=School child 6-15							0.492	1.293		
Workplace or school within distance band 1 (dummy)	1=Full-time worker									0.194	0.164
	2=Part time worker									0.194	0.164
	3=University student									0.194	0.164
	6=School child 16-17									0.194	0.164
Workplace or school within distance band 2 (dummy)	1=Full-time worker									0.184	0.419
	2=Part time worker									0.184	0.419
	3=University student									0.184	0.419
	6=School child 16-17									0.184	0.419
Minimum travel time to or from workplace (in min) (non-motorized not considered)	1=Full-time worker			-0.022	-3.277					-0.008	-0.598
	2=Part time worker			-0.022	-3.277					-0.008	-0.598
	3=University student			N/A						-0.008	-0.598
	4=Non-worker U65			N/A						N/A	

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
	5=Retiree 65+			N/A						N/A	
Escorting Accessibility by Car Sufficiency	1=Full-time worker			-0.102	-0.557	1.009	1.855	N/A		0.574	1.023
	2=Part time worker			-0.102	-0.557	1.009	1.855	N/A		0.574	1.023
	4=Non-worker U65			N/A		1.009	1.855	N/A		N/A	
	5=Retiree 65+			N/A		1.009	1.855	N/A		N/A	
No cars in household (dummy)	1=Full-time worker			-0.662	-1.395			N/A		-0.662	-1.395
	2=Part time worker			-0.662	-1.395			N/A		-0.662	-1.395
	3=University student			N/A				-0.662	-1.395	-0.662	-1.395
	4=Non-worker U65			N/A				N/A		N/A	
	5=Retiree 65+			N/A				N/A		N/A	
	6=School child 16-17			N/A				-0.662	-1.395	-0.662	-1.395
	7=School child 6-15			N/A				-0.662	-1.395	N/A	
Cars fewer than drivers in household (dummy)	3=University student							-0.955	-1.836		
	6=School child 16-17							-0.955	-1.836		
	7=School child 6-15							-0.955	-1.836		
# of pre-school children in household	1=Full-time worker			-0.039	-0.210			N/A		-0.143	-0.376
	2=Part time worker			-0.039	-0.210			N/A		-0.143	-0.376
	3=University student			N/A				-1.534	-1.598	-0.143	-0.376
number of school age children, with pattern other than M,	1=Full-time worker			-0.437	-1.323						
	2=Part time worker			-0.437	-1.323						

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Non-family household (dummy)	1=Full-time worker										
	2=Part time worker										
	3=University student	-1.094	-1.286							-1.094	-1.286
	4=Non-worker U65										
	5=Retiree 65+										
	6=School child 16-17	-1.094	-1.286							-1.094	-1.286
	7=School child 6-15										
Household income of 50K or higher (dummy)	1=Full-time worker										
	2=Part time worker										
	3=University student	0.689	1.614								
Alternative specific constant adjustment	1=Full-time worker			0.142							
	2=Part time worker			0.268							
	3=University student	0.363						0.525		1.007	
	6=School child 16-17							0.148		0.472	
	7=School child 6-15							-0.097			
usual work location is work-at-home		-999		-999						-999	
usual school location is school-at-home						-999		-999		-999	
usual work location is work-at-home, but there's a school		-999		-999						-999	

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
location											
usual school location is school-at-home, but there's a work location						-999		-999		-999	
work not available for non-driving children		-999		-999						-999	
work not available for driving children that are not employed		-999		-999						-999	
no mandatory tours for non-working adults		-999		-999		-999		-999		-999	
school not available for ft, pt workers						-999		-999		-999	
work only not available for school aged students		-999		-999							
2 work tours not available for university students				-999							
work tour not available for university students that are not employed		-999		-999						-999	

Findings

The following section summarized the most important findings and impacts on mandatory tour frequency:

- Person-type constants are very significant showing that person type itself and the characteristics of the person explains the frequency and purpose of the tours. Since the reference alternative was the most frequent one (one work tour for workers, one school tour for students), all constants are negative with the relative frequency of the other alternatives shown in the table above.
- Gender has a certain impact on frequency and purpose of mandatory tours. Female full-time workers are less likely to make two or more work tours or one school tour, but more likely to make a combination of work and school tour than male. Female part-time workers are more likely to make two work tours and one school tour, which can be explained by the nature of the part-time workers, who tend to work near their residence and need to take care of children related issues and return to work again. Female school and university students are less likely to make two or more school tours compared to male.
- Workers of younger age (under 36) have a school pattern more frequently. University students of older age (greater than 35) are more likely to have one work tour.
- The number of preschool children in household has a negative impact on workers to make two or more work tours or a combination of one work and one school tour. The number of school age children not going to school has the more negative impact on workers to make two or more work tours.
- Non-family household university students and school age children (16-17 yrs age) are less likely to make one work tour or a combination of one work and one school tour compared to their counterparts.
- Not having cars in the household at all reduces probability of having a double-tour pattern of any type. Car insufficiency lowers probability of students making double school tours.
- Usual workplace location has a strong impact on double-tour patterns. The closer the workplace location is to home, the more likely that the worker will implement two work tours (presumably to return home for lunch and then return to work). Usual school location has similar impact on double school tours, but not as strong as work location on double work tours. To capture the non-linear distance effects, two distance terms (0 to 0.5 and 0.5 to 3 miles for work, 0 to 0.5 and 0.5 to 2 miles for school) are used.
- Car escort accessibilities have a strong positive impact on workers, non-workers under 65 and retirees 65 and above making one school tour and a negative impact on making two work tours. It makes workers more likely to make a combination of one work and one school tour.

4.2.2, 4.3.4, 4.4.3, 4.5.3 Tour Time of Day Choice (Individual Mandatory, Individual/Joint Non-Mandatory, and At-Work Tours)

The tour time-of-day choice models predict tour departure-from-home and arrival-back-home time periods. The time periods are defined in one-half hour increments from 5 AM to 12 AM (midnight), and all other time periods are collapsed in two categories – between 3 AM and 5 AM or between 12 AM and 3 AM. The model was estimated as a multinomial logit model using the ALOGIT software, where the mode choice model provides accessibility measures for each of five broader time-of-day periods (early, AM peak, midday, PM peak and night), within which the more disaggregate one-half hour increments fall. This model is applied after tour destination choice and before tour mode choice. The model is segmented by tour purpose[1] (work, university, school, escort, shop, maintenance, eating out, visit, discretionary and at-work) and is applied for all tour types (individual and joint). It includes mode choice logsums, travel distance, tour characteristics, household travel patterns, household characteristics and person characteristics as explanatory variables.

Estimation Dataset

In the SANDAG 2006 household travel behavior survey, there are 9,563 individual observed tours, 808 observed joint tours and 406 observed at-work sub-tours. Figures 14 to 23 show the observed departure, arrival and duration distributions by tour purpose.

Among the three mandatory tour purposes, the work and school tours have clear peaking patterns. The departure peak is around 7:30 am to 8:30 am for all three mandatory purposes. For work, the arrival peak is between 5:00 pm to 5:30 pm and duration peak is around 9.5 hours. The duration peak is slightly longer than the average 8 hours work day because the travel time to/from work is included in the duration. For school, the duration is shorter with peaking around 7 hours and arrival peak is between 2:30 pm and 3:00 pm. The university purpose has another small peak for departure in the evening. This could be due to workers attending school after work hours. The duration for university tours peaks around 4 hours and decreases slightly over longer durations.

Among the non-mandatory purposes, escorting has very specific departure, arrival and duration patterns. There are two distinct peaks – one in the morning (6:30 am to 9:30 am) and another in the afternoon (1:30 pm to 4:00 pm), which represent drop-off and pick-up patterns for school children. The arrival peaks follow the departure peaks with a small lag, and the durations are very short.

Shopping and Maintenance tours have departures and arrivals all through the day starting around or after the AM peak. Shopping tours start later in the morning (after 9:30 am), which reflects typical opening hours of stores, compared to maintenance tours (including medical appointments), which start earlier in the morning (after 7:30 am). On average, shopping tours tend to have shorter durations than maintenance tours.

Eating Out tours have two distinct peaks for departure and arrival times – one around lunch time and another peak around typical dinner hours. More Eating Out tours are observed for dinner than for lunch. Most of the Eating Out tours have durations between 1 to 2 hours.

Visiting and other discretionary tours peak in the evening departure periods with late evening and night arrivals. Visiting tours tend to have longer durations than other discretionary tours.

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[1] The tour purpose is the purpose of the primary activity on the tour. The primary activity is identified based on purpose of the activity and duration of the activity. Mandatory activities such as work and school/university get priority over non-mandatory activities, and longer duration activities get priority over shorter duration activities.

At-work sub-tours usually occur during mid-day (peaking between 11:30 am and 1:00 pm) with short durations ranging from half-an-hour to an hour. Nearly 44% of all subtours are for eating out, 21% are work-related and the remaining 33% are for other non-mandatory activities.

Figure 14: Observed Departure, Arrival and Duration Distributions for Work Tours

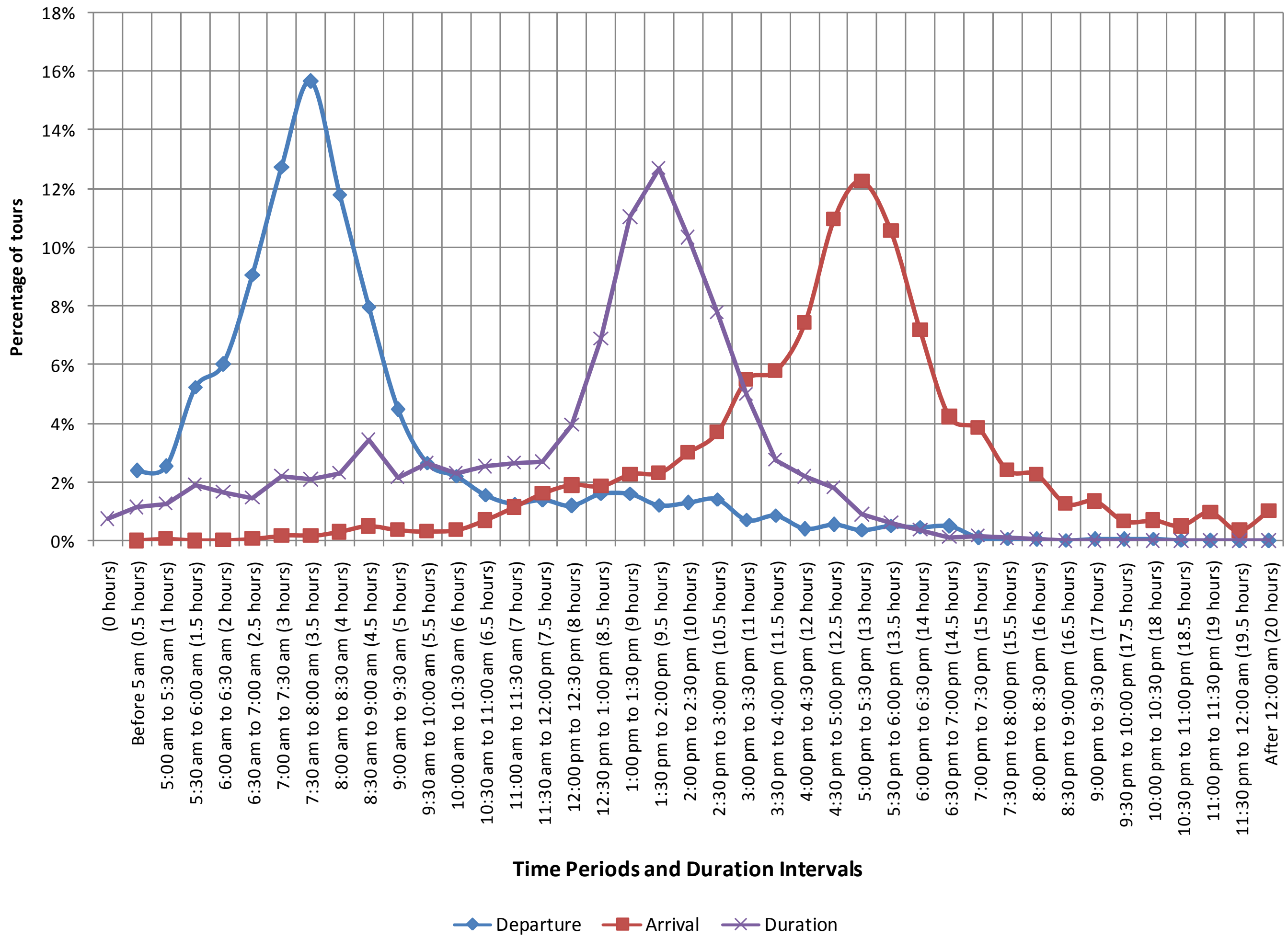


Figure 15: Observed Departure, Arrival and Duration Distributions for University Tours

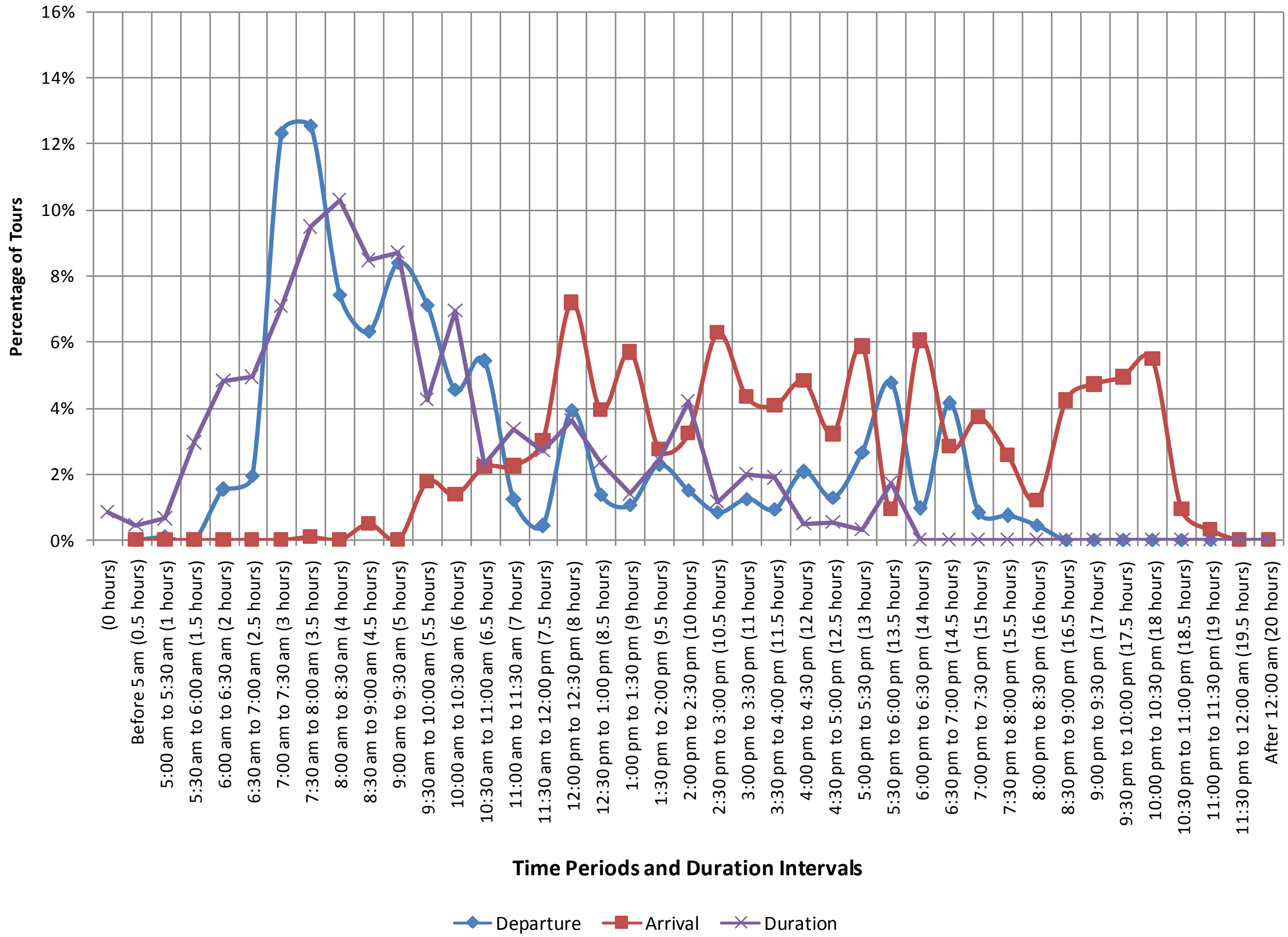


Figure 16: Observed Departure, Arrival and Duration Distributions for School Tours

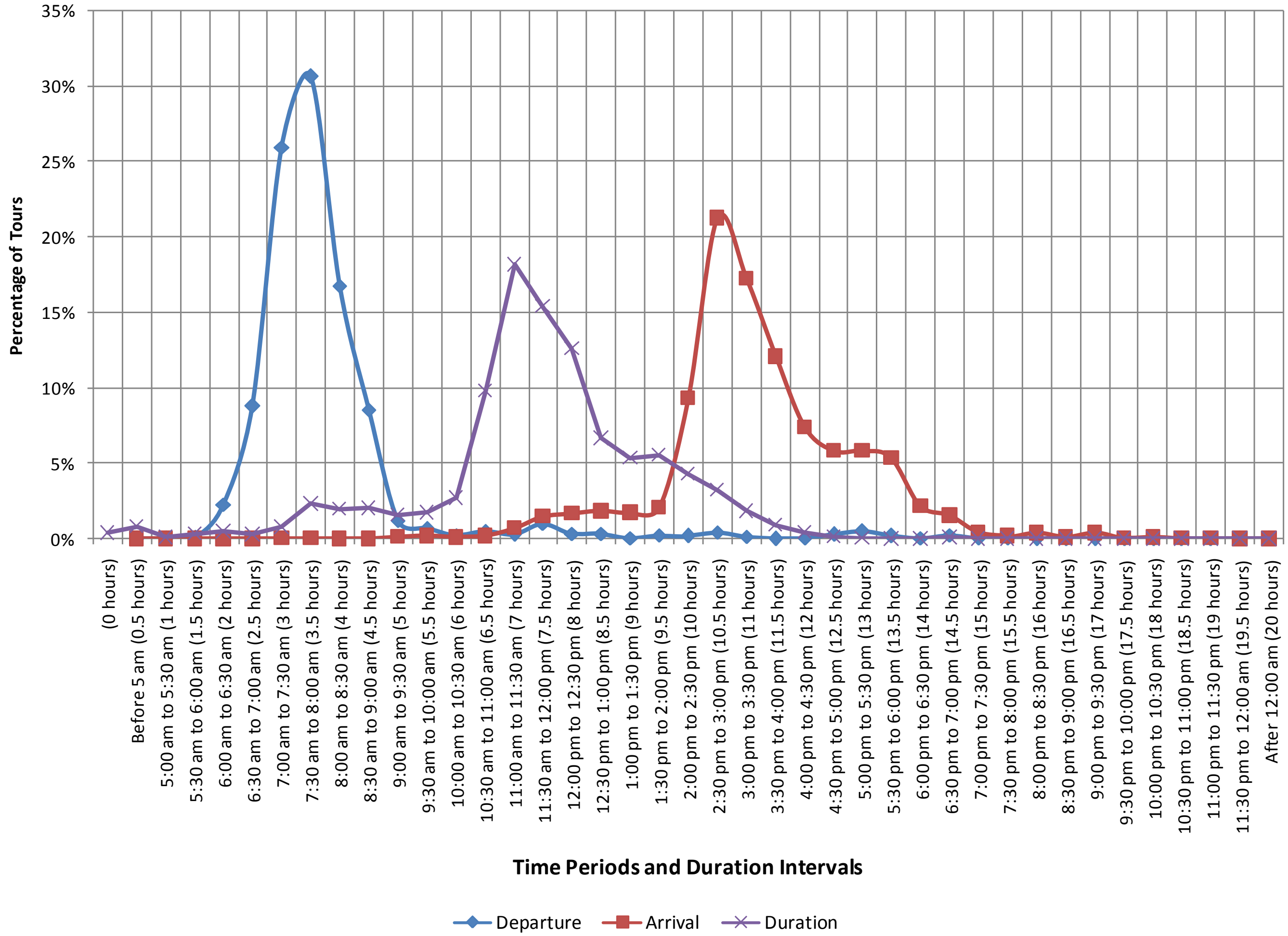


Figure 17: Observed Departure, Arrival and Duration Distributions for Escorting Tours

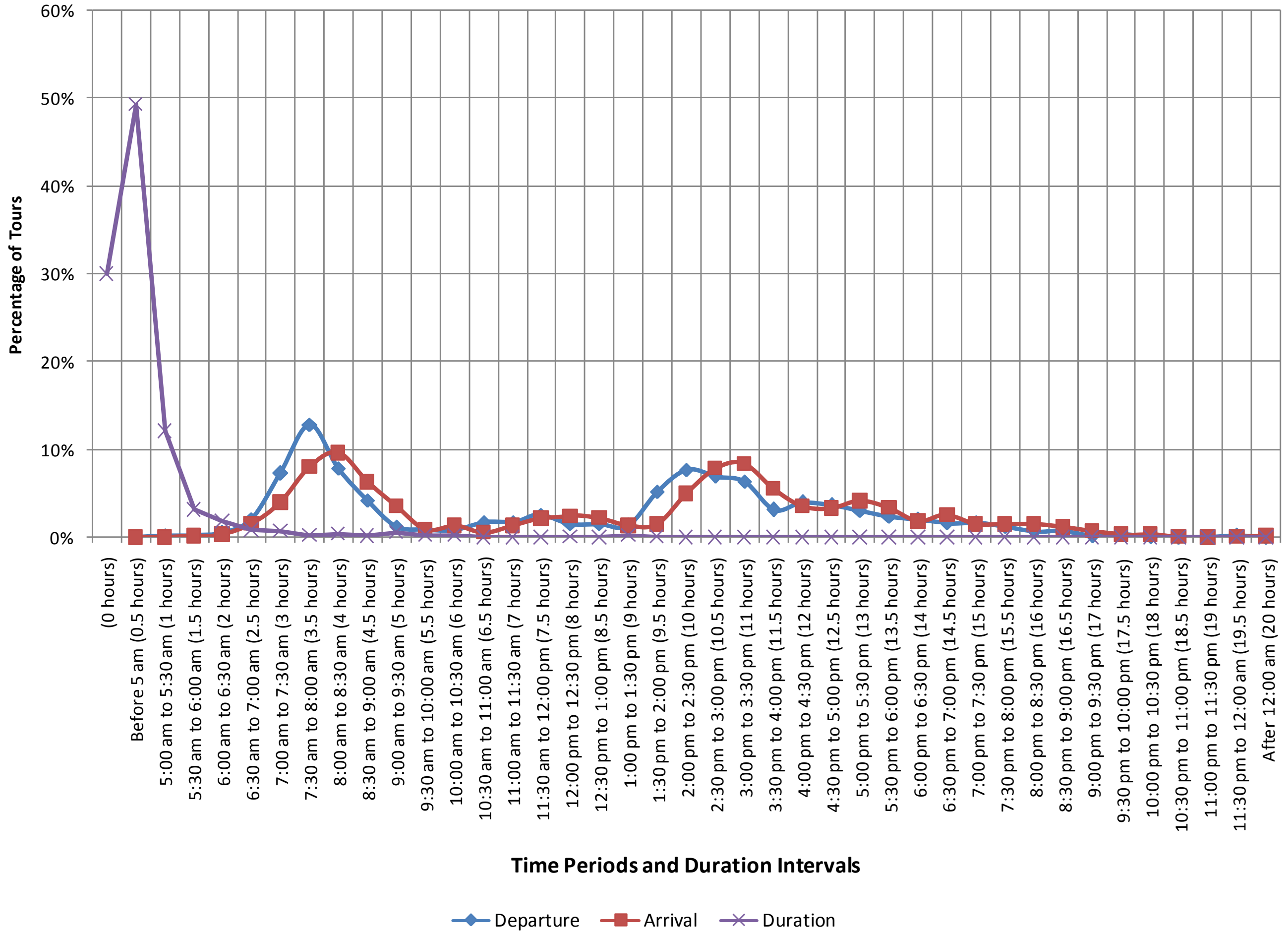


Figure 18: Observed Departure, Arrival and Duration Distributions for Shopping Tours

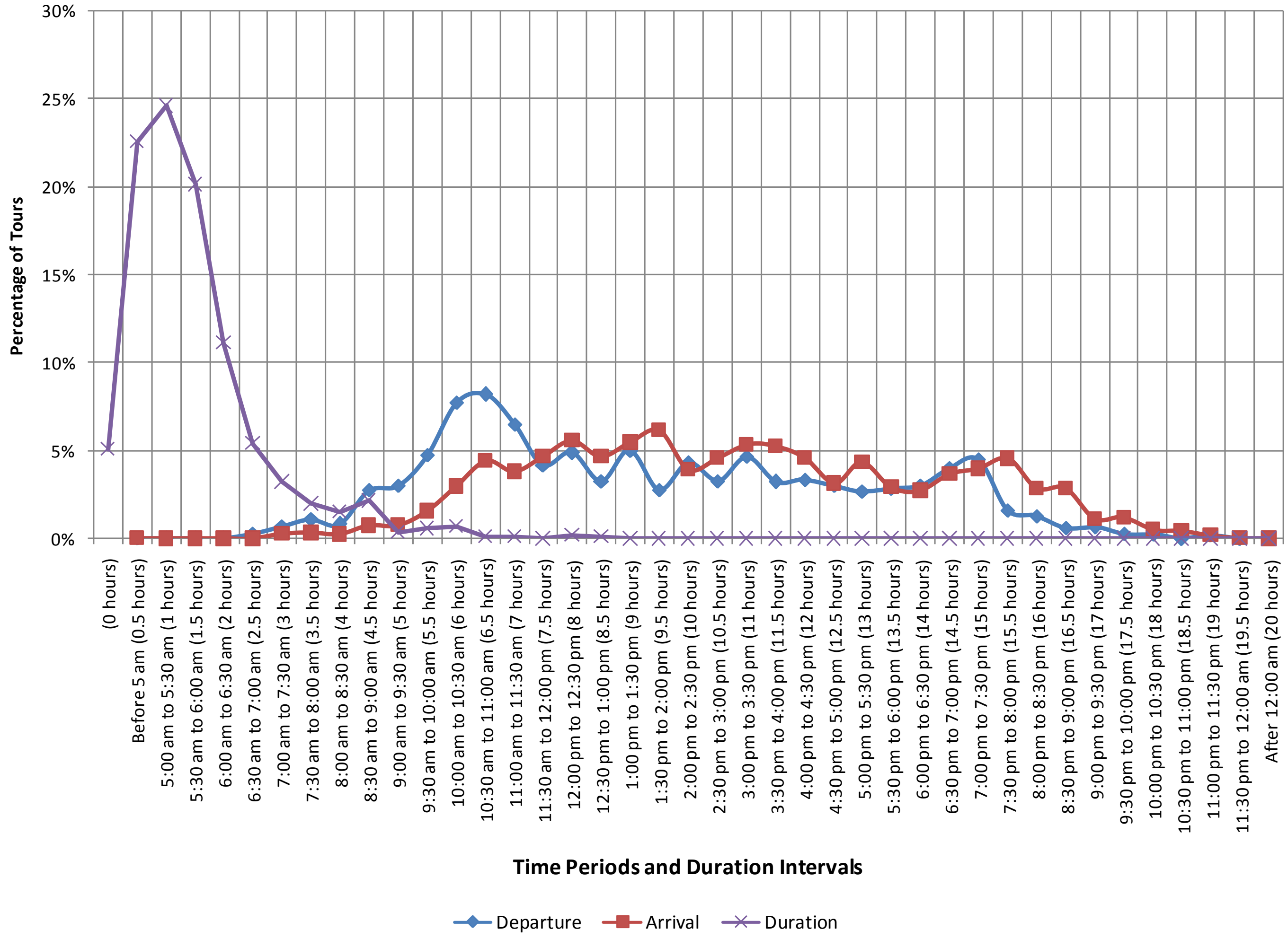


Figure 19: Observed Departure, Arrival and Duration Distributions for Maintenance Tours

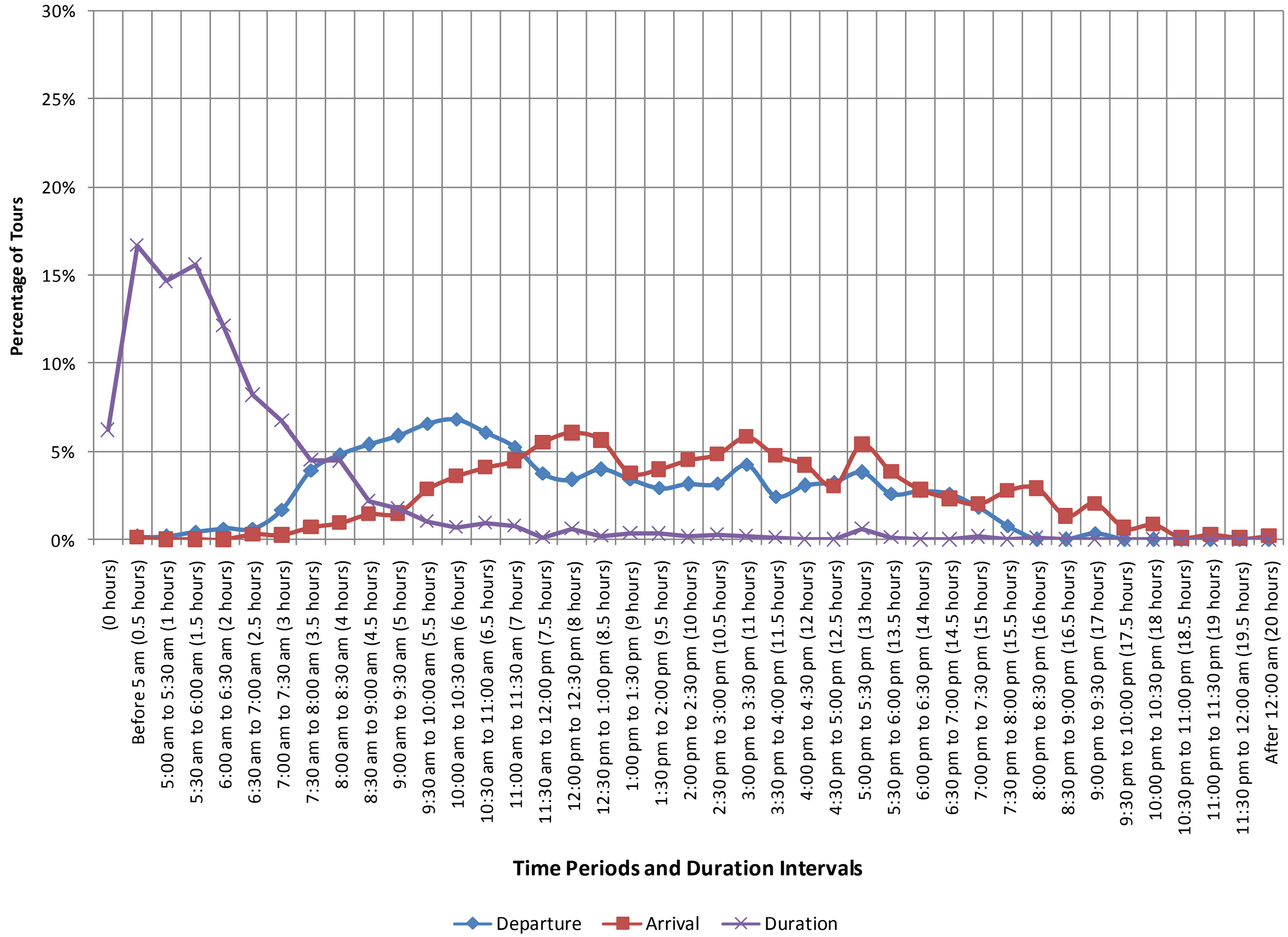


Figure 20: Observed Departure, Arrival and Duration Distributions for Eating Out Tours

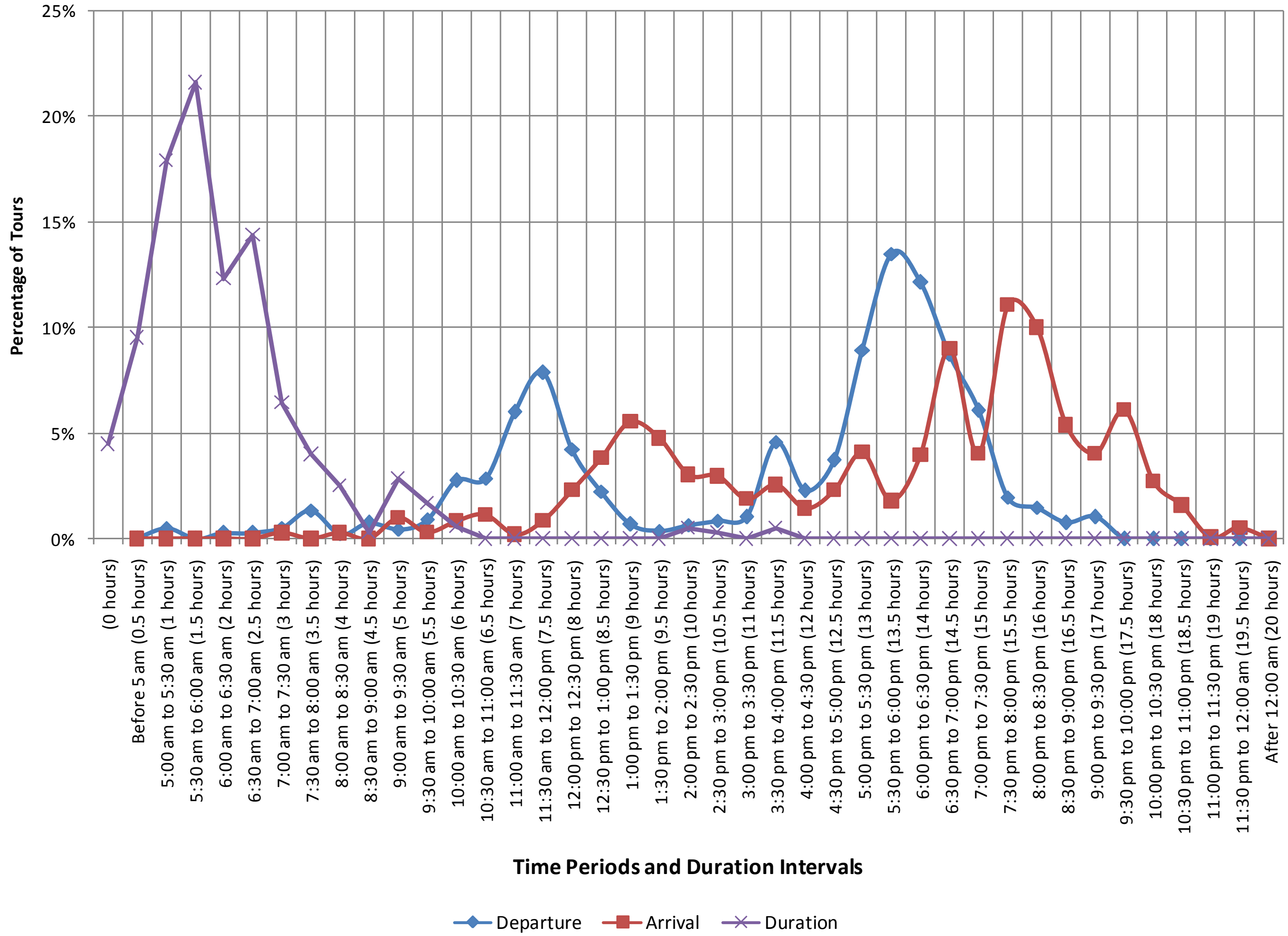


Figure 21: Observed Departure, Arrival and Duration Distributions for Visiting Tours

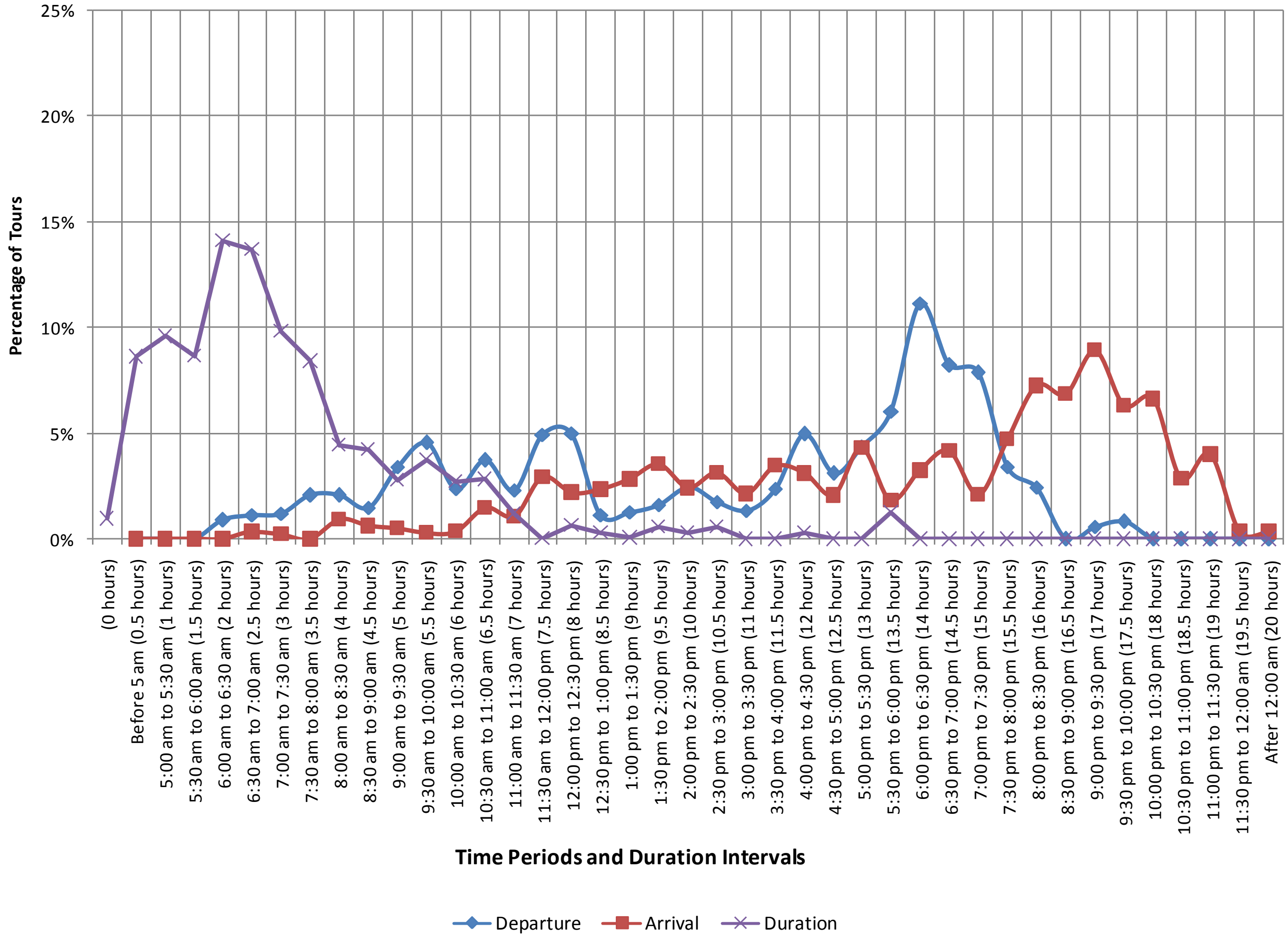


Figure 22: Observed Departure, Arrival and Duration Distributions for Discretionary Tours

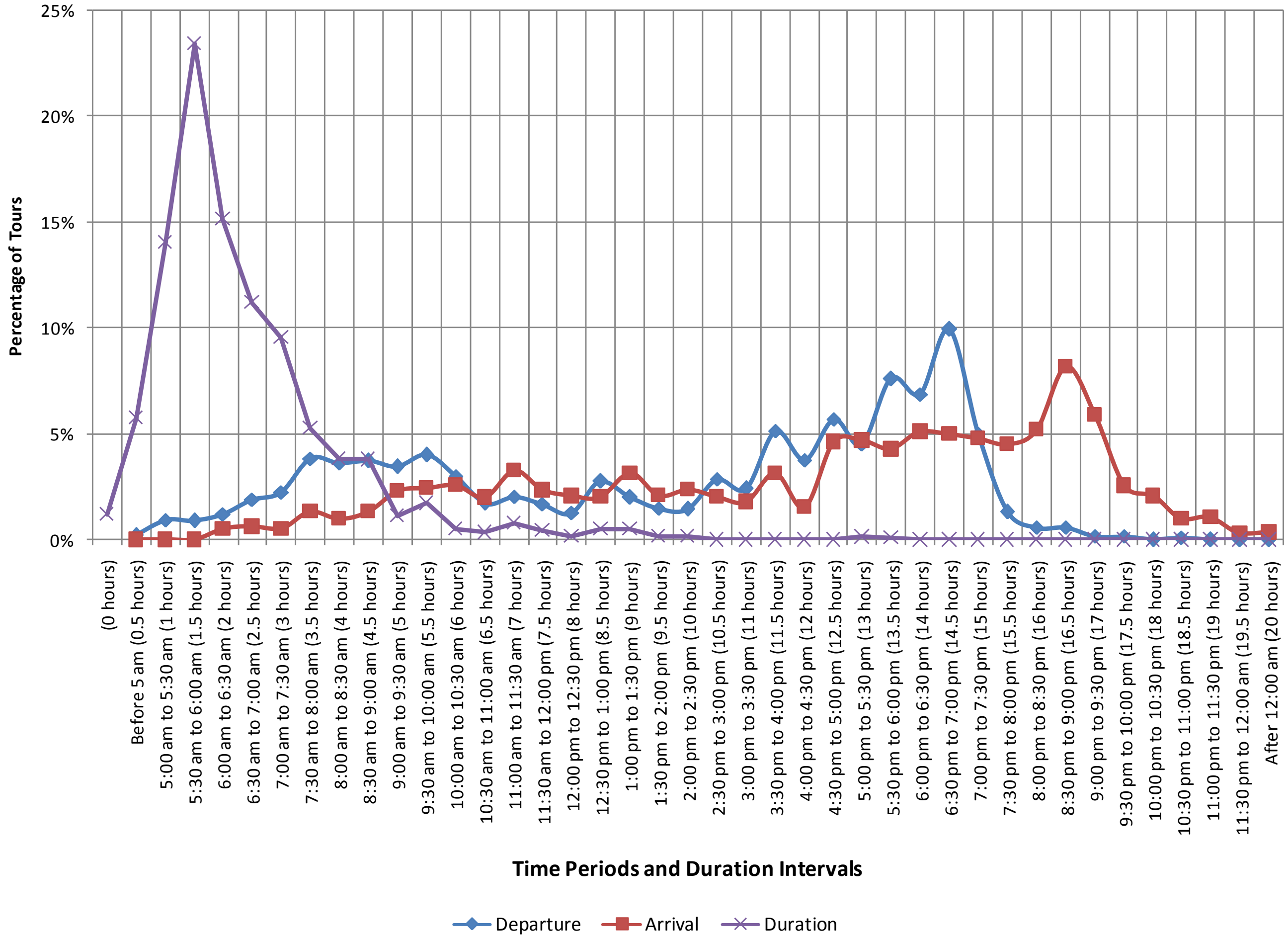
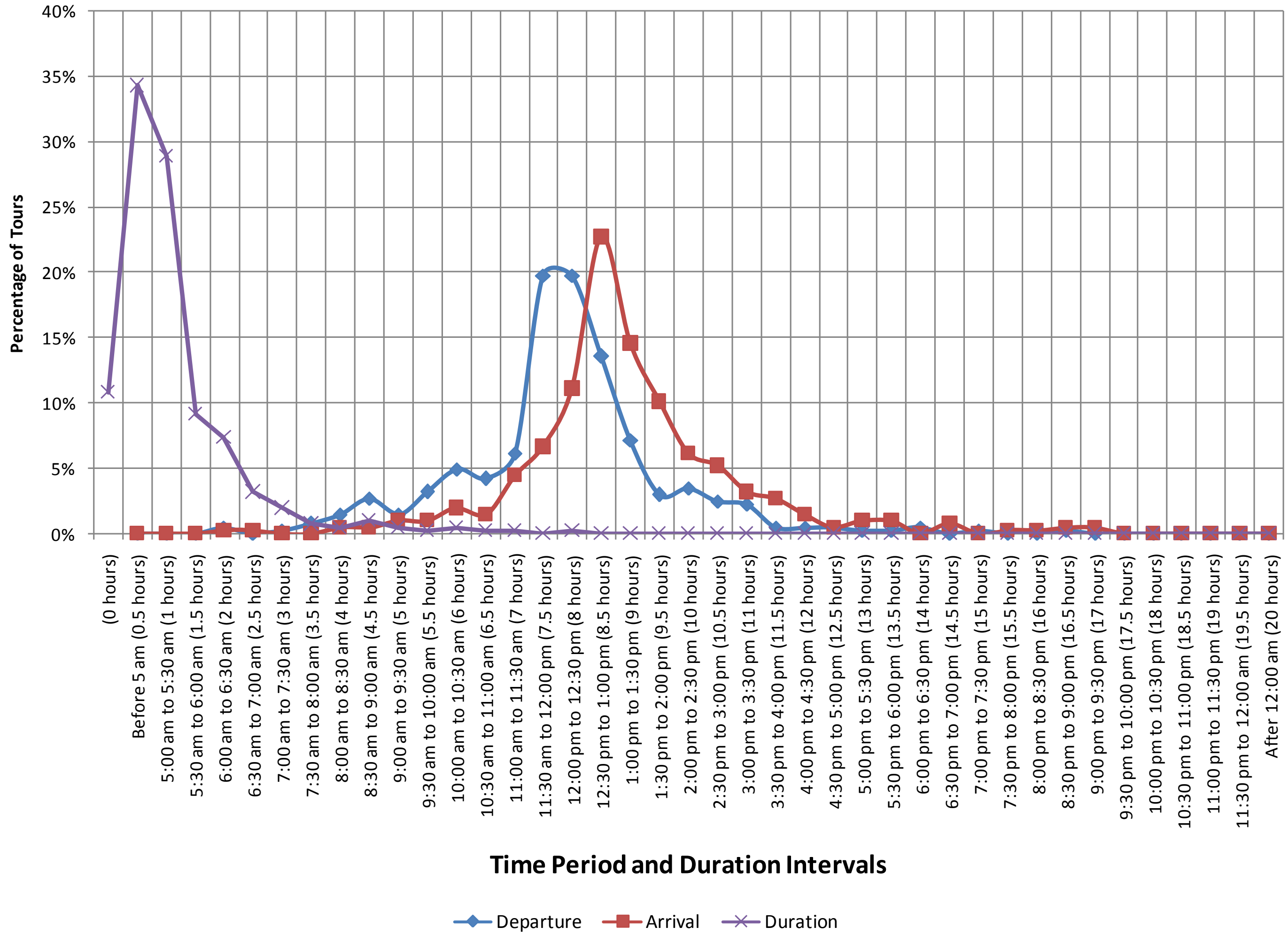


Figure 23: Observed Departure, Arrival and Duration Distributions for At-Work Sub-tours



Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

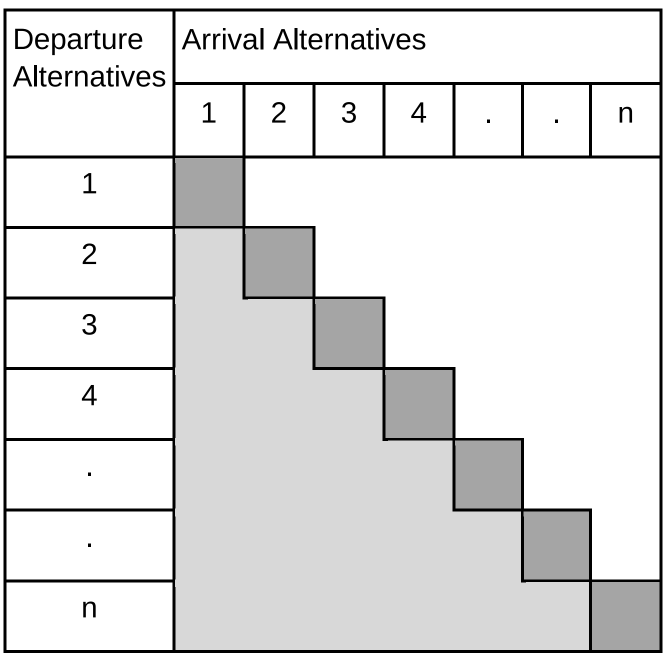
- Mode choice logsums
- Household income group:
  - Low income (less than $30,000)
  - Medium income($30,001-$60,000)
  - Medium high income ($60,001-100,000)
  - High income ($100,001 and more)
- Household composition
  - Presence of non-working adults
  - Presence of preschool child
  - Presence of school child
- Person characteristics
  - Person Type – Worker, Student, Non-Working Adult, Retiree, Pre-driving Age Child
  - Gender – Female vs. Male
  - Age group
- Time pressure - maximum continuous available time window divided by numbers of tours to be schedule including the current tour. The log form of this variable was used in the model. This variable is a person specific variable and is only applied for individual tours.
- Travel distance to primary destination (miles)
- Employment density at the destination
- Tour specific variables
  - Presence of joint travel in the household
  - First Mandatory tour of two mandatory tours
  - Joint Tour vs. Individual Tour
- Joint tour variables –Party size and party composition
- Subtour purpose – only applicable for at-work subtour model
  - Work related
  - Eating out
  - Other

Structure of the time-of-day choice model

The time-of-day choice model is a hybrid discrete choice and duration model that simultaneously predicts departure-from-home and arrival-back-home time for each tour with half-hour temporal resolution. The model formulation is fully consistent with the tour-based modelling paradigm and is designed for application in an individual micro-simulation framework such as the SANDAG ABM. Time-of-day choice models of this type have been estimated and applied as a part of activity-based travel demand model systems developed in other regions of the United States including Columbus (Ohio), Atlanta (Georgia), the San-Francisco Bay Area and Sacramento (California).

The model is essentially a discrete choice construct that operates with tour departure-from-home and arrival-back-home time combinations as alternatives. The utility structure is based on "continuous shift" variables representing an analytical hybrid that combines the advantages of a discrete choice structure (flexible in specification, easy to estimate and apply) with the advantages of a duration model (parsimonious structure with a few parameters that support any level of temporal resolution including continuous time). Shift variables have the effect of shifting the utility of departure, arrival, or duration lower or higher in a given time period based upon the interaction of a variable describing the number of periods the given period is from a reference period and some purpose-related, socio-economic or accessibility variable.

With 30 minute temporal resolution from 5am to 12am, there are 40 alternatives for departure and arrival time: 5:00 am or earlier, 5:00 am to 5:29 am, 5:30 am to 5:59 am, …, 11:30 pm to 11:59 pm, 12:00 am or after, while the remaining hours are collapsed with the first and the last period. There are 40 departure and 40 arrival alternatives which would give 40x40=1600 half- hourly departure-arrival time combinations. However, only combinations where the arrival half-hour period is equal to or later than the departure half-hour period are feasible. The matrix below shows the feasible alternatives (highlighted) considered for the choice given "n" departure alternatives and "n" arrival alternatives. The lower half of the matrix and diagonal = n×(n-1)/2+n.



Therefore the number of feasible alternatives is 40×39/2 (lower half matrix) + 40 (diagonal) =40×41/2=820.

The model is applied sequentially for all tours in the individual daily activity-travel pattern according to the predetermined priority of each activity type. The enhanced temporal resolution allows for applying direct availability rules for each subsequently scheduled tour to be placed in the residual time window left after scheduling higher-priority tours. This conditionality ensures a full consistency for the entire individual daily schedule as an outcome of the model. The travel tours implemented jointly by several household members for non-work activities are scheduled as one unit for all participants.

Model Structure

Hybrid choice and duration models

There has been a growing interest in and recognition of advantages of duration models that specifically address duration-related decisions. In particular, it has been recognized that decisions regarding the duration of some activity can be described by a model that conditions the activity-termination decision at each time interval on the duration of the activity undertaken previous to that interval. Thus, rather than having a multiple choice of activity duration of 1,2,3,4,5,6,7 or 8 hours, the model is formulated in terms of the probability of termination of activity at any hour as a function of the activity duration. In a case where this function can be formulated in a closed analytical form with a few parameters, the resulting model looks simpler and easier in estimation and application than the analogous direct choice model, while offering flexibility in terms of the level of temporal resolution addressed.

However, there is a strict analogue between standard choice models and duration models that may be obscured by the difference in analytical forms. This analogy is especially revealing in discrete space that we assume from this point on. Moreover, this analogue opens a way to reformulate any duration model as a discrete choice model with a special (sometimes very complicated, but some other times quite simple) set up for utility expressions. This reformulation leads to operational choice models that can be estimated using standard software like ALOGIT. These models, while being operational and having a simple discrete choice structure (multinomial logit in our case), inherit such important advantages of duration models as a parsimonious form in terms of a (limited) number of employed variables and parameters (utility coefficients) as well as practically unlimited temporal resolution that does not bring any significant additional burden to the model estimation and application.

The hybrid utility structure is created by using “shift variables”. A shift variable introduces increment/decrement in the utility function for a given time based upon the difference in duration between the given time period and a reference period, as well as an interaction effect describing the impacts of significant variables (socio-economic, accessibility, or other) upon the dimension considered. Shift variables have the effect of making departure, arrival, and/or duration in a given period more or less likely given the characteristics of the traveler, or the environment under which travel is taken. For example, congestion effects could cause the probability of departure to work increase for periods both before and after a reference period (8 AM, for example). The change in utility to depart for work earlier as a result of congestion could be greater than the change in utility to depart later than the reference period, depending on the shift variables specified and the magnitude of the coefficients estimated.

Utility Structure

The following notation is used:

m	=	tour mode (SOV, HOV, transit, non-motorized)
g,h	=	departure-from-home/arrival-home time period interval
s,t	=	departure-from-home/arrival-home aggregated skim period
j	=	destination zone
L	=	level-of-service variable (skim)

X^k = k^{th} household or person specific variable, where person specific variables are only included for individual tours

W^z = z^{th} zonal variable

J^r = r^{th} joint tour specific variable (such as party composition type), only included joint non-mandatory tours

The time-of-day choice model is formulated at the level of half an hour while mode choice logsums are aggregated at the level of 5 time periods. Since in estimation there were only 3 skims (AM, PM and Off-Peak) available from current 4-step model, the off-peak skim was used for early, midday and night periods. However, household and person characteristics capture internal shifts of departure/arrival time within each period as well as impacts on the activity durations. The model utility function is also very compact because the coefficients do not have indices g,h. Mode choice (accessibility) logsums can be calculated for each 30 minute period rather than for each period combination if 30 minute-specific skims are available.

The time-of-day choice utility takes the following form:

$$V_{gh}^{j} = \alpha_g + \alpha_h + \alpha_{h-g} + V_g^j + V_h^j + D_{h-g}^j + \mu \ln\left(\sum_m V_m^{jst}\right),$$

Where:

$\alpha_g, \alpha_h, \alpha_{h-g}$ = departure/arrival/ duration constants,

V_g^j, V_h^j = departure/arrival time specific components,

D_{h-g}^j = duration-specific components,

$\ln\left(\sum_m V_m^{jst}\right)$ = mode choice logsum.

Departure/arrival specific components were estimated using generic shift variables (household, person, tour and zonal characteristics):

$$V_g^j = \sum_k (g - R^g) \times X^k + \sum_z (g - R^g) \times W^{jz} + \sum_r (g - R^g) \times J^r + (g - R^g) \times L^j$$

Where, R^g is the departure time reference for calculating the value of the shift variables. Typically, the maximum observed alternative is chosen as the reference case. The shifts are negative for departure periods before the reference period and are positive for departure periods after the reference period. The variables examined in the departure/arrival components are mostly boolean dummies (household income, female, presence of school children, age group, etc.). Separate coefficients are defined for negative and positive shift variables. The absolute numerical value of the shift increases as the departure time alternative is farther away from the departure reference. It means the impacts of shift variables are larger for alternatives away from the reference.

The duration-specific component is proposed to be estimated in the following, similar form:

$$D_{h-g}^j = \sum_k \left(h - g - R^{h-g}\right) \times X^k + \sum_z \left(h - g - R^{h-g}\right) \times W^{jz} + \sum_r \left(h - g - R^{h-g}\right) \times J^r + \left(h - g - R^{h-g}\right) \times L^j$$

Where, R^{h-g} is the duration reference for calculating the shifts. The coefficients' interpretation will be in terms of the length of the duration. Note that actual index of the duration component is *h-g* rather than *g*h*, making the formation on the variables and estimation procedure much simpler.

In the estimation and the application of the model, available time-of-day alternatives are defined based on the residual time windows (after scheduling the higher-priority tours). Thus, in many cases only a very limited subset of alternatives will be available.

Tour Priority and Sequential Calculation of Available Time Windows

In this specification, tours are sequenced and scheduled in priority order in the following categories, from highest to lowest priority:

1. Work tours made by workers, school/university tours made by students
2. Work tours made by students, school/university tours made by workers
3. Joint maintenance tours
4. Joint shopping tours
5. Joint visit tours
6. Joint discretionary tours
7. Joint eating out tours.
8. Escort tours
9. Individual maintenance tours
10. Individual shopping tours
11. Individual visit tours
12. Individual discretionary tours
13. Individual eating out tours

Two or more tours within a category are sequenced and scheduled in chronological order. Once a tour is scheduled, no other tour may be scheduled during that period, so the availability for all remaining tours in the scheduling sequences is affected. Joint tours are treated differently because their scheduling is constrained by (and affects) the available time windows of all household members participating in the tour.

Results

The estimation results are summarized in Tables 28 to 35.

Table 28: Time of Day Choice Model Estimation Results for Work Tours

Number of Observations	3,154
Likelihood with Constants only	-17322.7786
Final likelihood	-16912.0291
ρ^2 w.r.t. zero	0.1995
ρ^2 w.r.t. constants	0.0237

Parameters	Coeff	T-Stat
Mode Choice Logsum	0.500	
Departure Time Constants		
Before 5:30 am	-2.901	-4.19
5:30 am to 6:00 am	-1.708	-3.28
6:00 am to 6:30 am	-1.355	-3.44
6:30 am to 7:00 am	-0.728	-2.73
7:00 am to 7:30 am	-0.290	-2.00
7:30 am to 8:00 am (Reference)	0.000	
8:00 am to 8:30 am	-0.175	-1.23
8:30 am to 9:00 am	-0.358	-1.37
After 9:00 am	-0.768	-1.99
Linear Shift for every 30 minutes after 9:30 am	0.259	1.86
Squared Shift for every 30 minutes after 9:30 am	-0.006	-3.55
Square Root Shift for every 30 minutes after 9:30 am	-0.595	-3.83
Arrival Time Constants		
Linear Shift for every 30 minutes before 2:30 pm	-0.072	-0.45
Squared Shift for every 30 minutes before 2:30 pm	0.000	-0.03
Square Root Shift for every 30 minutes before 2:30 pm	0.138	0.72
Before 3:00 pm	0.493	0.76
3:00 pm to 3:30 pm	-0.071	-0.14
3:30 pm to 4:00 pm	-0.150	-0.39
4:00 pm to 4:30 pm	-0.135	-0.51
4:30 pm to 5:00 pm	-0.016	-0.11
5:00 pm to 5:30 pm (Reference)	0.000	
5:30 pm to 6:00 pm	-0.189	-1.30
6:00 pm to 6:30 pm	-0.540	-2.06
6:30 pm to 7:00 pm	-0.968	-2.51
After 7:00 pm	-1.054	-2.09
Linear Shift for every 30 minutes after 7:30 pm	-0.223	-0.98

Parameters	**Coeff**	**T-Stat**
Squared Shift for every 30 minutes after 7:30 pm	0.010	0.58
Square Root Shift for every 30 minutes after 7:30 pm	-0.193	-0.60
Duration Constants		
Linear Shift for every 30 minutes less than 7.5 hrs	0.269	1.83
Squared Shift for every 30 minutes less than 7.5 hrs	-0.023	-7.68
Square Root Shift for every 30 minutes less than 7.5 hrs	-0.697	-4.23
8 hours or less	-0.595	-1.42
8.5 hours	-0.057	-0.19
9 hours	-0.196	-1.36
9.5 hours (Reference)	0.000	
10 hours	-0.093	-0.64
10.5 hours	-0.267	-1.02
11 hours or more	-0.505	-1.31
Linear Shift for every 30 minutes more than 11.5 hrs	0.261	1.05
Squared Shift for every 30 minutes more than 11.5 hrs	-0.044	-2.64
Square Root Shift for every 30 minutes more than 11.5 hrs	-0.559	-1.89
Household Variables		
Low Income (<=$29,999)		
Departure Before 5 am (Dummy)	-0.754	-2.58
Departure before 7:30 am (Linear Shift)	-0.245	-4.96
Departure after 8 am (Linear Shift)	0.033	2.49
Arrival after 12 am (Dummy)	1.176	2.74
Duration< 9.5 hrs (Linear Shift)	0.023	1.80
Duration>9.5 hrs (Linear Shift)	-0.046	-1.72
Medium Income ($30,000 to $59,999)		
Departure Before 5 am (Dummy)	-0.754	-2.58
Departure before 7:30 am (Linear Shift)	-0.133	-3.22
Departure after 8 am (Linear Shift)	0.033	2.49
Duration< 9.5 hrs (Linear Shift)	0.023	1.80
Duration>9.5 hrs (Linear Shift)	-0.046	-1.72
High Income (>= $100,000)		
Departure before 7:30 am (Linear Shift)	0.171	4.97
Departure after 8 am (Linear Shift)	-0.037	-2.96
Household with Joint Travel		

Parameters	Coeff	T-Stat
Arrival before 5:00 pm (Linear Shift)	-0.042	-2.79
Arrival after 5:30 pm (Linear Shift)	-0.024	-1.18
Presence of Non-Working Adult in the Household		
Departure before 7:30 am (Linear Shift)	-0.080	-2.17
Departure after 8 am (Linear Shift)	-0.023	-1.31
Arrival before 5:00 pm (Linear Shift)	0.031	1.65
Arrival after 5:30 pm (Linear Shift)	0.044	1.98
Person Specific Variables		
Full Time Worker, Departure after 10 am	-0.332	-2.54
Full Time Worker, Duration < 9.5 hrs	-0.730	-4.17
Full Time Worker, Arrival before 3 pm	-0.884	-5.75
Part-Time Worker		
Departure before 7:30 am (Linear Shift)	0.564	4.30
Departure before 7:30 am (Squared Shift)	-0.095	-3.56
Duration< 9.5 hrs (Linear Shift)	-0.096	-5.36
University Student/Driving Age Student		
Departure after 8 am (Linear Shift)	0.052	1.40
Duration< 9.5 hrs (Linear Shift)	-0.111	-1.11
Duration< 9.5 hrs (Squared Shift)	0.013	1.97
Female Worker		
Departure before 7:30 am (Linear Shift)	0.149	4.99
Departure after 8 am (Linear Shift)	-0.027	-2.34
Arrival after 5:30 pm (Linear Shift)	-0.017	-1.03
Female & Presence of Pre-School Child in the HH		
Departure before 7:30 am (Linear Shift)	0.120	1.70
Arrival before 5:00 pm (Linear Shift)	0.013	0.53
Arrival after 5:30 pm (Linear Shift)	-0.067	-1.85
Age Group		
Age 16 to 18 yrs - Departure after 8 am (Linear Shift)	0.137	3.53
Age 19 to 24 yrs - Departure before 7:30 am (Linear Shift)	-0.179	-2.87
Age 19 to 24 yrs - Departure after 8 am (Linear Shift)	0.148	7.42
Age 41 to 55 yrs - Departure before 7:30 am (Linear Shift)	-0.111	-3.59
Age 56 to 65 yrs - Departure before 7:30 am (Linear Shift)	-0.069	-1.71
Age 65+ yrs - Departure before 7:30 am (Linear Shift)	0.116	1.48

Parameters	Coeff	T-Stat
Age 16 to 18 yrs - Duration> 9.5 hrs (Linear Shift)	-0.137	-0.65
Age 19 to 24 yrs - Duration< 9.5 hrs (Linear Shift)	0.092	3.51
Age 19 to 24 yrs - Duration> 9.5 hrs (Linear Shift)	-0.082	-1.41
Age 41 to 55 yrs -Duration< 9.5 hrs (Linear Shift)	-0.045	-3.69
Age 56 to 65 yrs - Duration< 9.5 hrs (Linear Shift)	-0.045	-2.90
Age 65+ yrs - Duration< 9.5 hrs (Linear Shift)	-0.128	-6.84
First Work Tour out of Two Mandatory Tours		
subsequent tour must start after previous tour ends	-9.99	
First of 2+ work tours		
Departure before 7:30 am (Linear Shift)	-0.140	-2.34
Departure after 8 am (Linear Shift)	0.038	2.63
Duration< 9.5 hrs (Linear Shift)	-0.266	-16.01
Duration>9.5 hrs (Linear Shift)	-0.852	-3.10
First Tour of work and school tours		
Departure before 7:30 am (Linear Shift)	-0.250	-1.79
Departure after 8 am (Linear Shift)	0.026	0.63
Duration< 9.5 hrs (Linear Shift)	-0.120	-2.87
Duration>9.5 hrs (Linear Shift)	-0.621	-1.67
Distance		
Origin to Destination Distance, Departure before 7:30 am (Linear Shift)	-0.014	-10.13
Origin to Destination Distance, Departure after 8 am (Linear Shift)	-0.002	-2.60
Destination to Origin Distance, Arrival before 5:00 pm (Linear Shift)	0.004	5.25
Destination to Origin Distance, Arrival after 5:30 pm (Linear Shift)	0.002	1.90
Employment Density at Destination		
Departure after 8 am (Linear Shift)	-0.001	-3.01
Arrival before 5:00 pm (Linear Shift)	0.002	4.31
Arrival after 5:30 pm (Linear Shift)	0.001	2.36

Table 29: Time of Day Choice Model Estimation Results for University Tours

Number of Observations	242
Likelihood with Constants only	-1186.7432
Final likelihood	-1354.9503
ρ^2 w.r.t. zero	0.1491
ρ^2 w.r.t. constants	-0.1417

Parameter	Coeff	T-Stat
Mode Choice Logsum	0.200	
Departure Time Constants		
Before 6:00 am	-5.758	-4.68
6:00 am to 6:30 am	-3.268	-3.80
6:30 am to 7:00 am	-2.369	-4.01
7:00 am to 7:30 am	-0.541	-1.69
7:30 am to 8:00 am (Reference)	0.000	
After 8:00 am	-0.343	-1.45
Linear Shift for every 30 minutes after 8:30 am	-0.154	-2.24
Arrival Time Constants		
Linear Shift for every 30 minutes before 11:00 am	0.056	0.43
Before 11:30 am	-0.363	-0.79
11:30 am to 12:00 pm	-0.501	-1.13
12:00 pm to 12:30 pm (Reference)	0.000	
After 12:30 pm	-0.471	-1.24
Linear Shift for every 30 minutes after 1:00 pm	0.276	1.69
Squared Shift for every 30 minutes after 1:00 pm	-0.012	-3.05
Square Root Shift for every 30 minutes after 1:00 pm	-0.470	-1.18
Duration Constants		
1 hour or less	-3.381	
1.5 hours	-1.259	
2 hours to 2.5 hours	-0.863	-1.51
3 hours	-0.147	-0.44
3.5 hours	0.064	0.19
4 hours (Reference)	0.000	
4.5 hours	-0.165	-0.57
5 hours	-0.260	-0.81
5.5 hours or more	-0.330	-1.00
Linear Shift for every 30 minutes over 5.5 hrs	-0.136	-2.26

Household Variables		
Low and Medium Income (<=$59,999)		
Departure after 8:00 am (Linear Shift)	0.032	0.70
Duration < 4 hrs (Linear Shift)	0.066	0.46
Duration > 4 hrs (Linear Shift)	0.029	0.53
High Income (>= $100,000)		
Departure before 7:30 am (Linear Shift)	-0.204	-0.77
Duration > 4 hrs (Linear Shift)	-0.077	-1.10
Person Variables		
Full or Part Time Worker - Departure between 5:00 pm to 7:30 pm	0.994	1.04
Full or Part Time Worker - Departure before 11:00 am	-0.526	-1.31
Full or Part Time Worker - Arrival between 8:00 pm to 11:00 pm	0.846	2.41
Full or Part Time Worker - Duration between 2 to 2.5 hours	0.300	0.47
Not a full or part time worker - Departure between 4:30 pm to 7:30 pm	2.153	2.62
Age Group		
Age 16 to 24 yrs - Departure after 8 am (Linear Shift)	-0.044	-1.06
Age 16 to 24 yrs -Duration < 4 hrs (Linear Shift)	0.080	0.67
Age 56 to 65 yrs - Duration > 4 hrs (Linear Shift)	-0.177	-1.33
Age 65+ yrs - Duration > 4 hrs (Linear Shift)	-0.280	-1.42
Distance		
Origin to Destination Distance - Departure before 7:30 am (Linear Shift)	-0.033	-2.25
Origin to Destination Distance - Departure after 8:00 am (Linear Shift)	-0.001	-0.38
Destination to Origin Distance - Arrival before 12:00 pm (Linear Shift)	0.045	2.67
Destination to Origin Distance - Arrival after 12:30 pm (Linear Shift)	0.004	2.14
First University Tour of Two Mandatory Tours		
subsequent tour must start after previous tour ends	-9.99	
First Tour of work and school tours		
Departure after 8:00 am (Linear Shift)	-0.240	-2.80
Duration > 4 hrs (Linear Shift)	-0.261	-2.92
First of 2+ school tours		
Duration < 4 hrs (Linear Shift)	-0.542	-3.81
Duration > 4 hrs (Linear Shift)	-0.727	-1.92

Table 30: Time of Day Choice Model Estimation Results for School Tours

Number of Observations	1595
Likelihood with Constants only	-6660.8339
Final likelihood	-6621.9022
ρ^2 w.r.t. zero	0.3812
ρ^2 w.r.t. constants	0.0058

Parameter	Coeff	T-Stat
Mode Choice Logsum	0.100	
Departure Time Constants		
Before 6:30 am	-1.671	-5.19
6:30 am to 7:00 am	0.273	1.46
7:00 am to 7:30 am	0.745	6.62
7:30 am to 8:00 am (Reference)	0.000	
8:00 am to 8:30 am	-0.873	-9.25
After 8:30 am	-1.740	-11.91
Linear Shift for every 30 minutes after 9 am	-0.118	-0.91
Square Root Shift for every 30 minutes after 9 am	-1.954	-7.82
Arrival Time Constants		
Linear Shift for every 30 minutes before 2:00 pm	-0.080	-0.67
Squared Shift for every 30 minutes before 2:00 pm	-0.055	-4.48
Before 2:30 pm	-1.023	-8.80
2:30pm to 3:00 pm (Reference)	0.000	
3:00 pm to 3:30 pm	0.146	1.50
3:30 pm to 4:00 pm	-0.030	-0.22
4:00 pm to 4:30 pm	-0.275	-1.46
4:30 pm to 5:00 pm	-0.243	-1.07
After 5:00 pm	-0.152	-0.58
Linear Shift for every 30 minutes after 5:30 pm	-0.797	-8.34
Square Root Shift for every 30 minutes after 5:30 pm	0.728	3.36
Duration Constants		
Linear Shift for every 30 minutes under 6.5 hrs	0.097	1.28
6.5 hours or less	-0.153	-1.23
7 hours (Reference)	0.000	
7.5 hours	-0.470	-4.48
8 hours	-0.779	-5.30
8.5 hours or more	-1.451	-7.20

Parameter	Coeff	T-Stat
Linear Shift for every 30 minutes over 8.5 hrs	0.626	1.43
Squared Shift for every 30 minutes over 8.5 hrs	-0.124	-2.54
Square Root Shift for every 30 minutes over 8.5 hrs	-0.801	-1.61
Household Variables		
Low Income (<=$29,999)		
Departure after 8:00 am (Linear Shift)	0.157	2.76
Duration < 7 hrs (Linear Shift)	0.120	2.32
High Income (>= $100,000)		
Departure before 7:30 am (Linear Shift)	0.272	3.51
Duration < 7 hrs (Linear Shift)	0.107	3.04
All Adults are Full-Time Workers in the Household		
Departure before 7:30 am (Linear Shift)	-0.212	-2.95
Departure after 8:00 am (Linear Shift)	-0.126	-2.78
Arrival before 2:30 pm (Linear Shift)	0.165	3.13
Arrival after 3:00 pm (Linear Shift)	0.168	6.72
Person Variables		
Driving Age Child (Age over 16 years) - Duration less than 7 hrs	-0.383	-1.59
Pre-driving Age Child (Age under 16 years) - Arrival before 2:00 pm	-1.061	-5.10
Age Group		
Age 0 to 5 yrs - Departure before 7:30 am (Linear Shift)	1.094	7.82
Age 0 to 5 yrs - Departure after 8:00 am (Linear Shift)	0.101	1.77
Age 6 to 12 yrs - Departure before 7:30 am (Linear Shift)	0.836	9.43
Age 16 to 17 yrs- Departure after 8:00 am (Linear Shift)	0.213	3.43
Age 0 to 5 yrs - Duration < 7 hrs (Linear Shift)	-0.399	-8.03
Age 0 to 5 yrs - Duration > 7 hrs (Linear Shift)	0.170	4.87
Age 6 to 12 yrs - Duration < 7 hrs (Linear Shift)	0.048	0.97
Age 6 to 12 yrs - Duration > 7 hrs (Linear Shift)	-0.058	-2.02
First School Tour of Two Mandatory Tours		
subsequent tour must start after previous tour ends	-9.990	
First of 2+ school tours		
Departure before 7:30 am (Linear Shift)	-0.538	-2.68
Departure after 8:00 am (Linear Shift)	0.305	4.01
Duration < 7 hrs (Linear Shift)	-0.411	-6.05
Duration > 7 hrs (Linear Shift)	-0.242	-1.56

Parameter	Coeff	T-Stat
First Tour of work and school tours		
Duration > 7 hrs (Linear Shift)	-0.311	-1.64
Distance		
Origin to Destination Distance - Departure before 7:30 am (Linear Shift)	-0.010	-1.81
Destination to Origin Distance - Arrival after 3:00 pm (Linear Shift)	0.012	5.62

Table 31: Time of Day Choice Model Estimation Results for Escorting Tours

Number of Observations	1,341
Likelihood with Constants only	-5370.4805
Final likelihood	-5015.4364
ρ^2 w.r.t. zero	0.3742
ρ^2 w.r.t. constants	0.0661

Parameter	Coeff	T-Stat
Mode Choice Logsum	0.399	1.29
Departure Time Constants		
Linear Shift for every 30 minutes before 6:30 am	-1.419	-6.73
Before 7:00 am	-3.631	-8.13
7:00 am to 7:30 am	-1.164	-5.13
7:30 am to 8:00 am (Reference)	0.000	
8:00 am to 8:30 am	0.201	1.17
8:30 am to 9:00 am	-0.042	-0.16
After 9:00 am	-0.718	-2.18
Linear Shift for every 30 minutes after 9:30 am	0.205	3.42
1:30 pm to 2:00 pm	0.451	1.89
2:00 pm to 2:30 pm	0.734	2.59
2:30 pm to 3:00 pm	0.731	2.36
3:00 pm to 3:30 pm	1.236	3.65
After 3:30 pm	1.374	3.74
Linear Shift for every 30 minutes after 4:00 pm	0.121	2.01
Arrival Time Constants		
Before 7:00 am	3.706	6.71
7:00 am to 7:30 am	2.312	6.58
7:30 am to 8:00 am	1.139	5.45
8:00 am to 8:30 am (Reference)	0.000	
8:30 am to 9:00 am	-0.185	-1.03
After 9:00 am	-0.676	-2.47
Linear Shift for every 30 minutes after 9:30 am	-0.088	-1.53
2:00 pm to 2:30 pm	0.031	0.13
2:30pm to 3:00 pm	0.223	0.84
3:00 pm to 3:30 pm	-0.046	-0.14

Parameter	Coeff	T-Stat
After 3:30 pm	-0.722	-2.07
Linear Shift for every 30 minutes after 4:00 pm	-0.367	-6.19
Duration Constants		
0 hours	-0.485	-4.32
0.5 hours (Reference)	0.000	
1 hours	-0.898	-8.68
1.5 hours	-2.023	-10.22
2 hours	-2.480	-8.70
2.5 hours or more	-2.781	-7.34
Household Variables		
High Income (>= $100,000)		
Departure before 2:00 pm (Linear Shift)	0.046	1.87
Pre-Driving School Age Children Household with Mandatory Tour		
Departure after 8 am (Linear Shift)	-0.105	-1.22
Departure before 2:00 pm (Linear Shift)	0.262	2.28
Arrival before 8:00 am (Linear Shift)	0.606	4.91
Arrival after 8:30 am (Linear Shift)	-0.255	-3.28
Arrival before 3:00 pm (Linear Shift)	0.139	1.56
Arrival after 3:30 pm (Linear Shift)	-0.160	-5.11
Pre-School Child in Household with Mandatory Tour		
Departure before 7:30 am (Linear Shift)	0.442	1.29
Arrival before 8:00 am (Linear Shift)	0.510	2.10
Arrival after 8:30 am (Linear Shift)	0.137	3.23
Arrival before 3:00 pm (Linear Shift)	-0.254	-5.19
Arrival after 3:30 pm (Linear Shift)	-0.133	-3.04
Person Specific Variables		
Full-Time Worker Dummy		
Departure before 7:30 am (Linear Shift)	-0.164	-1.07
Arrival after 3:30 pm (Linear Shift)	0.110	3.70
Number of Non-Escorting Individual Tours		
Duration Shift for every 30 minutes over half an hour	-0.096	-1.72
First Escorting Tour of Multiple Escorting Tours		

Parameter	Coeff	T-Stat
Subsequent tour must start after previous tour ends	-9.99	
Departure before 7:30 am (Linear Shift)	-0.132	-0.83
Departure after 8 am (Linear Shift)	-0.125	-2.37
Departure before 2:00 pm (Linear Shift)	-0.148	-1.81
Duration Constant - 0 hours	0.391	2.58
Duration - 0.5 hours (Reference)	0.000	
Longer Duration Shift for every 30 minutes over half an hour	-0.206	-2.45
Distance to Destination		
Duration Constant - 0 hours - shorter duration shift effects	-0.162	-7.25
Duration - 0.5 hours (Reference)	0.000	
Longer Duration Shift for every 30 minutes over half an hour	0.019	5.21
Calibration Departure Constants		
7:00 am to 7:30 am	-0.209	
7:30 am to 8:00 am	0.429	
8:00 am to 8:30 am	0.449	
8:30 am to 9:00 am	0.374	
1:30 pm to 2:00 pm	0.374	
2:00 pm to 2:30 pm	0.390	
2:30 pm to 3:00 pm	0.418	
3:00 pm to 3:30 pm	0.291	
4:30 pm or Later	-0.468	
Calibration Arrival Constants		
6:30 am to 7:00 am	-0.878	
7:00 am to 7:30 am	-0.469	
7:30 am to 8:00 am	0.092	
8:00 am to 8:30 am	0.706	
8:30 am to 9:00 am	0.424	
1:30 pm to 2:00 pm	-0.377	
2:00 pm to 2:30 pm	0.358	
2:30 pm to 3:00 pm	0.353	
3:00 pm to 3:30 pm	0.424	

Parameter	Coeff	T-Stat
4:30 pm or Later	-0.399	

Table 32: Time of Day Choice Model Estimation Results for Maintenance and Shopping Tours

Number of Observations	2,084
Likelihood with Constants only	-10689.7244
Final likelihood	-10316.2704
ρ^2 w.r.t. zero	0.2024
ρ^2 w.r.t. constants	0.0349

Parameter	Shopping		Maintenance	
	Coeff	T-Stat	Coeff	T-Stat
Mode Choice Logsum	0.500		0.500	
Departure Time Constants				
Linear Shift for every 30 minutes interval before 9:30 am	-0.491	-7.13		
Before 10:00 am	-0.376	-2.29		
10:00 am to 10:30 am	-0.100	-0.63		
10:30 am to 11:00 am	0.000			
11:00 am or After	-0.233	-1.49		
Linear Shift for every 30 minutes after 11:30 am	0.099	2.52		
Square Root Shift for every 30 minutes after 11:30 am	-0.554	-4.08		
Linear Shift for every 30 minutes interval before 7:30 am			-0.679	-7.57
Before 8:00 am			-0.300	-1.58
8:00 am to 8:30 am			-0.200	-1.09
8:30 am to 9:00 am			-0.103	-0.79
9:00 am to 9:30 am			-0.103	-0.79
9:30 am to 11:00 am			0.000	
11:00 am to 11:30 am			-0.142	-0.91
11:30 am to 6:30 pm			-0.430	-3.19
After 6:30 pm			-0.359	-1.30
Linear Shift for every 30 minutes after 6:30 pm			-0.729	-5.23
Arrival Time Constants				
Linear Shift for every 30 minutes interval before 10:30 am	-0.034	-0.47		
Before 11:30 am	-0.522	-2.31		
11:30 am to 1:30 pm	-0.431	-2.61		
1:30 pm to 2:00 pm (reference)	0.000			
2:00 pm to 5:00 pm	-0.078	-0.48		
5:00 pm to 6:30 pm	-0.592	-2.40		
6:30 pm to 8:30 pm	-1.066	-3.40		
After 8:30 pm	-1.642	-4.13		

Parameter	Shopping Coeff	Shopping T-Stat	Maintenance Coeff	Maintenance T-Stat
Linear Shift for every 30 minutes interval after 9:00 pm	-0.524	-6.76		
Linear Shift for every 30 minutes interval before 9:30 am			-0.163	-2.26
Before 10:00 am			-0.438	-1.94
10:00 am to 11:00 am			-0.300	-1.62
11:00 am to 11:30 am			-0.161	-0.83
11:30 am to 12:00 pm			-0.054	-0.29
12:00 pm to 12:30 pm (Reference)			0.000	
12:30 pm to 4:30 pm			-0.140	-0.90
4:30 pm to 5:30 pm			-0.561	-2.77
After 5:30 pm			-1.102	-5.34
Linear Shift for every 30 minutes intervals after 6:00 pm			-0.146	-5.22
Duration Constants				
0 hours	-0.589	-2.92	0.082	0.39
0.5 hours	0.000			
1 hours	0.000		-0.225	-2.22
1.5 hours	-0.460	-4.81	-0.225	-2.22
2 hours	-0.935	-7.60	-0.535	-3.99
2.5 hours or more	-1.611	-11.65	-0.847	-6.43
Linear Shift for every 30 minutes over 2.5 hours	-0.503	-10.30	-0.406	-11.29
Calibration Duration constants - 0.5 hours	**-0.141**		**-0.155**	
Calibration Duration constants - 1.5 hours			**0.106**	
Household Variables				
Low Income (<=$29,999)				
Departure after 10:30 pm (Linear Shift)	-0.025	-2.01	-0.025	-2.01
Duration Shift for every 30 minutes over 1 hour	0.082	3.97	0.082	3.97
Medium Income ($30,000 to $59,999)				
Duration Shift for every 30 minutes over 1 hour	0.036	1.73	0.036	1.73
Household Size				
Longer Duration Shift for every 30 minutes over 1 hour	0.008	1.26	0.008	1.26
Person Specific Variables				
Non-Working Adult				
Duration - 0 hours	-0.537	-1.39	-0.537	-1.39
Duration - 0.5 hours to 1 hour (Reference)	0.000		0.000	

Parameter	Shopping Coeff	Shopping T-Stat	Maintenance Coeff	Maintenance T-Stat
Duration Shift for every 30 minutes over 1 hour	0.031	1.40	0.031	1.40
Female				
Duration - 0 hours	-0.747	-3.41	-0.747	-3.41
Duration - 0.5 hours to 1 hour (Reference)	0.000		0.000	
Duration Shift for every 30 minutes over 1 hour	0.072	4.14	0.072	4.14
Person Tour Pattern Specific Variables				
No Time Window is Available to schedule the tour	-999		-999	
Number of Additional Individual Tours of Same Purpose				
Duration - 0 hours	0.296	1.83	0.296	1.83
Duration - 0.5 hours to 1 hour (Reference)				
Duration Shift for every 30 minutes over 1 hour	-0.091	-3.52	-0.091	-3.52
First Tours (of Same Purpose) out of Multiple Tours				
Departure after 10:30 pm (Linear Shift)	-0.158	-5.69	-0.158	-5.69
Joint Tours Variables				
Subsequent tour must start after previous tour ends	-9.990		-9.990	
Duration over 1 hour (Dummy)	0.905	6.04	0.905	6.04
Departure before 10:00 am (Linear Shift)	0.042	0.88	0.042	0.88
Departure after 10:30 pm (Linear Shift)	-0.027	-2.01	-0.027	-2.01
Kids(Child under 16 years) on Joint Tour				
Duration - 0 hours	0.580	1.76	0.580	1.76
Duration - 0.5 hours to 1 hour (Reference)	0.000		0.000	
Duration Shift for every 30 minutes over 1 hour	-0.103	-2.33	-0.103	-2.33
Distance to Destination				
Duration - 0 hours	-0.270	-5.75	-0.270	-5.75
Duration - 0.5 hours to 1 hour (Reference)	0.000		0.000	
Duration Shift for every 30 minutes over 1 hour	0.009	11.05	0.009	11.05

Table 33: Time of Day Choice Model Estimation Results for Eating Out Tours

Number of Observations	260
Likelihood with Constants only	-1104.859
Final likelihood	-1189.7889
ρ^2 w.r.t. zero	0.2169
ρ^2 w.r.t. constants	-0.0772

Parameter	Coeff	T-Stat
Mode Choice Logsum	0.369	0.48
Departure Time Constants		
Before 7:30 am	-0.313	-0.37
Linear Shift for every 30 minutes before 10:30 am	-0.242	-2.06
10:30 am to 11:00 am	-0.246	-0.45
11:00 am to 11:30 am	0.835	1.77
11:30 am to 12:00 pm	0.891	1.84
12:00 pm to 12:30 pm	0.371	0.69
After 12:30 pm	-0.495	-0.81
Square Root Shift for every 30 minutes after 1:00 pm	-0.053	-0.17
Square Root Shift for every 30 minutes before 4 pm	-0.756	-2.25
Before 4:30 pm	-1.664	-2.26
4:30 pm to 5:00 pm	-1.604	-2.27
5:00 pm to 5:30 pm	-0.668	-1.52
5:30 pm to 6:30 pm (Reference)	0.000	
6:30 pm to 7:00 pm	-0.593	-1.43
7:00 pm to 7:30 pm	-0.638	-1.39
After 7:30 pm	-2.769	-3.77
Arrival Time Constants		
Before 12:00 pm	1.113	1.35
12:00 pm to 12:30 pm	1.136	1.48
12:30 pm to 1:00 pm	1.578	2.30
1:00 pm to 1:30 pm	1.852	2.89
1:30 pm to 2:00 pm	1.838	2.99
2:00 pm to 3:30 pm	1.477	2.76
3:30 pm to 5:00 pm	0.181	0.34
5:00 pm to 6:00 pm	0.251	0.56

Parameter	Coeff	T-Stat
6:00 pm to 7:30 pm	-0.030	-0.11
7:30 pm to 8:00 pm	0.000	
8:00 pm to 8:30 pm	-0.192	-0.61
8:30 pm to 9:00 pm	-0.210	-0.61
After 9:00 pm	-0.153	-0.42
Linear Shift for every 30 minutes after 9:30 pm	-0.477	-3.66
Duration Constants		
0 hours	0.421	0.53
0.5 hours	1.291	2.33
1 hours	0.922	2.48
1.5 hours	0.000	
2 hours	0.000	
2.5 hours	-0.571	-1.77
3 hours to 3.5 hours	-0.971	-2.65
4 hours or more	-1.639	-3.34
Household Variables		
Low Income (<=$29,999)		
Departure before 5:30 pm (Linear Shift)	-0.042	-0.42
Duration shorter than 1.5 hours (Linear Shift)	0.213	1.00
Medium Income ($30,000 to $59,999)		
Duration shorter than 1.5 hours (Linear Shift)	0.213	1.00
High Income (>= $100,000)		
Departure after 6:30 pm (Linear Shift)	0.068	0.54
Duration longer than 1.5 hours (Linear Shift)	-0.121	-1.26
Household Size		
Duration shorter than 1.5 hours (Linear Shift)	0.033	0.41
Person Variables		
Worker or University Student with Mandatory Pattern		
Departure - Before 5:00 pm (Dummy)	-0.234	-0.50
Female		
Duration shorter than 1.5 hours (Linear Shift)	0.497	2.01
Duration longer than 1.5 hours (Linear Shift)	0.092	0.94

Parameter	Coeff	T-Stat
Person Tour Pattern Specific Variables		
No Time Window is Available to schedule the tour	-999.0	
Time Pressure		
Departure before 5:30 pm (Linear Shift)	-0.069	-1.13
Tour Specific Variable		
Joint Tours (Dummy)		
Subsequent tour must start after previous tour ends	-9.990	
Departure between 11:00 am and 12:30 pm	-0.152	-0.34
Departure between 5:00 pm and 5:30 pm	0.163	0.20
Departure between 5:30 pm and 6:30 pm	-0.337	-0.40
Departure between 6:30 pm and 7:00 pm	0.245	0.26
Departure between 7:00 pm and 7:30 pm	-0.216	-0.22
Departure after 7:30 pm	0.268	0.24
Arrival after 6:30 pm	-0.099	-0.21
Arrival before 12:00 pm	-0.887	-1.24
Duration 0 hours	-2.175	-1.71
Duration 0.5 hours	-1.327	-2.01
Duration 1 hours	-0.334	-0.76
Duration 2.5 hours	0.767	1.89
Duration 3 hours	0.459	0.94
Duration 3.5 hours	0.325	0.61
Kids (Child under 16 years) on Joint Tour		
Arrival before 7:30 pm (Linear Shift)	-0.120	-0.95
Duration longer than 1.5 hours (Linear Shift)	-0.180	-0.95
Auto Distance		
Duration shorter than 1.5 hours (Linear Shift)	0.153	4.16
Duration longer than 1.5 hours (Linear Shift)	0.011	1.90
ASC Adjustments		
Departure - Before 5:00am to 11:00 am	-0.461	
ASC Adjustments Departure - Before 11:00 am to 12:00 pm	-0.201	
ASC Adjustments Departure - 12:00 pm to 3:30 pm	-0.399	
ASC Adjustments Departure - 3:30 pm to 7:00 pm	0.539	

Parameter	Coeff	T-Stat
ASC Adjustments Arrival - Before 5:00 am to 10:30 am	0.080	
ASC Adjustments Arrival - 10:30 am to 1:30 pm	-0.127	
ASC Adjustments Arrival - 8:00 pm to 9:30 pm	0.637	
ASC Adjustments Arrival - 9:30 pm to 12:00 am	0.640	

Table 34: Time of Day Choice Model Estimation Results for Visiting and Other Discretionary Tours

Number of Observations	1,229
Likelihood with Constants only	-6206.7258
Final likelihood	-6158.2767
ρ^2 w.r.t. zero	0.1404
ρ^2 w.r.t. constants	0.0078

	Visiting		Discretionary	
Parameter	**Coeff**	**T-Stat**	**Coeff**	**T-Stat**
Mode Choice Logsum	0.500		0.500	
Departure Time Constants				
Linear Shift for every 30 minutes before 7:00 am			-0.468	-5.32
Linear Shift for every 30 minutes before 8:30 am	-0.468	-4.15		
Before 7:30 am	0.752	1.90	0.156	0.73
7:30 am to 9:00 am	0.752	1.90	0.630	4.60
9:00 am to 10:00 am	1.066	3.79	0.630	4.60
10:00 am to 12:30 pm	1.066	3.79		
Linear Shift for every 30 minutes before 4:00 pm			0.043	1.75
Linear Shift for every 30 minutes before 5:30 pm	-0.054	-1.33		
Before 4:30 pm	-0.499	-1.89	-0.336	-1.86
4:30 pm to 5:30 pm	-0.499	-1.89	-0.227	-1.35
5:30 pm to 6:00 pm	-0.499	-1.89	-0.224	-1.52
6:00 pm to 6:30 pm (reference for visiting)	0.000		-0.224	-1.52
6:30 pm to 7:00 pm (reference for discretionary)	-0.190	-0.65	0.000	
7:00 pm to 7:30 pm	-0.211	-0.67	-1.046	-4.66
7:30 pm or Later	-0.849	-2.25	-1.685	-5.82
Linear Shift for every 30 minutes after 8 pm	-0.254	-1.59	-0.354	-2.25
Arrival Time Constants				
Linear Shift for every 30 minutes before 8:30 am			-0.130	-1.65
Linear Shift for every 30 minutes before 11:30 am	0.039	0.43		
Before 9:30 am	-0.230	-0.47	-0.573	-1.67
9:30 am to 12:00 pm	-0.230	-0.47	-0.532	-2.05
12:00 pm to 4:30 pm	0.186	0.57	-0.532	-2.05
4:30 pm to 7:30 pm	0.186	0.57	-0.421	-2.55
7:30 pm to 8:00 pm	0.027	0.07	-0.421	-2.55

8:00 pm to 8:30 pm	0.005	0.01	-0.421	-2.55
8:30 pm to 9:00 pm	-0.035	-0.10	-0.257	-1.38
9:00 pm to 9:30 pm (reference)	0.000		0.000	
9:30 pm to 10:00 pm	0.170	0.57	-0.839	-3.35
10:00 pm to 10:30 pm	0.170		-0.861	-3.45
10:30 pm to 11:00 pm	-0.376	-1.05	-0.861	-3.45
11:00 pm to 11:30 pm	-0.376		-0.861	-3.45
11:30 pm to 12:00 pm	-1.708	-2.23	-0.861	-3.45
12:00 pm or Later	-1.626	-2.10	-0.861	-3.45
Linear Shift for every 30 minutes after 10:30 pm			-0.237	-1.94
Duration Constants				
0 hours	-1.956	-2.95	-2.190	-5.35
0.5 hours	0.110	0.34	-0.630	-2.65
1 hours	-0.093	-0.43	-0.137	-0.89
1.5 hours (reference for Discretionary)	-0.093	-0.43	0.000	
2 hours	0.000		-0.335	-2.93
2.5 hours	-0.219	-0.91	-0.651	-4.86
3 hours	-0.517	-1.96	-0.970	-6.06
3.5 hours or more	-0.675	-2.82	-1.263	-7.72
Linear Shift for every 30 minutes after 3.5 hours	-0.379	-6.75	-0.393	-9.11
Household Variables				
Low Income (<=$29,999)				
Departure before 6:00 pm (Linear Shift)	-0.050	-1.58		
Departure before 6:30 pm (Linear Shift)			-0.050	-1.58
Duration Shift for every 30 minutes over 1.5 hours	0.071	2.39	0.071	2.39
Household Size (Individual Tours Only)				
Duration Shift for every 30 minutes over 1.5 hours	-0.014	-1.47	-0.014	-1.47
Person Specific Variables				
Non-Working Adult				
Duration Shift for every 30 minutes under 1.5 hours	-0.314	-1.78	-0.314	-1.78
Non-Working Adult with Pre-driving Age Child in the Household				
Duration Shift for every 30 minutes over 1.5 hours	-0.145	-1.18	-0.145	-1.18
Retiree				

Duration Shift for every 30 minutes under 1.5 hours	-0.119	-0.92	-0.119	-0.92
Pre-driving Age Child				
Duration Shift for every 30 minutes under 1.5 hours	0.122	0.24	0.555	1.99
Duration Shift for every 30 minutes over 1.5 hours	0.202	3.09	0.025	0.44
Female				
Duration Shift for every 30 minutes over 1.5 hours	-0.028	-1.20	-0.028	-1.20
Person Tour Pattern Specific Variables				
Time Pressure				
No Time Window is Available to schedule the tour	-999.0		-999.0	
Duration Shift for every 30 minutes under 1.5 hours	0.032	0.61	0.032	0.61
Duration Shift for every 30 minutes over 1.5 hours	0.034	2.47	0.034	2.47
Number of Additional Individual Tours of Same Purpose				
Duration Shift for every 30 minutes under 1.5 hours	-0.084	-0.77	-0.084	-0.77
First Tours (of Same Purpose) out of Multiple Tours				
Departure before 6:00 pm (Linear Shift)	-0.236	-3.77	-0.236	-3.77
Joint Tours Variables				
Subsequent tour must start after previous tour ends	-9.990			
Departure before 6:00 pm (Linear Shift)	0.094	3.44		
Departure before 6:30 pm (Linear Shift)			0.094	3.44
Departure after 6:30 pm (Linear Shift)	-0.150	-1.18		
Departure after 7:00 pm (Linear Shift)			-0.150	-1.18
3 or More Persons on the Joint Tour				
Departure before 6:00 pm (Linear Shift)	0.096	1.78		
Departure before 6:30 pm (Linear Shift)			0.096	1.78
Kids (Child under 16 years) on Joint Tour				
Arrival before 9:00 pm (Linear Shift)	-0.125	-3.50	-0.125	-3.50
Arrival after 9:30 pm (Linear Shift)	-0.225	-1.68	-0.225	-1.68
Distance to Destination				
Duration Shift for every 30 minutes under 1.5 hours	0.075	5.22	0.075	5.22
Duration Shift for every 30 minutes over 1.5 hours	0.009	7.81	0.009	7.81
ASC Adjustments for Visiting				
ASC Adjustments Departure - Before 5:00am to 8:00 am	-0.018			
ASC Adjustments Departure - Before 12:30 pm to 5:30 pm	0.227			

ASC Adjustments Departure - 5:30 pm to 7:30 pm	0.640			
ASC Adjustments Departure - 7:30 pm to 12:00 am	-0.261			
ASC Adjustments Arrival - Before 5:00 am to 10:30 am	-0.637			
ASC Adjustments Arrival - 10:30 am to 1:30 pm	-0.228			
ASC Adjustments Arrival - 8:00 pm to 9:30 pm	0.394			
ASC Adjustments Arrival - 9:30 pm to 12:00 am	-0.061			
ASC Adjustments for Discretionary				
ASC Adjustments Departure - Before 5:00 am to 7:30 am			-0.188	
ASC Adjustments Departure - 7:30 am to 10:00 am			-0.055	
ASC Adjustments Departure - 3:30 pm to 7:00 pm			0.455	
ASC Adjustments Departure - 7:00 pm to 12:00am			-0.089	
ASC Adjustments Arrival - Before 5:00am to 6:30 am			-0.508	
ASC Adjustments Arrival - 6:30 am to 11:00 am			-0.310	
ASC Adjustments Arrival - 4:30 pm to 9:30 pm			0.308	
ASC Adjustments Arrival - 9:30 pm to 12:00 am			-0.116	
ASC Adjustments Departure - Before 5:00 am to 7:30 am			-0.188	

Table 35: Time of Day Choice Model Estimation Results for At-Work Sub-tours

Number of Observations	405
Likelihood with Constants only	-1535.9007
Final likelihood	-1546.3511
ρ^2 w.r.t. zero	0.2658
ρ^2 w.r.t. constants	-0.0068

	At-Work	
Parameter	**Coeff**	**T-Stat**
Mode Choice Logsum	0.500	
Departure Time Constants		
Linear Shift for every 30 minutes before 11:00 am	-0.797	-6.74
11:30 am or Earlier	-2.022	-7.28
11:30 am to 12:00 pm	-0.465	-2.52
12:00 pm to 12:30 pm (reference)	0.000	
12:30 pm to 1:00 pm	-0.035	-0.17
1:00 pm or Later	-0.443	-1.63
Linear Shift for every 30 minutes after 1:30 pm	-0.186	-1.45
Arrival Time Constants		
11:30 am or Earlier	0.137	0.40
11:30 am to 12:00 pm	0.065	0.23
12:00 pm to 12:30 pm	-0.175	-0.86
12:30 pm to 1:00 pm (reference)	0.000	
1:00 pm to 1:30 pm	-0.696	-3.70
1:30 pm to 2:00 pm	-1.194	-4.85
2:00 pm or Later	-1.689	-5.35
Linear Shift for every 30 minutes after 2:30 pm	-0.418	-2.46
Square Root Shift for every 30 minutes after 2:30 pm	-0.112	-0.30
Duration Constants		
0 hours	-0.404	-1.08
0.5 hours (reference)	0.000	
1 hours	-0.008	-0.05
1.5 hours to 2 hours	-0.973	-4.16
2.5 hours or more	-2.505	-5.17
Household Variables		

Parameter	At-Work	
	Coeff	T-Stat
Low Income (<=$29,999)		
Duration under 0.5 hours	0.792	1.22
Medium Income ($30,000 to $59,999)		
Duration under 0.5 hours	0.328	0.69
High Income (>= $100,000)		
Duration under 0.5 hours	-0.827	-1.94
Duration Shift for every 30 minutes over 0.5 hours	0.078	1.05
Distance to Destination		
Duration under 0.5 hours	-0.447	-3.28
Duration Shift for every 30 minutes over 0.5 hours	0.019	4.23
Subtour Purpose		
Work-Related Subtour		
Departure Shift for every 30 minutes before 12:00 pm	-0.550	-5.31
Departure Shift for every 30 minutes after 12:30 pm	0.405	4.04
Duration Shift for every 30 minutes over 0.5 hours	0.427	5.29
Non-Eating Non-Mandatory Subtour		
Departure Shift for every 30 minutes before 12:00 pm	-0.475	-5.03
Departure Shift for every 30 minutes after 12:30 pm	0.305	3.45
Duration under 0.5 hours	0.460	1.28
Subsequent Tout		
subsequent tour must start after previous tour ends	-9.990	
No Time Window is Available to schedule the tour	-999.000	
Calibration constants		
Calibration departure constants - 11:30 am to 12:00 pm	0.202	
Calibration departure constants - 12:00 pm to 12:30 pm	0.411	
Calibration departure constants - 12:30 pm to 1:00 pm	0.295	
Calibration departure constants - 1:00 pm to 1:30 pm	0.333	
Calibration Arrival constants - 12:00 pm to 12:30 pm	0.157	
Calibration Arrival constants - 12:30 pm to 1:00 pm	0.247	

Parameter	At-Work	
	Coeff	T-Stat
Calibration Arrival constants - 1:00 pm to 1:30 pm	0.276	
Calibration Duration constants - 0 hours	-0.254	
Calibration Duration constants - 0.5 hours	0.180	

Findings

The main findings of the above tables are summarized below:

- **Level of service effects**
    - Mode choice logsums: Congestion effects on time-of-day choice are captured by logsums from the mode choice model, which also capture changes in transit service levels across the day. A separate mode choice logsum is calculated for every combination of the 5 time periods for which highway and transit network skims are available – Early, AM peak, midday, PM peak and night. The logsum coefficients are asserted for some models to values between 0 and 1. Higher values represent higher sensitivity to change in departure and arrival times when mode level-of-service changes. The coefficients are weak for school and university purposes because these tours are less flexible in scheduling.

- **Travel distance effects**
    - The longer the distance from home to the primary destination, longer is the tour duration. This result implies that the duration of activities at the destination takes precedence over the duration of activities at home, and that people adjust the time they leave and arrive at home to allow for longer distances. For mandatory tours, there is a departure time shift effect and an arrival time shift effect. People with longer distances tend to depart earlier, even earlier than would be required to simply account for the travel duration. For non-mandatory activities, there is a duration shift effect for longer durations since the departure and arrival times are flexible for these tour purposes.
- **Person/household/tour shift effects: These vary by tour purpose…**
    - *Work tours:* Part-time workers and university students tend to leave home later and have shorter durations compared to full-time workers. People of lower income tend to leave earlier in the day. Workers tend to arrive earlier from work if there is a joint tour in the household. Females tend to leave around the peak period, but tend to arrive earlier in the day; these effects are stronger if the female has a pre-school child in the household. Older workers are less likely to leave earlier and more likely to have shorter durations.
    - *University tours:* Students less than 24 years old tend to start school earlier and have longer durations. Younger students are undergraduate students or full-time students, whereas older students could be part-time students or enrolled in higher degree programs with flexible schedules.
    - *School tours:* Compared to grade school students, preschoolers tend to begin school tours later in the day. The departures are earlier and arrivals are later for the school tour if all adults in the household are full-time workers.
    - *Escorting tours:* Most of the escorting tours are carried out for the purpose of dropping off and picking up school students. The departure and arrival shifts are such that the scheduling of escorting tours is around school timings in the morning and afternoon if there is a school or preschool child in the household with mandatory tour. The departures tend to be earlier and arrivals tend to be later for full-time workers because they schedule the escorting tour around their work tour.
    - *Shopping or Maintenance tours:* The departures are shifted to later periods for joint tours and the durations tend to be longer than an hour for joint tours. However, the durations are shorter if there are children under 15 years of age on the joint tour. The durations are longer for lower income groups which could be a manifestation of fewer trips made by lower income groups. For individual tours, durations are shorter if there are multiple tours of same purpose. The durations tend to be longer for non-working adults or females or bigger households.
    - *Eating out tours:* These tours tend to peak around the lunch and dinner hours. Workers and university students with mandatory tours are less likely to depart for an eating out tour before 5 pm. For individual tours, females tend to have longer durations and persons in bigger households tend to have shorter durations. For joint tours, if there are kids on the tour, durations are shorter and the arrivals are earlier.

- *Visiting and Discretionary tours:* The durations tend to be longer for pre-driving age children, whereas durations are shorter for non-working adults, retirees and females. Children have more free time therefore they are more likely to have longer durations for visiting friends or for discretionary activities. Lower income groups tend to depart earlier and have longer durations for visiting and discretionary activities.
- *At-Work Subtours*: The durations tend to be longer for work-related subtours and tend to be shorter for non-eating non-mandatory subtours, as compared to eating out subtours. Also, the departure is either earlier than 12 pm or later for non-eating out tours. Subtour durations tend to be longer for higher income workers. Since, most of the at-work subtours are comprised of eating out tours; it could reflect high income group workers tending to take longer eating out lunch breaks (sit down places).

- **Pattern-specific shift effects:** For all purposes, it is found that the first of two or more tours for the same purpose tends to be both earlier and shorter than it would be if only a single tour were made. (Note that two or more tours for the same purpose are scheduled in chronological order.) For the second of two or more tours of the same purpose, the available time window to make the tour is shorter because the hours used for the first tour are "blocked out", so the model structure will tend to make the second tour later and shorter. For work and school tours, departure time shifts are observed for the first tour to either earlier or later times.
- **Dummy variables for extreme periods and additional dummy variables:**
    - *Work tours*: Full-time workers are unlikely to have tour durations less than 9 hours or to leave home after 10 am or to arrive before 3 pm.
    - *University tours*: Workers and non-workers are more likely to depart in the late afternoon/early evening period for the university tour. The workers would tend to make the university tour after work hours which will push the departure times later in the day. There are classes offered in late evening/night taken by non-workers.
    - *School tours*: Driving age students are less likely to have tour durations shorter than 7 hours. And, pre-driving age students are less likely to arrive before 2 pm.
    - Additional time window and remaining tours effects: The variable labeled time pressure is calculated as log of "remaining maximum continuous time window/remaining tours". The higher value shows more time available and lower value shows higher time pressure. We expect a positive shift for longer durations, meaning that the more time window available for the person and fewer tours left to schedule in the day, the more likely they are to choose long durations. The resulting coefficient is strongly positive for non-mandatory purposes.

4.2.3, 4.3.5, 4.4.4, 4.5.4 Tour Mode Choice Model (Individual Mandatory, Individual/Joint Non-Mandatory, At Work Sub Tours)

This model determines the "main tour mode" used to get from the origin to the primary destination and back is determined. The tour-based modeling approach requires a certain reconsideration of the conventional mode choice structure. Instead of a single mode choice model pertinent to a four-step structure, there are two different levels where the mode choice decision is modeled:

- The tour mode level (upper-level choice),
- The trip mode level (lower-level choice conditional upon the upper-level choice).

Mode Specification

The tour mode choice model predicts the 'preferred' mode for the tour. The model considers the following alternatives:

1. Drive-alone
2. Shared-Ride 2
3. Shared-Ride 3+
4. Walk
5. Bike
6. Walk-Transit
7. Park-and-Ride Transit (drive to transit station and ride transit)
8. Kiss-and-Ride Transit (drop-off at transit station and ride transit)
9. School Bus (only available for grade school and high school tour purposes).

The mode of each tour is identified based on the combination of modes used for all trips on the tour, according to the following rules:

1. If any trip on the tour is Park-and-Ride Transit, then the tour mode is Park-and-Ride Transit.
2. If any trip on the tour is Kiss-and-Ride Transit, then the tour mode is Kiss-and-Ride Transit.
3. If any trip on the tour is School Bus, then the tour mode is School Bus.
4. If any trip on the tour is Walk-Transit, then the tour mode is Walk-Transit.
5. If any trip on the tour is Bike, then the tour mode is Bike.
6. If any trip on the tour is Shared-Ride 3+, then the tour mode is Shared-Ride 3+
7. If any trip on the tour is Shared-Ride 2, then the tour mode is Shared-Ride 2.
8. If any trip on the tour is Drive-Alone, then the tour mode is Drive-Alone.
9. All remaining tours are Walk.

These tour modes create a hierarchy of importance that ensures that transit is available for trips on tours with transit as the preferred mode, and that high-occupancy vehicle lanes are available for trips on tours where shared-ride is the preferred mode. It also ensures that if drive-transit is utilized for the outbound trip on the tour, that mode is also available for the return journey (such that the traveler can pick up their car at the parking lot on the way home).

The tour mode choice model takes into account round-trip (outbound and return) level-of-service on each tour mode according to the travel period of the journey. The tour mode choice model assumes that the mode of the outbound journey is the same as the mode for the return journey in the consideration of level-of-service information. This is a simplification that results in a model with a relatively modest number of alternatives, and also allows the estimation process to utilize data from an on-board survey in which the mode for only one direction is known (see below). Only these aggregate tour modes are used in lower level model components such as stop frequency, stop location, and as constraints in trip mode choice.

However, the estimation and application process calculates utilities for a more disaggregate set of modes in lower level alternatives that are consistent with the more detailed modes in trip mode choice. This allows the tour mode choice model to consider the availability of multiple transit line-haul modes and/or managed lane route choices in the choice of tour mode, with their specific levels-of-service and modal constants. The more aggregate tour modes act as constraints in trip mode choice; for example, if walk-transit is chosen in tour mode choice, only shared-ride, walk, and walk-transit modes are available in trip mode choice. Ultimately, trips are assigned to networks using the more disaggregate trip modes.

The lower level nest mode choices (which are same as the trip mode choice model alternatives) are:

1. Drive-alone Free
2. Drive-Alone Pay
3. Shared-Ride 2 Free (General Purpose Lane)
4. Shared-Ride 2 Free (HOV Lane)
5. Shared-Ride 2 Pay
6. Shared-Ride 3+ Free (General Purpose Lane)
7. Shared-Ride 3+ Free (HOV Lane)
8. Shared-Ride 3+ Pay
9. Walk
10. Bike
11. Walk-Local Bus
12. Walk-Express Bus
13. Walk-Bus Rapid Transit
14. Walk-Light Rail Transit
15. Walk-Commuter Rail
16. PNR-Local Bus
17. PNR-Express Bus
18. PNR-Bus Rapid Transit
19. PNR-Light Rail Transit
20. PNR-Commuter Rail
21. KNR-Local Bus
22. KNR-Express Bus
23. KNR-Bus Rapid Transit
24. KNR-Light Rail Transit
25. KNR-Commuter Rail
26. School Bus

Note that the trip mode choice model explicitly considers line-haul transit mode, including local bus, express bus, bus rapid transit (did not exist in the base year), light-rail transit, and commuter rail. Pictures of these options in San Diego are given below.




Estimation Datasets

Both the SANDAG 2006 Household Interview Survey and the 2009 Transit On-Board Survey were utilized for mode choice model estimation. A significant amount of data processing was required in order to code on-board survey data to be consistent with household survey data to the maximum extent possible. A series of Stata (a data analysis program) *.do* files were written to automate the coding procedure. The coding procedures are summarized below.

The on-board survey contains 43,854 trip observations, and was composed of data collected from two separate survey forms: the "Planner's Data" and the "Modeler's Data". Each respondent received only one of the two forms. Both data retrieval forms shared certain questions, such as origin and destination address and purpose, list of routes utilized for trip, and common socio-economic data such as income, household vehicles available, and household size. In addition, the Planner's Data form collected information on ethnicity of respondent, frequency of transit use, and transit fare information. The Modeler's Data form contained additional questions on work address, whether household members were with the traveler, and some clarifying questions targeted towards better understanding the tour purpose for trips without work or school at either end.

A data record was coded as usable for estimation purposes if both origin and destination Master Geographic Reference Area (MGRA) was geocoded, and if both origin and destination trip purpose was coded. Out of 43,854 observations, 28,303 had both valid origin and destination locations and trip purposes.

On-Board Survey Tour Purpose

A tour purpose was coded in each on-board survey data observation based on origin and destination purpose codes. The following tour purposes were coded, as shown in Table 36:

- Work
- University
- School
- Maintenance
- Discretionary
- Work-Based (Modelers Data Only)

Table 36: Trip Purpose to Tour Purpose Codes

Origin Trip Purpose	Destination Trip Purpose						
	Home	**Work**	**School/College**	**Shop**	**Recreation/Visit**	**Medical Services**	**Other**
Home		Work	University if age>18 and school type not K-12, else School	Allocated	Discretionary	Discretionary	Discretionary
Work	Work	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
School/College	University if age>18 and school type not K-12, else School	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Shop	Maintenance	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recreation/Visit	Discretionary	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Medical Services	Discretionary	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Other	Discretionary	Work-Based or Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

It was possible to code the tour purpose as work-based if the origin purpose was work and the respondent indicated that they were going to return to work – however, this was only available from the Modeler's data form. In addition, a joint tour indicator was coded if the respondent indicated that there were one or more household members with them, but again this information was only available from the Modeler's form. School type was also used to code school tours, but this variable was also only available from the Modeler's Data form. The final tabulation of valid trips by tour purpose for model estimation is given in Table 37.

Table 37: On-Board Survey Valid Trips by Tour Purpose

Tour Purpose	Trips	Percent
Work	9,262	32.72%
University	4,920	17.38%
School	2,330	8.23%
Maintenance	2,281	8.06%
Discretionary	5,552	19.62%
Work-Based (Modelers Data Only)	62	0.22%
Unknown	3,896	13.77%
Total	28,303	100.00%

Mode Codes

Mode was coded based on all reported transit routes taken for the trip (surveyed route and all other routes) and reported access/egress mode. The reported route to tour line-haul mode correspondence codes are given in Table 38. Access mode was coded based on reported access/egress mode, according to the following rules:

- If either trip access or trip egress mode was Park-and-Ride, the tour access mode was coded as Park-and-Ride;
- If either trip access or trip egress mode was Kiss-and-Ride, the tour access mode was coded as Kiss-and-Ride;
- All other trips were coded with walk tour access mode.

Table 38: Reported Route Type to Tour Line Haul Mode Correspondence

Reported Route Type	Tour Line-Haul Mode
Bus	Local or Express Bus (depending on route number)
Trolley-Green	Light-Rail Transit
Trolley-Blue	Light-Rail Transit
Trolley-Orange	Light-Rail Transit
Coaster	Commuter Rail
Sprinter	Light-Rail Transit

Expansion Factor and Alternative Utility Adjustment Calculations

Expansion factors for the onboard survey were calculated by route, direction, and time-of-day. The expansion factors take into account only valid observations, and were used in the calculation of alternative-specific adjustments to mode choice utilities that account for the use of the choice-based sample in estimation. First, a boarding weight was calculated as the ratio of total observed boardings provided by SANDAG for the survey year by route, to valid surveyed boardings on each route by direction and time-of-day.

$\text{Boarding Weight}_{\text{route, direction, time period}} = \text{Observed Boardings}_{\text{route, direction, time period}}/\text{Valid Surveyed Boardings}_{\text{route, direction, time period}}$

Next, a trip expansion factor was computed for each observation which is equal to the boarding factor for the surveyed route, direction, and time period divided by the number of boardings reported for the observation. This factor accounts for multiple boardings on a trip.

$\text{Trip Expansion Factor} = 1/\text{reported boardings} * \text{Boarding Weight}_{\text{route, direction, time period}}$

A tabulation of expanded trips by line-haul mode and mode of access is given in Table 39.

Table 39: On-Board Survey Expanded Trips by Line-Haul Mode and Access Mode

Tour Mode	Trips	Percent
Walk-Local	122,241	49%
Walk-Express	6,328	3%
Walk-LRT	86,883	35%
Walk-Commuter Rail	1,845	1%
PNR-Local	2,874	1%
PNR-Express	1,104	0%
PNR-LRT	11,725	5%
PNR-Commuter Rail	2,459	1%
KNR-Local	2,971	1%
KNR-Express	409	0%
KNR-LRT	8,821	4%
KNR-Commuter Rail	471	0%
Total	**248,131**	**100%**

Alternative utility term adjustments are required to account for use of a mixed sample (random and choice-based) in mode choice model estimation. The household survey is a random sample and the onboard survey is a selective sampling of responders with specific mode choices. A factor was calculated and added to the utility term for each alternative that adjusts for the over-representation of transit observations in the data. The adjustment factors account for over-representation of transit and under-representation of non-transit modes. The alternative-specific adjustment factors were calculated by tour purpose according to the following formula:

$Factor_{p,i} = -\ln([Expanded\_Share_{p,i}/Survey\_Share_{p,i}])$

Where:

$Expanded\_Share_{p,i}$	=	$\text{Expanded Tours}_{p,i}/\sum \text{Expanded Tours}_{p}$
$Survey\_Share_{p,i}$	=	$\text{Survey Records}_{p,i}/\sum \text{Survey Records}_{p}$
p	=	Tour Purpose
i	=	Mode

The expansion factors for household survey are household based weights, and the expansion factors for onboard survey were calculated based on boarding as discussed above.

Departure/Arrival Time Period Calculations

In order to attach level-of-service skims to each observation, and compute the tour duration (used for parking cost calculations), it is necessary to determine the outbound and return time periods. In the on-board survey, this data was not captured. Two steps were necessary to calculate the departure and arrival time period; one set of calculations involves the determination of the time period for the *surveyed direction*. The time period for the *non-surveyed direction* was based on an imputation procedure.

For the *surveyed* direction, the time departing the tour origin or arriving back at the tour origin was calculated based on the start time of the vehicle run upon which the respondent was surveyed, the operating speed of the transit vehicle, and the distance from the start location of the vehicle run to the surveyed boarding location (for trips surveyed in the outbound direction) or alighting location (for trips surveyed in the return direction). The access time (for trips surveyed in the outbound direction) or egress time (for trips surveyed in the return direction) was also taken into account for records where both the boarding (alighting) and origin (destination) locations were reported, based on the distance between the boarding (alighting) location and the trip origin (destination) location. Transit vehicle operating speeds were based on observed data.

For example, if a trip was surveyed in the outbound (from tour origin to primary destination) direction on Route 530, with a transit vehicle trip start time at 6:30 AM, and the trip boarding location was 10 miles from the starting location of the transit vehicle, at an operating speed of 15 miles per hour, the calculated trip boarding time would be 7:10 AM (40 minutes after vehicle trip start time, or 60 minutes/hour * 10 miles/15 miles/hour). Further, if the respondent reported a tour origin location ¼ mile from their boarding location, the tour departure time would be calculated as 7:05 AM (at a walk speed of 3 miles per hour, it would have taken 5 minutes to walk from the tour origin to the boarding location).

For the non-surveyed direction, the tour departure (arrival) time was imputed using Monte Carlo sampling based on the distribution of departure (arrival) times by tour purpose after completing the calculations for the surveyed direction as described above.

Table 40 - Table 43 shows transit tours by departure/arrival time period. The definitions of time periods are as follows:

- Early A.M.: 3:00 A.M. to 5:59 A.M.
- A.M. Peak: 6:00 A.M. to 8:59 A.M.
- Early Midday: 9:00 A.M. to 11:59 A.M.
- Late Midday: 12:00 P.M. to 3:29 P.M.

- P.M. Peak: 3:30 P.M. to 6:59 P.M.
- Evening: 7:00 P.M. to 2:59 A.M.

Table 40: Work Transit Tour Time-of-Day Distribution

Outbound Time Period	Return Time Period						Total
	Early A.M.	A.M. Peak	Early Midday	Late Midday	P.M. Peak	Evening	
Early A.M.	266	479	385	1,663	7,614	1,046	11,454
A.M. Peak	0	2,058	3,369	7,502	31,650	6,857	51,436
Early Midday	0	0	494	3,120	9,510	2,487	15,611
Late Midday	0	0	0	2,228	1,193	5,878	9,299
P.M. Peak	0	0	0	0	1,018	2,768	3,787
Evening	0	0	0	0	0	1,498	1,498
Total	**266**	**2,537**	**4,248**	**14,513**	**50,985**	**20,535**	**93,085**

Table 41: University Transit Tour Time-of-Day Distribution

Outbound Time Period	Return Time Period						Total
	Early A.M.	A.M. Peak	Early Midday	Late Midday	P.M. Peak	Evening	
Early A.M.	1	565	0	260	53	590	1,469
A.M. Peak	0	8	4,316	10,515	7,225	2,726	24,790
Early Midday	0	0	28	3,122	5,635	2,183	10,968
Late Midday	0	0	0	576	4,267	4	4,848
P.M. Peak	0	0	0	0	0	2,049	2,049
Evening	0	0	0	0	0	393	393
Total	**1**	**573**	**4,344**	**14,474**	**17,180**	**7,945**	**44,517**

Table 42: School (K-12) Transit Tour Time-of-Day Distribution

Outbound Time Period	Return Time Period						Total
	Early A.M.	A.M. Peak	Early Midday	Late Midday	P.M. Peak	Evening	
Early A.M.	0	0	0	40	547	27	614
A.M. Peak	0	95	1,030	7,145	5,642	823	14,735
Early Midday	0	0	44	699	827	355	1,925
Late Midday	0	0	0	256	191	0	446
P.M. Peak	0	0	0	0	84	165	249
Evening	0	0	0	0	0	0	0
Total	**0**	**95**	**1,074**	**8,140**	**7,291**	**1,370**	**17,969**

Table 43: Non-Mandatory Transit Tour Time-of-Day Distribution

Outbound Time Period	Return Time Period						Total
	Early A.M.	A.M. Peak	Early Midday	Late Midday	P.M. Peak	Evening	
Early A.M.	12	557	142	6	108	131	958
A.M. Peak	0	3,716	6,071	5,200	3,002	1,014	19,004
Early Midday	0	0	6,174	17,219	6,450	1,920	31,762
Late Midday	0	0	0	8,474	12,196	1,232	21,902
P.M. Peak	0	0	0	0	6,160	9,228	15,389
Evening	0	0	0	0	0	2,704	2,704
Total	**12**	**4,273**	**12,388**	**30,898**	**27,917**	**16,229**	**91,718**

Main Explanatory Variables

Many of the variables used in estimation were collected in the household survey and/or on-board survey instruments, including household size, auto sufficiency (0 autos, autos<adults, autos>=adults), household income, gender, and age. Other variables include round-trip level-of-service levels for each mode and land-use variables.

The modeling area is represented by a TAZ system of 4,600 zones, and a finer-detailed spatial system of 23002 polygons, referred to as Master Geographic Reference Areas (MGRAs), as shown in Figure 24. 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 25.

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 walk barriers such as freeways and canyons and absolute elevation change between MGRA centroid and transit stops (Figure 26). A generalized cost function (parameters shown in Table 44) is used to select the best boarding/alighting TAP-pair for each line-haul mode (local bus, express bus, bus-rapid transit, light-rail transit, and commuter rail) and access mode (walk, park-and-ride, and kiss-and-ride) for each estimation record based on the geocoded origin and destination MGRA. The skims associated with the best-TAP pair was appended to each observation for model estimation; the same approach is used in model application.

Custom Java software was written to calculate the generalized costs and choose the best TAP-pairs by line-haul mode and access mode.

Table 44: Generalized Cost Parameters for Transit Path-Building

Variable	Coefficient	Equivalent Minutes
In-Vehicle Time	-0.02800	1.00
First Wait Time	-0.04200	1.50
Transfer Wait Time	-0.08400	3.00
Walk\Drive Time	-0.05600	2.00
Fare & drive access cost (cents)	-0.00159	10.57
Light-Rail\Commuter Rail Constant	0.42000	-15.00

Figure 24: MGRAs (thin grey lines) and TAZs (thick brown lines)

Figure 25: Transit Network, Stops, and Transit Access Points

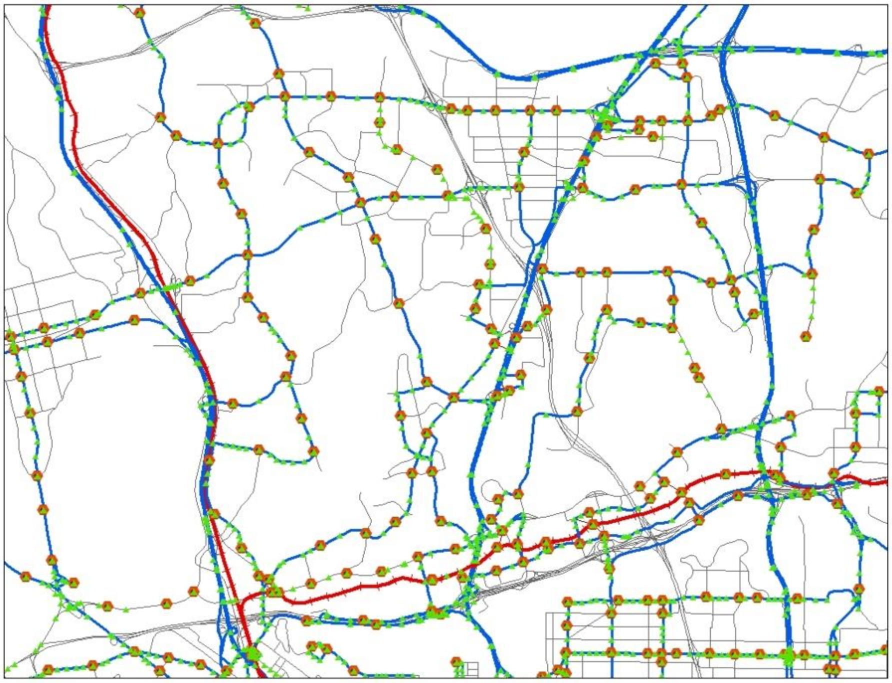
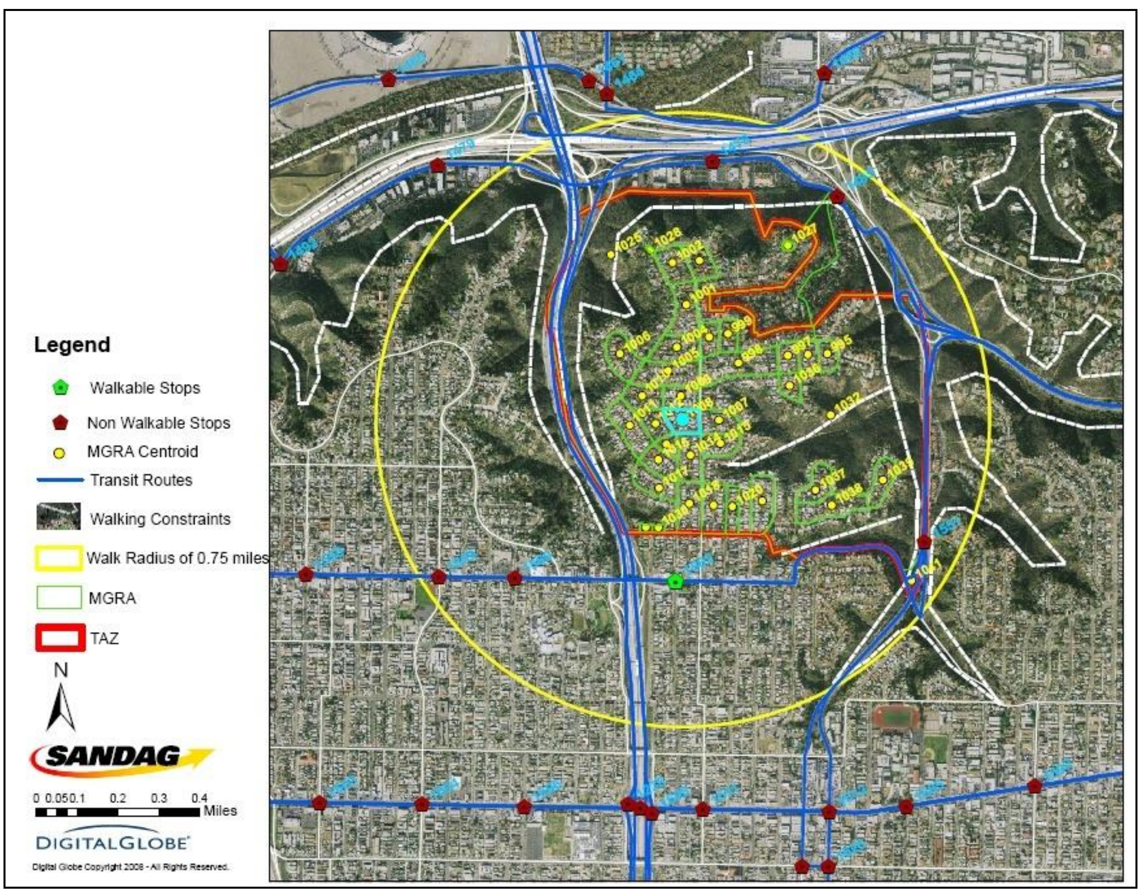


Figure 26: Walking Constraints

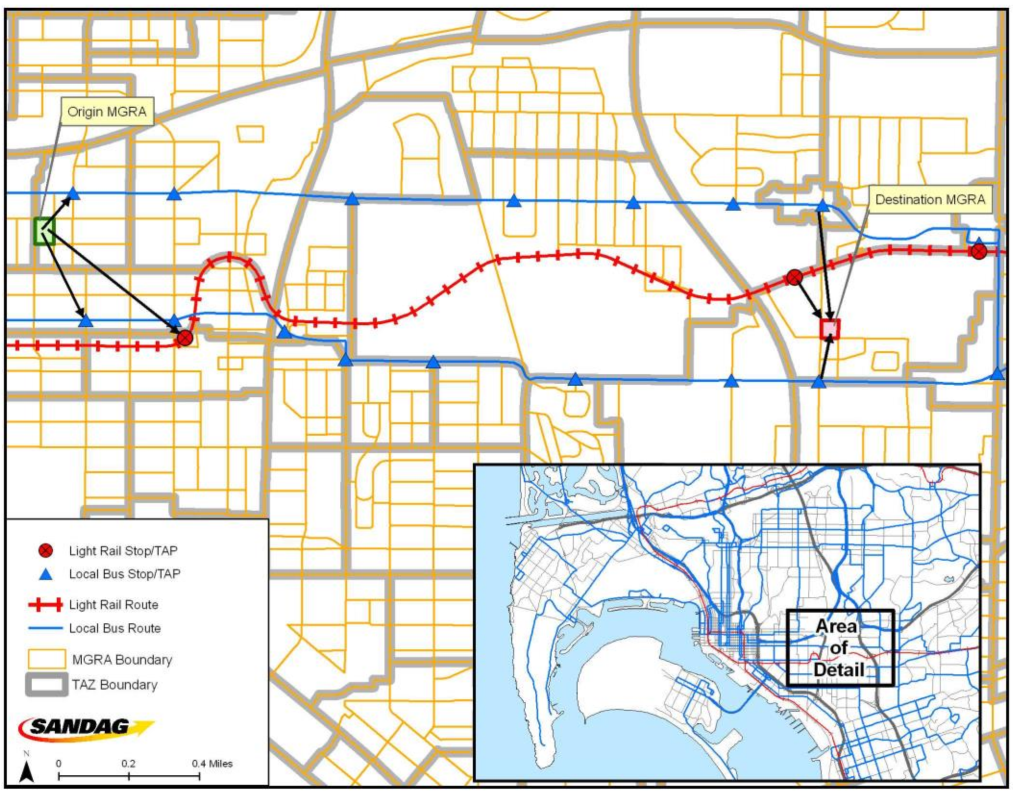


This approach ensures that the access times that are computed using GIS are consistent with the in-vehicle times that are calculated using the TransCAD transit skimming procedure. This is a significant improvement over other ABMs that utilize detailed location data, which assume that the nearest transit 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 27 illustrates 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.

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.

Figure 27: Transit Paths



Land use variables appended to each record included the household density, population density, employment density, and number of intersections in a one-half mile buffer around each origin and destination MGRA, as well as a measure of the mixture of employment and households, as follows:

Mix = Household Density * Employment Density/ (Household Density + Employment Density)

This formula results in values that are high when household density and/or employment density is high, and whose maximum value for any given household or employment density combination is realized when they are equal.

Final Usable Records by Purpose

There were many transit on-board survey records whose chosen mode was not found in the transit network. As part of the skim-building and estimation process, several iterations of transit skims were built to try to address the problem, including adjustment of the TransCAD combination factor which controls the amount of multi-pathing in transit hyper-paths used in path finding (see Travel Demand Modeling with TransCAD 5.0, page 298) . The combination factor specifies the amount of transit headway to ignore during best path calculations. During this process, a number of transit paths were traced through the network to better understand how this parameter affected the ability of the path-finder to find premium versus local transit paths. As a result of the process, it was determined that a combination factor of 0 (essentially turning off hyper-paths) resulted in transit paths that best matched the observed transit mode. However, there remained many records whose path could not be found. The final number of usable records by purpose and mode from both the home-interview survey and transit on-board survey is given in Table 45.

Table 45: Usable Records by Tour Purpose and Mode

Mode	Work	University	School	Maintenance	Discretionary	Work-Based	Total
Drive-Alone Free	2,127	129	57	1,059	616	164	**4,152**
Drive-Alone Toll		0	0	8	0	0	**8**
Shared 2 NH-NT	709	28	759	1,682	745	131	**2,881**
Shared 2 HOV	4	0	1	3	4	0	**9**
Shared 3+ NH-NT	86	4	390	413	210	18	**643**
Shared 3+ HOV	0	0	0	0	1	0	**1**
Walk	79	10	200	321	196	77	**707**
Bike	23	3	19	27	22	2	**93**
School Bus		6	139	0	1	0	**122**
Walk-Local	3,543	2,390	1,177	1,467	2,728	22	**11,251**
Walk-Express	477	122	32	40	137	2	**810**
Walk-LRT	1,728	740	350	359	1,040	3	**4,166**
Walk-Commuter Rail	74	6	3	4	22	0	**109**
PNR-Local	88	90	17	9	30	0	**234**
PNR-Express	252	8	0	0	3	0	**263**
PNR-LRT	107	44	32	8	35	0	**226**
PNR-Commuter Rail	180	2	3	2	17	0	**204**
KNR-Local	91	91	87	21	48	0	**338**
KNR-Express	43	6	6	1	9	0	**65**
KNR-LRT	93	78	71	16	57	0	315
KNR-Commuter Rail	46	2	1	0	6	0	55
Total	**9,750**	**3,759**	**3,344**	**5,440**	**5,927**	**419**	**26,652**

Work Tour Mode Choice Model Estimation

The first tour mode choice model estimated was for the work purpose. This was the most extensive estimation, and the results of this estimation informed the specification of models for the other purposes. There were 9,660 observations used for estimation of this model after elimination of non-available alternatives. The non-availability rules exclude cases where a skim is not available for outbound or inbound direction of the tour for the chosen mode. Drive-alone and Park-and-ride mode options are unavailable for households with no cars. Also, observations with an outbound or inbound in-vehicle time of over 120 minutes were excluded.

Model Utility and Structure:

The utility expression for each mode (i) is specified as a linear function of alternate specific constants, level of service variables (such as time and cost), location specific measures and socio-economic (SE) characteristics as shown below:

$$U_i = \beta_1 * Time_i + \beta_2 * Cost_i + \beta_3 * Location_{Var} + \beta_4 * SE + \beta_0$$

The travel time variables are typically disaggregated into in-vehicle and out-of-vehicle time at a minimum, with out-of-vehicle time stratified by walk time, initial wait, and transfer wait time (the latter two categories applicable to the transit mode(s)). Similarly, travel cost is often disaggregated into the more general out-of-pocket costs (i.e., automobile operating costs and transit fare) and destination parking cost. Location specific variables are used to reflect a set of unique geographically based characteristics such as employment\household mix index, intersection density and employment density.

The socio-economic variables include auto sufficiency, household size, gender, and age. In these segmentations, the mode selection was sometimes grouped into shared-ride 2, shared-ride 3+, non-motorized and transit. Estimation also included 4D variables, including the mix index (both origin and destination), intersection density (origin end), and employment density (destination end).

The nested model structure is a 3-level nested structure. For the first level, the primary choice of mode is among auto, non-motorized, transit and school bus (only available for school tours). At the second level, auto has 3 sub-modes (drive-alone, shared-ride 2 and shared-ride 3+), non-motorized has choice between walk and bike, and transit has 3 access options (walk, PNR and KNR). These sub-modes have further choices based as shown in Figure 28.

In application, the model independently addresses modes at the lowest nest level and computes modal utilities. For example, the utility of choosing Drive-Alone-GP (1) and Drive-Alone-Pay (2) would be U_{DA-GP} and U_{DA-Pay} . A composite of the utilities or logsum will represent these drive-alone sub-modes at the next level of nest. The logsum term is the maximum expected utility provided by all sub-modes of a primary mode and it is calculated as

$$LogSum_{DA} = \ln[\, e^{U_{DA-GP}/\theta_1\theta_2} + e^{U_{DA-Pay}/\theta_1\theta_2} \,]$$

where θ_1 is the nesting coefficient for the lower level nest and θ_2 is the nesting coefficient for the upper level nest.

Similarly, logsums are calculated for all the nine modes – drive-alone, shared-ride 2, shared-ride 3+, walk, bike, walk access transit, PNR transit, and KNR transit. Then, the logsums are computed for the upper level nest as shown below for Auto nest.

$$LogSum_{Auto} = \ln[e^{\theta_1 LogSum_{DA}} + e^{\theta_1 LogSum_{SR2}} + e^{\theta_1 LogSum_{SR3+}}]$$

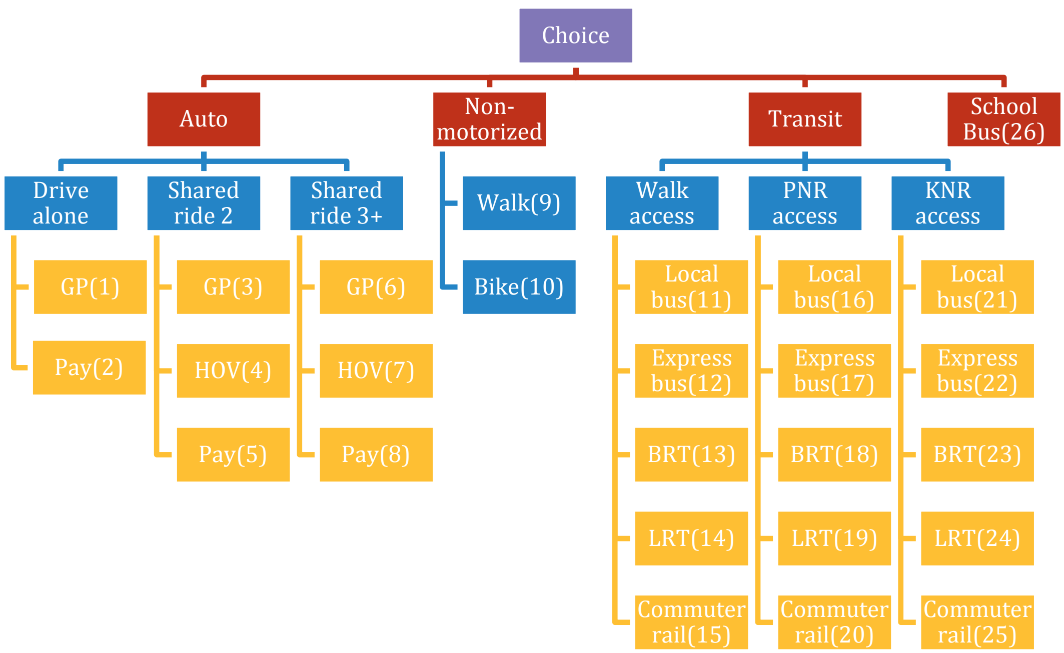
The probability of choosing auto is given by

$$P_{Auto} = \frac{e^{\theta_2 LogSum_{Auto}}}{e^{\theta_2 LogSum_{Auto}} + e^{\theta_2 LogSum_{Non-Motorized}} + e^{\theta_2 LogSum_{Transit}} + e^{\theta_2 LogSum_{SchoolBus}}}$$

The value of nesting coefficients should be between 0 and 1. A value of 1.0 indicates that the lower level modes are not a sub-choice but rather are full options equally competitive with the primary modes. In this instance, these lower level choices can be simplified or included directly in the upper level. A value of 0.0 would indicate that the lower level choices are perfect substitutes for each other.

A number of different model nesting structures were tested in estimation; however, no structures resulted in reasonable nesting coefficients across all nests. Therefore, the nesting coefficients were imposed on the final estimation.

Figure 28: Mode Choice Nesting Structure



Model Estimation Findings:

- Value of time (in-vehicle time over cost) was estimated as one value, and also stratified by income classes (low, medium low, medium-high, very high, income unknown). The stratification by income class showed a reasonable relationship by income class.
- Transit access time was estimated for walk to transit and drive to transit modes. The values were negative and significant.
- It was difficult to estimate logical wait time parameters from the data for all tour purposes. Ratios of both first wait time and transfer wait time coefficients to in-vehicle time coefficient were significant and less than 1 in nearly all estimations. A number of attempts

were made in order to determine the cause of this problem, including analyzing records from the on-board survey in greater detail, experimenting with different transit skim settings, and attempting different specifications of wait time (segmenting into short and long wait, parameters on wait time by mode, using total wait and number of transfers, etc.). The relationship of wait time to in-vehicle time was consistent throughout these tests, leading us to believe that either wait time is perceived as being similar to in-vehicle time in San Diego (perhaps due to the relatively mild climate) or that the significant presence of captive transit riders is downward-biasing the wait time parameter.

- To test the impact of density on mode choice, a mix variable that combines household and employment density was created. The variable is defined as (households * employment)/(households + employment). This variable acts as a proxy for determining high density downtown locations that may be more amenable for non-auto modes. This variable was tested for the walk, bike, walk to transit, and drive to transit modes. Walk, bike, and walk to transit were tested at both the origin and destination ends. Drive to transit was only tested at the destination end. The reasoning for that test is that if a person is choosing to drive to transit, they must have an easy way to get to their destination once they leave the transit vehicle, and we already know they chose to drive at their origin end. We expect that as density increases, people are more likely to walk or bike or take transit, resulting in a positive coefficient. The most successful of these coefficients were walk, bike, and walk to transit at the origin end, which were all positive.
- In addition to testing the mix index, variables for the intersection and employment density were tested. The intersection density was tested at the origin end, because the person would obviously choose the mode as soon as they left the origin location, and employment density was tested at the destination end, because this is for work tours which are more likely to end in places with high employment density where they have access to their job and other services. Intersection density was tested for combined bike and walk and was positive. Although not significant, it was kept in the model for potential future policy tests. The employment density was tested for both walk/bike and transit. Only the walk/bike was positive and significant.
- Walk and Bike mode time were tested and were both negative and significant, meaning that as the times increase, these modes are less preferable.
- Alternative specific constants (ASCs) were tested for each mode independent of interactions with other variables. Some of the model runs attempted to estimate each line-haul mode separately, but results were mixed; either certain modes were insignificant, or resulted in equivalent minutes of in-vehicle time that were unexplainable.

Table 46: Work Mode Choice Estimation

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone	0 (reference)	
	Shared-Ride 2	-2.08 (-7.92)	130.23
	Shared-3+	-3.95 (-6.76)	246.68
	Walk	0.52 (1.12)	-32.60
	Bike	-3.83 (-6.99)	239.63
	Transit	-1.71 (-11.07)	106.75
	Express Bus	0.048 (0.72)	-3.00
	LRT	0.56 (11.22)	-35.00
	Commuter Rail	0.72 (4.27)	-45.00
	Transit Drive	-4.24 (-23.64)	264.77
	Transit KNR	0.37 (1.94)	-23.18
	HOV Lane	-2.42 (-4.79)	151.32
In-vehicle time		-0.0160 (Constr)	1
Cost - Low (<30k)		-0.0027 (Constr)	0.17
Cost - Medium-Low (30-60k)		-0.0012 (constr)	0.07
Cost - Medium-High (60-100k)		-0.0007 (constr)	0.05
Cost - Very High (100k+)		-0.0003 (constr)	0.02
Cost - Unknown		-0.0027 (-9.78)	0.17
Transit Access Time	Walk	-0.03 (-10.57)	1.88
	Drive	-0.02 (constr)	1.50
Total Wait Time		-0.02 (constr)	1.50
Number of Transfers		0 (constr)	0
Mix Density Variables (*.01)Origin MGRA	Walk	0.21 (4.51)	-13.13
	Bike	0.21 (4.51)	-13.13
	Walk Transit	-0.0043 (-0.29)	0.27
Intersection Density	Walk/Bike	0.003 (1.14)	-0.19

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Walk Mode Time	Walk	-0.06 (-7.7)	3.69
Bike Mode Time	Bike	-0.05 (-5.61)	3.08
Auto Sufficiency, Autos = 0	Shared-Ride 3+	0.42 (0.38)	-26.53
	Walk	0.54 (0.83)	-33.67
	Bike	0.82 (1.04)	-51.54
	Walk-Transit	2.65 (6.31)	-165.78
	KNR-Transit	0.8 (1.67)	-50.27
Auto Sufficiency, Autos >=HH Size	Shared-Ride 2	-0.39 (-3.2)	24.17
	Shared-Ride 3+	-0.1 (-0.33)	6.43
	Walk	-1.45 (-4.44)	90.71
	Bike	-1.73 (-3.74)	108.09
	Walk-Transit	-1.78 (-17.89)	111.52
	PNR-Transit	-1.1 (-7.72)	68.97
	KNR-Transit	-2.08 (-13.22)	130.19
Auto Sufficiency Unknown	Walk - Transit	1.74 (11.27)	-108.81
	PNR - Transit	1.22 (6.45)	-76.43
Household Size 2	Shared-Ride 2	1.07 (4.52)	-66.85
	Shared-Ride 3+	-0.47 (-0.81)	29.21
Household Size 3	Shared-Ride 2	1.58 (6.61)	-98.76
	Shared-Ride 3+	0.65 (1.23)	-40.91
Household Size 4+	Shared-Ride 2	1.69 (7.24)	-105.52
	Shared-Ride 3+	1.5 (3.09)	-93.67
Female	Shared-Ride 2	0.59 (6.66)	-37.17
	Shared-Ride 3+	0.85 (3.74)	-53.00
	Transit	0.16 (2.09)	-9.86
Gender Unknown	Transit	4.59 (4.5)	-287.01
Age 16 to 24	Shared-Ride 2	-0.21 (-1.24)	13.37
	Shared-Ride 3+	-1.79 (-2.44)	111.89
	Non-Motorized	0.3 (0.65)	-18.95
	Transit	0.79 (5.89)	-49.67
Age 41 to 55	Shared-Ride 2	-0.31 (-3.01)	19.15
	Shared-Ride 3+	-0.41 (-1.73)	25.64
	Non-Motorized	-0.18 (-0.57)	11.10
	Transit	-0.42 (-4.56)	26.44

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Age 56 to 64	Shared-Ride 2	-1.03 (-5.87)	64.35
	Shared-Ride 3+	-0.86 (-1.88)	53.53
	Non-Motorized	-0.65 (-1.49)	40.33
	Transit	-0.45 (-3.63)	28.12
Age 65+	Shared-Ride 2	-0.67 (-2.69)	41.94
	Shared-Ride 3+	-1.43 (-1.39)	89.66
	Non-Motorized	-1.45 (-2.64)	90.83
	Transit	-1.12 (-5.8)	70.19
Age Unknown	Shared-Ride 2	-0.2 (-0.61)	12.75
	Non-Motorized	-2.21 (-1.42)	137.92
	Transit	0.65 (2.72)	-40.69
Initial likelihood		**-21247**	
Final likelihood		**-9610**	

Final Model:

The final model is a mix of estimated and asserted coefficients. In cases where the estimated values were not reasonable, but the coefficient was important to ensure a logical and explainable model, the coefficients were asserted.

- The estimated in-vehicle time coefficient was highly significant and negative across all model runs. In most model runs, the coefficient was approximately -0.016. In the final run, the coefficient was fixed at -0.0160 so that its value did not change when out-of-vehicle time parameters were preset to ensure reasonable relationships to in-vehicle time.
- The cost coefficient was estimated as one value initially and then split into income classes. In all cases, cost was negative and highly significant. The estimated cost parameters were larger than expected, although there was a good relationship between the income classes (with cost coefficients decreasing in size with respect to household income). However, the larger values resulted in lower value of times than is reasonable. In the final run, cost coefficients were constrained such that values of time for work tours were based on one-half of the average hourly wage rate for each household income range, as follows:
    - $0-$30,000: $15,000 (average yearly income) / 2080 (hours/year) * ½ * 1 (workers/household) = $3.61/hour
    - $30,001 - $60,000: $45,000 (average yearly income) / 2080 (hours/year) * ½ * 1.33 (workers/household) = $8.13/hour
    - $60,001 - $100,000: $80,000 (average yearly income) / 2080 (hours/year) * ½ * 1.44 (workers/household) = $13.33/hour
    - $100,001 and greater: $186,472 (average yearly income) / 2080 (hours/year) * ½ * 1.18 (workers/household) = $38.14/hour (capped at $30.00/hour)

- Transit access walk time was estimated as a negative and significant value. The transit access drive time and total walk time were asserted at -.0240 which is one and a half times the in-vehicle time.
- Total wait time was set to -0.0240, or one and a half times in-vehicle time. A coefficient will be tested in calibration on number of transfers, to ensure that the transfer rate replicates observed data.
- The mix density coefficient was both positive and significant for walk tours and bike tours at the origin MGRA. Although the size of the coefficient is not very large (0.2101), it is a coefficient with potential policy applications and it is very reasonable that it would be positive for those two modes.
- Similarly, intersection density was positive and very close to significance for non-motorized modes at the origin MGRA. This coefficient was kept in the model for potential policy applications.
- Employment density was positive and significant for walk/bike tours at the destination end of the tour, although the magnitude was small like the other density-related parameters.
- When the ASCs were stratified by auto sufficiency, all estimated modes had positive coefficients and most were significant. Drive-alone was set to the base mode, and disallowed for 0-vehicle households in all purposes. When the number of autos is greater than or equal to the household size, all of the alternative specific constants were negative, which shows a strong preference for driving alone when a vehicle is available, all else being equal.
- A set of constants on shared-ride 2 and shared-ride 3+ modes were introduced, stratified by household size. When household size is 2, shared-ride 2 is positive and significant, while shared-ride 3+ is negative and insignificant, most likely because the vehicle occupancy is greater than the household size. For three person households, both shared-ride 2 and shared-ride 3+ constants are positive and significant (or very close to significance). For households of 4+ persons, both shared-ride 2 and shared-ride 3+ are positive and very significant. These results are all reasonable, because they show a preference towards shared-ride modes as household size increases.
- The gender stratification showed that women are more likely than men to choose one of the shared-ride modes and transit. This may reflect auto allocation biases that exist in households with limited car availability, or a relatively higher value-of-time bias by men.
- Alternative-specific constants were also stratified by age, where the 25-40 year age range was set as the base group. The results showed that younger persons (age 16-24) are less likely to share a ride (negative signs), but more likely to use a non-motorized or transit mode (positive signs). Persons in all other age groups were less likely to take any mode other than the base of drive-alone. This may indicate relatively lower values-of-time in younger adults, and/or auto allocation biases within multi-generational households.
- Given the problems estimating reasonable alternative-specific constants by transit line-haul mode, the final implemented model relies on the recently-calibrated trip mode choice model for line-haul mode constants. Those constants are calculated by taking twice the value of the trip-based home-based work model constants in equivalent minutes, to convert from trip-based model values to tour-based model values, assuming two trips per tour. The constants by line-haul mode will be further evaluated and/or adjusted in model calibration. All other

modal alternative-specific constants (shared-2, shared-3+, walk, bike, walk-transit and drive-transit) were retained from their originally estimated values.

Table 47: Implemented Work Tour Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
Travel Time Variables		
In Vehicle Time coefficient (c_ivt)	-0.016	1
First wait time coefficient	-0.024	1.5
Transfer wait time coefficient	-0.024	1.5
Walk access time coefficient	-0.02502	1.564
Walk egress time coefficient	-0.02502	1.564
Walk auxiliary time coefficient	-0.02502	1.564
Drive access time coefficient	-0.03002	1.876
Transfer penalty - non-PNR modes	c_ivt*5	5
Transfer penalty - PNR	c_ivt*15	15
Express bus IVT factor	0.900	-56.250
BRT IVT factor	0.900	-56.250
LRT IVT factor	0.850	-53.125
Commuter rail IVT factor	0.750	-46.875
Walk mode time coefficient	-0.04247	2.654
Bike mode time coefficient	-0.04923	3.077
Travel Cost Variables		
Cost coefficient for income < $30k	-0.00266	0.166
Cost coefficient for income $30k-$60k	-0.00118	0.074
Cost coefficient for income $60k - $100k	-0.00072	0.045
Cost coefficient for income > $100k	-0.00032	0.02
Location Specific Variables		
Origin MGRA du/emp mix coefficient, applied to walk, bike	0.210144	-13.134
Origin MGRA intersection density coefficient, applied to walk, bike	0.002998	-0.187
Destination MGRA emp density coefficient, applied to walk, bike	0.020707	-1.294
Normalized Land Use Variable Sum [Origin Intersection + DU]	0.08327	-5.204

Coefficient Name	Value	Equivalent Value in IVT
Normalized Landuse Variable Sum [Origin Intersection + DU]	0.00931	-0.582
Normalized Destination Employment	0.09981	-6.238
Socio-economic Variables		
Age 16 to 24, shared-ride 2	-0.21388	13.36769
Age 16 to 24, shared-ride 3+	-1.79023	111.8895
Age 16 to 24, non-motorized	0.303216	-18.951
Age 16 to 24, transit	0.794718	-49.6699
Age 41 to 55, shared-ride 2	-0.30638	19.14864
Age 41 to 55, shared-ride 3+	-0.41025	25.64055
Age 41 to 55, non-motorized	-0.17752	11.0952
Age 41 to 55, transit	-0.42301	26.43805
Age 56 to 64, shared-ride 2	-1.02962	64.35146
Age 56 to 64, shared-ride 3+	-0.85641	53.52536
Age 56 to 64, non-motorized	-0.64534	40.33371
Age 56 to 64, transit	-0.44991	28.1196
Age 65 plus, shared-ride 2	-0.67111	41.94461
Age 65 plus, shared-ride 3+	-1.43462	89.66383
Age 65 plus, non-motorized	-1.45334	90.83371
Age 65 plus, transit	-1.1231	70.19362
Female, shared-ride 2	0.594728	-37.1705
Female, shared-ride 3+	0.848064	-53.004
Female, transit	0.157786	-9.86162
Household size 2, shared-ride 2	1.069642	-66.8526
Household size 2, shared-ride 3+	-0.46736	29.20983
Household size 3, shared-ride 2	1.580184	-98.7615
Household size 3, shared-ride 3+	0.654631	-40.9145
Household size 4+, shared-ride 2	1.688389	-105.524
Household size 4+, shared-ride 3+	1.498703	-93.669
Age 41 to 55, bike	-0.73111	45.694
Age 56 to 64, bike	-0.64352	40.220
Age 65 plus, bike	-1.54867	96.792
Female, bike	-1.19364	74.603

Coefficient Name	Value	Equivalent Value in IVT
Income 100k plus, bike	0.64138	-40.086
Normalized Landuse Variable Sum [Origin Employment + DU]	0.08327	-5.204
Bike logsum coefficient inbound	0.13433	-8.396
Bike logsum coefficient outbound	0.13433	-8.396
Miles to coast from origin MGRA	-1.42018	88.761
Miles greater than 2 to coast from origin MGRA	1.33508	-83.443
Miles greater than 5 to coast from origin MGRA	0.07956	-4.973
Age under 16, walk	2.18840	-136.775
Age 16 to 24, walk	1.43059	-89.412
Age 41 to 55, walk	-0.43207	27.004
Age 56 to 64, walk	-0.51999	32.499
Age 65 plus, walk	-0.83162	51.976
Income 60k to 100k, walk	-0.20839	13.024
ASC - Shared-Ride 2	-2.0836	130.2261
ASC - Shared-3+	-3.9470	246.6847
ASC –Walk	0.0000	0
ASC –Bike	0.000	0
ASC –Transit	-1.7080	106.7478
ASC - Express Bus	0.5600	-35.0
ASC – BRT	0.3200	-20.0
ASC – LRT	0.5600	-35
ASC - Commuter Rail	0.8000	-50.0
ASC - TransitDrive	-4.2364	264.7739
ASC - Transit KNR	0.3708	-23.1756
ASC - 0 Autos - Shared-Ride 3+	0.4246	-26.5346
ASC - 0 Autos - Walk-Transit	2.6525	-165.781
ASC - 0 Autos - KNR-Transit	0.8043	-50.2704
ASC - Auto Sufficient - Shared-Ride 2	-0.3867	24.16615
ASC - Auto Sufficient - Shared-Ride 3+	-0.1030	6.43498

Coefficient Name	Value	Equivalent Value in IVT
ASC - Auto Sufficient - Walk-Transit	-1.7843	111.5201
ASC - Auto Sufficient - PNR-Transit	-1.1035	68.96915
ASC - Auto Sufficient - KNR-Transit	-2.0831	130.193
Shared Ride 3+ for 0 Autos	1.5967	-99.794
0 Autos - Walk	3.1367	-196.044
0 Autos - Bike	3.1126	-194.538
0 Autos - Walk-Transit	0.8231	-51.444
0 Autos - KNR-Transit	3.7742	-235.888
0 Autos - PNR-Transit	-999.0	62437.5
Auto insufficient – Shared-Ride 2	-0.1613	10.081
Auto insufficient - Shared-Ride 3+	1.6694	-104.338
Auto insufficient - Walk	1.2979	-81.119
Auto insufficient - Bike	1.1608	-72.550
Auto insufficient – Walk-Transit	1.4626	-91.413
Auto insufficient – PNR-Transit	3.6878	-230.488
Auto insufficient – KNR-Transit	3.4396	-214.975
Auto sufficient – Shared-Ride 2	0.0796	-4.975
Auto sufficient - Shared-Ride 3+	1.9640	-122.750
Auto sufficient - Walk	-1.2452	77.825
Auto sufficient - Bike	-0.8894	55.588
Auto sufficient – Walk-Transit	0.6434	-40.213
Auto sufficient – PNR-Transit	2.9891	-186.819
Auto sufficient – KNR-Transit	2.5374	-158.588
Constant to make up for coast - Bike	1.5524	-97.025
Commuter rail constant - business shuttles	'-15*c_ivt*CRShuttleDistrict	-15

Coefficient Name	Value	Equivalent Value in IVT
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	'c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	'c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
Walk Transit - Pseudo area type constant	'-20*c_ivt	-20
PNR and KNR Transit - Pseudo area type constant	'-60*c_ivt	-60
PNR – Premium – PNR-EXP / PNR-CR	'-50*c_ivt	-50
PNR – Premium – PNR-BRT / PNR-LR	'-25*c_ivt	-25

University Tour Mode Choice Model Estimation

There were 3,773 university observations used for estimation of this model after removing unavailable or invalid choices.

Model Estimation Findings:

- Estimated cost coefficient stratified by income classes were not reasonable or significant for university tours, most likely due to low observations in the higher income groups. Therefore, the cost coefficient was collapsed into one cost coefficient for all observations with a reported income, and one coefficient for unknown.
- Given estimation problems previously described, the ratio of wait time to in-vehicle time asserted for the work purpose was maintained in this model.
- The mix variable coefficients were significant in this model. Additionally, one model run tested employment density for the transit mode at the destination MGRA, but the sign of the estimated coefficient was negative, which is the opposite of what the density coefficients should be, so it was dropped.
- ASCs were estimated for each mode, but as with the work purpose, transit drive and transit KNR had to be combined, and the HOV lane mode could not be estimated.
- The ASCs were stratified by auto sufficiency. Some of the modes could not be estimated for this purpose due to the low number of observations.
- The household size, age and gender stratification were less successful for this purpose than for work tours. Most of the household size and age categories were dropped due to insignificance or a sign in the wrong direction. None of the gender coefficients were maintained.
- Similar to the results for work purpose, it was not possible to estimate reasonable transit line-haul mode constants for university tours.

Table 48: University Mode Choice Estimation

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone		
	Shared-Ride 2	-2.58 (-2.24)	161.36
	Shared-3+	-4.59 (-3.49)	286.80
	Walk	0.76 (0.67)	-47.21
	Bike	-7.09 (-2.47)	442.48
	Transit	1.69 (5.05)	-105.70
	Express Bus	-0.9 (-7.58)	56.00
	LRT	0.56 (8.66)	-35.00
	Commuter Rail	0.72 (0.92)	-45.00
	Transit Drive	-3.67 (-15.23)	229.29
	Transit KNR	0.01 (0.06)	-0.82
In-vehicle time		-0.0160 (-13.29)	1
Cost		-.001 (-3.1)	0.08
Cost - Unknown		-0.01 (-4.6)	0.32
Transit Access Time	Walk	-0.03 (-6.35)	2.19
	Drive	-0.04 (-5.7)	2.32
Total Wait Time		-.024 (constr)	1.50
Number of Transfers		0 (constr)	0
Mix Density Variables (*.01), Origin MGRA	Walk	0.12 (1)	-7.64
	Bike	0.49 (2.01)	-30.68
Intersection Density	Walk/Bike	0.01 (1.38)	-0.57
Employment Density	Walk/Bike	0.08 (3.78)	-5.11
Walk Mode Time	Walk	-0.06 (-3.98)	3.99
Bike Mode Time	Bike	-0.05 (-1.18)	3.42
Auto Sufficiency, Autos = 0	Walk-Transit	2.21 (2.91)	-137.87
	KNR-Transit	0.06 (0.07)	-3.50
Auto Sufficiency, Autos >=HH Size	Shared-Ride 2	-0.52 (-1.24)	32.46
	Shared-Ride 3+	-1.04 (-1.1)	64.83
Auto Sufficiency Unknown	Walk	-2.38 (-2.5)	148.82
	Walk-Transit	-1.43 (-5.36)	89.52
	PNR-Transit	-0.89 (-2.77)	55.62
	KNR-Transit	-1.79 (-5.82)	111.80
	Walk - Transit	0.95 (4.97)	-59.05

	PNR - Transit	-0.38 (-1.25)	23.74
Household Size 2 or 3	Shared-Ride 2+	2 (1.72)	-124.85
Household Size 4+	Shared-Ride 2+	2.55 (2.22)	-159.33
Age 16 to 24	Transit	0.48 (2.36)	-29.84
Age Unknown	Transit	0.92 (3.33)	-57.47
Initial likelihood	**-8673**		
Final likelihood	**-2910**		

Final Model:

- In-vehicle time was not asserted for this model, because it was estimated very close to the value that was asserted for the work purpose.
- Density variables for the mix coefficient for walking/biking at the origin MGRA end were both positive, although the walk variable was not significant. It was kept in the model for policy applications. Similarly, the walk/bike for intersection density at the origin end was positive and not significant, and maintained for policy applications. The coefficient on employment density at the destination end was positive and very significant for non-motorized modes.
- Walk and bike mode time were both correctly-signed. Bike mode time was not quite significant, but it was quite close and therefore maintained.
- It was not possible to estimate ASCs for shared-ride or non-motorized modes for 0 auto households due to a lack of observations. However, the 0-auto household walk-transit constant was both positive and significant, as expected. The signs for auto sufficient households were all negative for shared-ride, walk, and walk-transit, PNR transit, and KNR transit, although the coefficients for the shared-ride and PNR transit were not significant.
- The only household size stratification that was maintained was shared-ride 2+ for 2, 3, or 4+ person households. These were positive, showing that people who live in households with more members are more likely to share a ride.
- When stratified by age, only a transit coefficient for persons aged 16 to 24 could be estimated. The parameter was both positive and significant, showing a tendency towards transit use for the younger age group.
- The value of time calculation was $7.62 cents for all persons with a known income.

Table 49: Implemented University Tour Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
In-vehicle time coefficient	-0.016013	1.00
First wait time coefficient	-0.0240	1.50
Transfer wait time coefficient	-0.0240	1.50
Walk access time coefficient	-0.0292	1.82
Walk egress time coefficient	-0.0292	1.82
Walk auxiliary time coefficient	-0.0292	1.82
Drive access time coefficient	-0.0372	2.325
Transfer penalty	-0.0801	5.00
Transfer penalty - PNR	-0.2402	15.00
Express bus IVT factor	0.9000	-56.20
BRT IVT factor	0.9000	-56.20
LRT IVT factor	0.8500	-53.08
Commuter rail IVT factor	0.7500	-46.84
Walk mode time coefficient	-0.04247	2.65
Bike mode time coefficient	-0.0547	3.42
Cost coefficient for income < $30k	-0.0013	0.08
Cost coefficient for income $30k-$60k	-0.0013	0.08
Cost coefficient for income $60k - $100k	-0.0013	0.08
Cost coefficient for income > $100k	-0.0013	0.08
Origin MGRA du/emp mix coefficient, applied to walk, bike	0.12231	-7.63842
Origin MGRA intersection density coefficient, applied to walk, bike	0.00907	-0.56653
Destination MGRA emp density coefficient, applied to walk, bike	0.08179	-5.10746
Age 16 to 24, transit	0.46117	-28.7995
Household size 2, shared-ride 2	1.87118	-116.853

Coefficient Name	Value	Equivalent Value in IVT
Household size 2, shared-ride 3+	1.87118	-116.853
Household size 3, shared-ride 2	1.87118	-116.853
Household size 3, shared-ride 3+	1.87118	-116.853
Household size 4+, shared-ride 2	2.42627	-151.518
Household size 4+, shared-ride 3+	2.42627	-151.518
Age 41 to 55, bike	-0.73111	45.66
Age 56 to 64, bike	-0.64352	40.19
Age 65 plus, bike	-1.54867	96.71
Female, bike	-1.19364	74.54
Income 100k plus, bike	0.64138	-40.05
Normalized Landuse Variable Sum [Origin Employment + DU]	0.08327	-5.20
Bike logsum coefficient inbound	0.13433	-8.39
Bike logsum coefficient outbound	0.13433	-8.39
Age under 16, walk	2.18840	-136.66
Age 16 to 24, walk	1.43059	-89.34
Age 41 to 55, walk	-0.43207	26.98
Age 56 to 64, walk	-0.51999	32.47
Age 65 plus, walk	-0.83162	51.93
Income 60k to 100k, walk	-0.20839	13.01
Normalized Landuse Variable Sum [Origin Intersection + DU]	0.00931	-0.58
Normalized Destination Employment	0.09981	-6.23
ASC - Shared-Ride 2	-2.5839	161.3585
ASC - Shared-3+	-4.5926	286.8048
ASC - Walk	0.0000	0.00
ASC -Bike	0.0000	0.00
ASC - Transit	1.6925	-105.78-
ASC - Express Bus	0.6405	-40.03
ASC - BRT	0.3200	-20.00
ASC - LRT	0.6405	-40.03

Coefficient Name	Value	Equivalent Value in IVT
ASC - Commuter Rail	0.6405	-40.03
ASC - TransitDrive	-3.6716	229.48
ASC – 0 Autos - Walk	3.9595	-247.47
ASC - 0 Autos - Walk-Transit	2.2077	-137.98
ASC - Auto Sufficient - Shared-Ride 2	-0.5198	32.49
ASC - Auto Sufficient - Shared-Ride 3+	-1.0382	64.89
ASC - Auto Sufficient - Walk	-1.7060	106.63
ASC - Auto Sufficient - Bike	-0.9879	61.74
ASC - Auto Sufficient - Walk-Transit	-1.4335	89.51836
ASC - Auto Sufficient - PNR-Transit	-0.8906	55.61688
ASC - Auto Sufficient - KNR-Transit	-1.7902	111.7978
Constant		
Shared Ride 2 Unavailable for 0 Autos	-15.0	936.73
Shared Ride 3+ Unavailable for 0 Autos	-15.0	936.73
0 Autos - Walk	11.4148	-712.84
0 Autos - Bike	3.5635	-222.54
0 Autos - Walk-Transit	-0.2907	18.15
0 Autos - KNR-Transit	1.9296	-120.50
0 Autos - PNR-Transit	-999.0	62386.36
Constant		
Auto insufficient – Shared-Ride 2	-0.5517	34.45
Auto insufficient - Shared-Ride 3+	1.3033	-81.39
Auto insufficient - Walk	2.4310	-151.81
Auto insufficient - Bike	1.2842	-80.20
Auto insufficient – Walk-Transit	-0.4758	29.71
Auto insufficient – PNR-Transit	0.6858	-42.83
Auto insufficient – KNR-Transit	1.2061	-75.32
Constant		
Auto sufficient – Shared-Ride 2	0.3876	-24.21
Auto sufficient - Shared-Ride 3+	2.2318	-139.37
Auto sufficient - Walk	-0.9439	58.95
Auto sufficient - Bike	-0.0067	0.42

Coefficient Name	Value	Equivalent Value in IVT
Auto sufficient – Walk-Transit	-2.0042	125.16
Auto sufficient – PNR-Transit	-0.3082	19.25
Auto sufficient – KNR-Transit	0.1521	-9.50
Constant to make up for coast - Bike	-2.0	124.90
Pro-bike district constant (District27==8) + (District27==9)	1.5524	-96.95
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	'c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	'c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
Walk Transit - Pseudo area type constant	'-20*c_ivt	-20
PNR and KNR Transit - Pseudo area type constant	'-60*c_ivt	-60
PNR – Premium – PNR-EXP / PNR-CR	'-60*c_ivt	-60
PNR – Premium – PNR-BRT / PNR-LR	'-30*c_ivt	-30

School Tour Mode Choice Model Estimation

There were 3,342 observations available for estimation of the school tour mode choice model.

This model also included estimation for the school bus mode, which is not considered by the other purposes. This mode competes equally with auto, non-motorized, and transit modes.

Model Estimation Findings:

- In-vehicle time was estimated for each model run, as the resulting coefficient was a reasonable value.
- The cost coefficient was estimated for the different income groups, because the estimated coefficients had a reasonable relationship with each other and a significant negative value, as expected.
- Transit walk and drive time parameters were both estimated and had negative and significant values.
- Total wait time was estimated, but had a positive sign and was not significant. It was constrained to 1.5 times in-vehicle time (-0.015) for the final run.
- The number of transfer's coefficient was insignificant and very small; therefore it was dropped from estimation.
- The mix density variables were not successful in this model estimation. As the model runs progressed, the coefficients became quite insignificant. This indicates that mixed land-uses have little effect on school tour mode choice.

- Intersection density for the origin end of walk/bike trips was close to significant for most of the estimation runs, and significant in the final run. It was positive for all the estimations, as expected. Employment density had a negative sign, which is the opposite of the desired effect; therefore it was not maintained in the estimation.
- Walk and bike mode time had significant and negative coefficients across the estimations.
- ASCs were initially estimated for all modes, including school bus, which is a mode that is specific to this estimation.
- ASCs were stratified by auto sufficiency. The 0 auto households had positive coefficients for shared-ride 3+, walk, bike, and KNR transit, which is the expected result with drive-alone as the base mode. The shared-ride 3+ and KNR transit coefficients were not significant but were maintained because they were correctly signed. Auto sufficient households showed positive coefficients on shared-ride modes, which most likely reflects children being taken to school by parents. Walk and transit modes had negative coefficients, and bike had a small positive coefficient that was insignificant. The ASCs were also stratified by household size for household size 3 and 4+, for shared-ride 2 and shared-ride 3+ modes. These coefficients were positive, although not always significant across the estimation runs.
- The ASCs were also stratified for females for the shared-ride 2, shared-ride 3+ and transit. The results show that female students are more likely to get a ride to school or take transit than they are to walk or bike to school, all else being equal. This could reflect concerns about safety.
- Alternative specific constants were stratified by three age groups; under 6 (pre-school), 6 to 12(grade school) and 13 to 15 (high school pre-driving age). The modes used were school bus, non-motorized, and transit. For the youngest age group, the constant on school bus was not significant, which is reasonable given that preschoolers do not typically ride a school bus. The youngest age group had negative coefficients on non-motorized and transit, which is reasonable because children that young are most likely driven by an adult to school. The older age groups had positive coefficients on school bus, and the oldest group also had a positive coefficient on non-motorized, which makes sense since older students are more independent and can walk or bike to school themselves.

Table 50: School Mode Choice Estimation

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone		
	Shared-Ride 2	1.47 (4.42)	-147.13
	Shared-3+	-0.62 (-1.53)	62.15
	Walk	4.1 (9.03)	-411.04
	Bike	-0.38 (-0.51)	38.53
	Transit	1.77 (5.71)	-177.45
	Express Bus	-0.56 (1.59)	56.00
	LRT	0.349 (constr)	-35.00
	Commuter Rail	0.45 (0.53)	-45.00
	TransitDrive	-5.04 (-14.81)	505.07
	Transit KNR	1.47 (4.55)	-147.28
	School Bus	-0.65 (-2.36)	64.90
In-vehicle time		-0.01 (-7.53)	1
Cost - Low (<30k)		-0.01 (-9.55)	1.09
Cost - Medium-Low (30-60k)		0 (-6.5)	0.45
Cost - Medium-High (60-100k)		0 (-4.91)	0.31
Cost - Very High (100k+)		0 (-3.69)	0.30
Cost - Unknown		-0.01 (-9.93)	1.32
Transit Access Time	Walk	-0.04 (-6.15)	3.58
	Drive	-0.02 (-2.6)	1.63
Total Wait Time		-0.015 (constr)	1.50
Intersection Density	Walk/Bike	0.003 (1.63)	-0.30
Walk Mode Time	Walk	-0.06 (-11.26)	5.61
Bike Mode Time	Bike	-0.08 (-4.14)	8.31
Auto Sufficiency, Autos = 0	Shared-Ride 3+	0.56 (0.88)	-56.03
	Walk	2.13 (4.32)	-213.77
	Walk-Transit	1.25 (2.82)	-125.41
	KNR-Transit	0.32 (0.54)	-31.99
Auto Sufficiency, Autos >=HH Size	Shared-Ride 2	0.86 (3.94)	-85.84
	Shared-Ride 3+	0.95 (3.74)	-95.41
	Walk	-0.08 (-0.29)	8.24
	Bike	0.66 (0.99)	-65.73
	Walk-Transit	-0.97 (-4.31)	97.12

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
	PNR-Transit	-0.98 (-2.61)	98.18
	KNR-Transit	-0.97 (-3.62)	96.98
Auto Sufficiency Unknown	Walk-Transit	0.95 (2.69)	-95.57
	PNR-Transit	1.39 (2.46)	-139.00
Household Size 3	Shared-Ride 2+	0.67 (2.48)	-66.96
Household Size 4+	Shared-Ride 2	0.41 (1.67)	-41.24
	Shared-Ride 3+	2.1 (6.69)	-210.18
Female	Shared-Ride 2	0.37 (2.73)	-37.10
	Shared-Ride 3+	0.33 (2.12)	-32.69
	Transit	0.61 (3.67)	-61.06
Gender Unknown	Transit	1.64 (2.68)	-163.93
Age Under 6	Non-Motorized	-1.16 (-3.35)	116.47
	Transit	-6.5 (-8.71)	651.39
Age 6 to 12	School Bus	1.45 (5.63)	-145.17
	Non-Motorized	-0.58 (-2.07)	57.80
	Transit	-4.6 (-17.95)	460.86
Age 13 to 15	School Bus	1.3 (4.48)	-129.93
	Non-Motorized	0.69 (2.2)	-68.86
	Transit	-1.18 (-7.36)	118.60
Age Unknown	Transit	-3.31 (-6.4)	332.19
Initial likelihood	-8673		
Final likelihood	-3758		

Final Model:

- Intersection density for the walk/bike mode was the only one of the density variables maintained for the final run. It has a very small coefficient, but is positive and significant. This result shows that when urban form is supportive of non-motorized modes, students are more likely to choose those modes to get to school.
- The alternative specific constants for the transit drive and transit KNR modes were grouped together into just two modes.
- The auto sufficiency stratification on the alternative specific constants for 0 auto households was maintained for shared-ride 3+, walk transit, and KNR transit. All of these coefficients were positive, although shared-ride 3+ and KNR transit were not significant. Auto sufficient households showed a positive and significant coefficient on the shared-ride modes, but a negative and significant coefficient on the transit modes. This shows that children are more likely to share a ride and less likely to take transit than to drive-alone, which makes sense since very few of them can drive.

- The gender stratification on the alternative specific constants showed that females are more likely to take a shared-ride mode or transit than males.
- The age stratification on the alternative specific constants showed that in the youngest age group (under 6), persons are less likely to take a non-motorized mode and even less likely to take transit than the base auto modes. A constant on school bus was not estimated in the final run because it was not significant for this age group. Ages 6 to 12 have a positive coefficient on school bus, but a negative on non-motorized or transit mode. The oldest age group considered (13 to 15) had positive coefficients on school bus and non-motorized, and a negative coefficient on transit. Overall, these results show that students are more likely to take the school bus if it is available, and be driven to school otherwise, until they reach the oldest age group when walking or biking is also an option for them, all else being equal.
- The value of time calculations reflected that children have a lower value of time than working adults:
    - $0.55 Low Income
    - $1.33 Medium-Low
    - $1.91 Medium-High
    - $1.99 Very High
    - $0.46 Income Unknown

Table 51: Implemented School Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
In-vehicle time coefficient (c_ivt)	-0.00998	1.00
First wait time coefficient (c_fwt)	-0.0150	1.50
Transfer wait time coefficient	-0.0150	1.50
Walk access time coefficient (c_wacc)	-0.0298	2.98
Walk egress time coefficient	-0.0298	2.98
Walk auxiliary time coefficient	-0.0298	2.98
Drive access time coefficient	-0.0162	1.62
Transfer penalty	c_ivt*5	5
Transfer penalty - PNR	c_ivt*15	15
Express bus IVT factor	0.9000	-90.19
BRT IVT factor	0.9000	-90.19
LRT IVT factor	0.8500	-85.18
Commuter rail IVT factor	0.7500	-75.16
Walk mode time coefficient	-0.06795	6.795
Bike mode time coefficient	-0.0829	6.81
Cost coefficient for income < $30k	-0.0108	8.31

Coefficient Name	Value	Equivalent Value in IVT
Cost coefficient for income $30k-$60k	-0.0045	1.08
Cost coefficient for income $60k - $100k	-0.0031	0.45
Cost coefficient for income > $100k	-0.0030	0.31
Origin MGRA intersection density coefficient, applied to walk, bike	0.00295	0.30
Constants		
Age 1 to 5, non-motorized	-1.16217	116.47
Age 1 to 5, transit	-6.49996	651.39
Age 6 to 12, school bus	1.44859	-145.17
Age 6 to 12, non-motorized	-0.57675	57.80
Age 6 to 12, transit	-4.59870	460.86
Age 13 to 15, school bus	1.29649	-129.93
Age 13 to 15, non-motorized	0.68716	-68.86
Age 13 to 15, transit	-1.18344	118.60
Female, shared-ride 2	0.37019	-37.10
Female, shared-ride 3+	0.32616	-32.69
Female, transit	0.60931	-61.06
Household size 3, shared-ride 2	0.66814	-66.96
Household size 3, shared-ride 3+	0.66814	-66.96
Household size 4+, shared-ride 2	0.41147	-41.24
Household size 4+, shared-ride 3+	2.09725	-210.18
Age 41 to 55, bike	-1.16978	117.23
Age 56 to 64, bike	-1.02963	103.18
Age 65 plus, bike	-2.47787	248.32
Female, bike	-1.90983	191.39
Income 100k plus, bike	1.02621	-102.84
Normalized Landuse Variable Sum [Origin Employment + DU]	0.13323	-13.35
Bike logsum coefficient inbound	0.21493	-21.54
Bike logsum coefficient outbound	0.21493	-21.54
Miles to coast from origin MGRA	-2.27229	227.72
Miles greater than 2 to coast from origin MGRA	2.13612	-214.07

Coefficient Name	Value	Equivalent Value in IVT
Miles greater than 5 to coast from origin MGRA	0.12730	-12.76
Age under 16, walk	3.37115	-337.84
Age 16 to 24, walk	2.12664	-213.12
Age 41 to 55, walk	-0.76078	76.24
Age 56 to 64, walk	-0.90034	90.23
Age 65 plus, walk	-1.38069	138.37
Income 60k to 100k, walk	-0.35622	35.70
Normalized Landuse Variable Sum [Origin Intersection + DU]	0.70159	-70.31
Normalized Destination Employment	0.19166	-19.21
ASC - Shared-Ride 2	1.4700	-147.32
ASC - Shared-3+	-0.6200	62.13
ASC - School Bus	-0.6476	64.90
ASC - Transit	1.7700	-177.38
ASC - Express Bus	0.0998	-10.00
ASC - BRT	0.1996	-20.00
ASC - LRT	0.3991	-40.00
ASC - Commuter Rail	0.3991	-40.00
ASC - TransitDrive	-5.0400	505.08
ASC - Transit KNR	1.4700	-147.32
ASC - 0 Autos - Shared-Ride 3+	0.5600	-56.12
ASC - 0 Autos - Walk-Transit	1.2500	-125.27
ASC - 0 Autos - KNR-Transit	0.3200	-32.07
ASC - Auto Sufficient - Shared-Ride 2	0.8600	-86.18
ASC - Auto Sufficient - Shared-Ride 3+	0.9500	-95.20
ASC - Auto Sufficient - Walk	-2.1859	219.06
ASC - Auto Sufficient - Bike	1.2967	-129.95
ASC - Auto Sufficient - Walk-Transit	-0.9700	97.21
ASC - Auto Sufficient - PNR-Transit	-0.9800	98.21
ASC - Auto Sufficient - KNR-Transit	-0.9700	97.21

Coefficient Name	Value	Equivalent Value in IVT
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
Walk Transit - Pseudo area type constant	-30*c_ivt	-30
PNR and KNR Transit - Pseudo area type constant	-60*c_ivt	-60
PNR - Premium	-60*c_ivt	-60
ASC Adjustment - Toll	20*c_ivt	20
Pro-bike district constant (District27==8) + (District27==9)	1.5524	-155.57
0 Autos – Shared3	1.5120	-151.52
0 Autos - Walk	3.1678	-317.46
0 Autos - Bike	6.1205	-613.36
0 Autos - Walk-Transit	4.5553	-456.51
0 Autos - PNR-Transit	-999.0000	100114.45
0 Autos - KNR-Transit	1.0189	-102.11
0 Autos – School Bus	3.3521	-335.93
Auto insufficient – Shared2	0.0912	-9.14
Auto insufficient – Shared3	1.0890	-109.13
Auto insufficient - Walk	0.7733	-77.50
Auto insufficient - Bike	4.2470	-425.61
Auto insufficient - Walk-Transit	3.6049	-361.26
Auto insufficient - PNR-Transit	6.4146	-642.84
Auto insufficient - KNR-Transit	5.9146	-592.73
Auto insufficient – School Bus	1.7581	-176.19
Auto sufficient – Shared2	-3.2128	321.97
Auto sufficient – Shared3	-1.7177	172.14
Auto sufficient - Walk	-0.7471	74.87
Auto sufficient - Bike	-0.7451	74.67
Auto sufficient - Walk-Transit	-1.5217	152.50
Auto sufficient - PNR-Transit	2.0895	-209.40

Coefficient Name	Value	Equivalent Value in IVT
Auto sufficient - KNR-Transit	0.1295	-12.98
Auto sufficient – School Bus	-1.9876	199.19

Maintenance Tour Mode Choice Model Estimation

There were 5,421 observations used for estimation of the maintenance tour mode choice model. The maintenance purpose includes escorting, shopping, and other maintenance purposes, which were combined for the purposes of estimation due to the inability to identify differences in the transit on-board survey and due to limited observations.

Model Estimation Findings:

- The in-vehicle time parameter was estimated in the first few model runs, and resulted in a value of around -0.017.
- In the initial model runs, the cost coefficients were split into income classes. However, the coefficients were unreasonably large. Transit access walk and drive time were both estimated. Across the estimations, the results were negative and significant.
- Total wait time was asserted at 1.5 times the in-vehicle time, as with the other models, due to difficulties in estimation previously described.
- The estimated coefficient for number of transfers moved from negative and significant to positive and insignificant across model estimations. It was fixed to 0 for later model runs.
- Land-use mix of the origin MGRA was interacted with non-motorized modes and walk-transit. Walk-transit had a negative coefficient, which is unreasonable, therefore it was dropped. The walk mode interaction term was positive and significant, indicating that land-use mix has a positive influence on walk mode for maintenance tours.
- Intersection and employment density were interacted with non-motorized modes, but did not yield positive or significant coefficients.
- Walk and bike mode times were both negative and significant.
- Alternative specific constants were estimated by line-haul mode, but were mostly out of logical ranges in equivalent minutes of in-vehicle time.
- Alternative specific constants by auto sufficiency were estimated and reasonable. Constants for walk, walk-transit, bike, and KNR were positive and significant. Shared-ride and transit mode constants for auto sufficient households were negative and significant.
- A set of constants was estimated for shared-ride modes by household size category (2, 3, and 4+). The constant for shared-ride 2 was dropped for household size 2 due to insignificance. The constant for shared-ride 3+ was negative for household size 2 and for household size 3, indicating that maintenance trips tend to be made with less than the total number of household members. For 4+ person households, both shared-ride 2 and shared-ride 3+ were positive. In these larger households, children may be more likely to accompany parents on maintenance tours.
- Modal constants were also stratified by gender, with varying results. In general, it was found that females have positive and significant constants for shared-ride modes, probably

indicating child-care responsibilities while conducting shopping and other maintenance tours.

- Model constants were also stratified by age, with varying results. The only significant constant for the youngest age category (16 to 24) was transit. Other age-specific constants showed trends similar to those discussed elsewhere in this memorandum.
- A set of modal constants was estimated for the escort tour purpose. Shared-ride2 and 3+ were not significant and were dropped. Non-motorized and transit constants for the escort purpose were negative and significant, which indicates that people are more likely to use auto modes for escort tours, all else being equal.
- If the tour purpose was joint, all modes whose occupancy is lower than the number of persons on the tour were made unavailable. For example, drive-alone is always unavailable for joint tours, and a joint tour with 3 or more persons does not have shared-ride 2 available. Higher auto occupancy modes are available for joint tours because it is always possible to include non-household members on joint tours. Joint tour constants were estimated for shared-ride 3+, non-motorized, and transit modes (shared-ride 2 is the base mode for joint tours). The coefficients were negative and significant for most model runs, indicating that carpooling is preferred to other modes for joint travel, all else being equal. Note that the joint tour constant for shared-ride 3+ had a very small coefficient, and became positive in the last model run.

Table 52: Maintenance Tour Mode Choice Estimation

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone		
	Shared-Ride 2	-0.13 (-0.59)	7.89
	Shared-3+	-1.56 (-3.36)	91.64
	Walk	2.92 (9.98)	-172.05
	Bike	-3.09 (-8.55)	181.93
	Transit	-1.38 (-5.73)	80.98
	Express Bus	-2.2 (-10.69)	129.32
	LRT	0.199 (2.58)	-11.69
	Commuter Rail	-0.22 (-0.34)	12.92
	TransitDrive	-5.7 (-11.32)	335.43
	Transit KNR	2.75 (5.57)	-161.65
In-vehicle time		-0.017 (constr)	1
Cost - Low (<30k)		-0.004 (0.24)	0.24
Cost - Medium-Low (30-60k)		-0.002 (0.11)	0.11
Cost - Medium-High (60-100k)		-0.001 (0.06)	0.06
Cost - Very High (100k+)		-0.001 (0.03)	0.03
Cost - Unknown		-0.007 (0.42)	0.42

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Transit Access Time	Walk	-0.024 (-4.36)	1.43
	Drive	-0.059 (-3.66)	3.45
Total Wait Time		-0.027 (0)	1.59
Number of Transfers		0	
Mix Variables - Origin MGRA	Walk	0.15 (5.71)	-8.57
Walk Mode Time	Walk	-0.07 (-15.34)	4.37
Bike Mode Time	Bike	-0.09 (-4.88)	5.05
Auto Sufficiency, Autos = 0	Walk	2.36 (6.64)	-138.68
	Bike	2.16 (2.69)	-127.05
	Walk-Transit	3.39 (11.69)	-199.65
	KNR-Transit	1.61 (3.23)	-94.77
Auto Sufficiency, Autos >=HH Size	Shared-Ride 2	-0.74 (-4.62)	43.34
	Shared-Ride 3+	-0.53 (-2.49)	31.33
	Walk	-1.18 (-5.51)	69.62
	Walk-Transit	-1.51 (-8.68)	88.94
	PNR-Transit	-1.17 (-0.89)	68.59
	KNR-Transit	-2.39 (-5.63)	140.62
Auto Sufficiency Unknown	Walk-Transit	3.18 (9.59)	-187.28
	PNR-Transit	3.13 (5.31)	-184.34
Household Size 2	Shared-Ride 3+	-1.68 (-3.81)	98.81
Household Size 3	Shared-Ride 2	0.49 (3.14)	-28.71
	Shared-Ride 3+	-1.34 (-2.81)	78.53
Household Size 4+	Shared-Ride 2	0.31 (2.11)	-18.13
	Shared-Ride 3+	0.59 (1.44)	-34.45
Female	Shared-Ride 2	0.32 (3.13)	-19.05
	Shared-Ride 3+	0.34 (2.27)	-20.15
Gender Unknown	Transit	2.64 (4.63)	-155.52
Age 16 to 24	Transit	1.62 (7.66)	-95.36
Age 41 to 55	Shared-Ride 2	-0.82 (-4.68)	48.39
	Shared-Ride 3+	-1.94 (-8.48)	113.85
	Non-Motorized	-1.34 (-5.9)	78.91
	Transit	-1.39 (-7.02)	81.95
Age 56 to 64	Shared-Ride 2	-0.95 (-4.49)	56.17
	Shared-Ride 3+	-2.17 (-4.79)	127.52

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
	Non-Motorized	-1.34 (-4.57)	78.95
	Transit	-1.46 (-6.45)	85.99
Age 65+	Shared-Ride 2	-1.06 (-5.53)	62.48
	Shared-Ride 3+	-2.15 (-5.99)	126.30
	Non-Motorized	-2.32 (-8.69)	136.51
	Transit	-2.86 (-12.76)	168.53
Escorting Tours	Non-Motorized	-1.26 (-6.92)	73.99
	Transit	-5.84 (-11.21)	343.46
Joint Tours	Shared-Ride 3+	0.47 (3.66)	-27.72
	Non-Motorized	-1.64 (-8.47)	96.44
	Transit	-2.83 (-17.23)	166.66
Initial likelihood	**-10938**		
Final likelihood	**-3867**		

Final Model:

- In the estimation runs, the value of time estimate was coming out unreasonably low due to the cost estimates being too large. Fixing the cost coefficients to smaller values based on the wage rate of San Diego in the calibration year resulted in a more reasonable value of time. The cost coefficients were set to 25% of the average hourly wage rate by income group.
- The mix variable of du/emp for the walk/bike mode at the origin MGRA was the only density measure that was significant and positive.
- The ASCs for the transit drive and transit KNR modes were grouped together into just two modes.
- 0 auto households had positive and significant coefficients on the walk, bike, walk-transit, and KNR-transit modes. The auto sufficient households had negative and significant coefficients for all modes tested: shared-ride 2, shared-ride 3+, walk, walk-transit, PNR transit, KNR transit. This shows a bias towards driving alone when autos are available for all household members.
- Larger households are more likely to use the shared-ride modes for their maintenance tours, although not when the shared-ride mode is for a size larger than or the same size as the household.
- Women are more likely to use shared-ride modes, implying that they may be more likely to take a child on a maintenance tour with them.
- The only age group that has a preference for any mode tested is the youngest group (16 to 24) which has a positive and significant coefficient on the transit mode. All other age groups were less likely to share a ride, take non-motorized modes, or transit for their maintenance tours.

- Escorting and joint tours are less likely to use non-motorized or transit modes compared to other maintenance tour purposes. Joint tours are more likely to ride-share.
- The following values of time were asserted:
    - $2.49 Low Income
    - $5.67 Medium-Low
    - $9.27 Medium-High
    - $20.40 Very High

Table 53: Implemented Maintenance Tour Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
In-vehicle time coefficient	-0.0170	1
First wait time coefficient	-0.0270	1.588
Transfer wait time coefficient	-0.0270	1.588
Walk access time coefficient	-0.0203	1.194
Walk egress time coefficient	-0.0203	1.194
Walk auxiliary time coefficient	-0.0203	1.194
Drive access time coefficient	-0.0586	3.447
Transfer penalty	c_ivt*5	5
Transfer penalty - PNR	c_ivt*15	5
Express bus IVT factor	0.9000	-52.941
BRT IVT factor	0.9000	-52.941
LRT IVT factor	0.8500	-50.000
Commuter rail IVT factor	0.7500	-44.118
Walk mode time coefficient	-0.03997	2.351
Bike mode time coefficient	-0.0859	5.053
Cost coefficient for income < $30k	-0.0041	0.241
Cost coefficient for income $30k-$60k	-0.0018	0.106
Cost coefficient for income $60k - $100k	-0.0011	0.065
Cost coefficient for income > $100k	-0.0005	0.029
Origin MGRA du/emp mix coefficient, applied to walk, bike	0.14563	-8.566
Age 16 to 24, transit	1.62111	-95.359
Age 41 to 55, shared-ride 2	-0.82262	48.389

Coefficient Name	Value	Equivalent Value in IVT
Age 41 to 55, shared-ride 3+	-1.93552	113.854
Age 41 to 55, non-motorized	-1.34146	78.909
Age 41 to 55, transit	-1.39312	81.948
Age 56 to 64, shared-ride 2	-0.95497	56.175
Age 56 to 64, shared-ride 3+	-2.16777	127.516
Age 56 to 64, non-motorized	-1.34220	78.953
Age 56 to 64, transit	-1.46184	85.991
Age 65 plus, shared-ride 2	-1.06222	62.484
Age 65 plus, shared-ride 3+	-2.14710	126.300
Age 65 plus, non-motorized	-2.32071	136.512
Age 65 plus, transit	-2.86495	168.526
Female, shared-ride 2	0.32387	-19.051
Female, shared-ride 3+	0.34258	-20.152
Household size 2, shared-ride 3+	-1.67985	98.815
Household size 3, shared-ride 2	0.48809	-28.711
Household size 3, shared-ride 3+	-1.33504	78.532
Household size 4+, shared-ride 2	0.30824	-18.132
Household size 4+, shared-ride 3+	0.58568	-34.452
Age 41 to 55, bike	-0.68811	40.477
Age 56 to 64, bike	-0.60566	35.627
Age 65 plus, bike	-1.45757	85.739
Female, bike	-1.12343	66.084
Income 100k plus, bike	0.60365	-35.509
Normalized Landuse Variable Sum [Origin Employment + DU]	0.07837	-4.610
Bike logsum coefficient inbound	0.22000	-12.941
Bike logsum coefficient outbound	0.22000	-12.941
Miles to coast from origin MGRA	-1.33664	78.626
Miles greater than 2 to coast from origin MGRA	1.25654	-73.914
Miles greater than 5 to coast from origin MGRA	0.07488	-4.405
Age under 16, walk	1.98303	-116.649

Coefficient Name	Value	Equivalent Value in IVT
Age 16 to 24, walk	1.25096	-73.586
Age 41 to 55, walk	-0.44752	26.325
Age 56 to 64, walk	-0.52961	31.154
Age 65 plus, walk	-0.81217	47.775
Female, walk	0	0.000
Income 60k to 100k, walk	-0.20954	12.326
Normalized Landuse Variable Sum [Origin Intersection + DU]	0.41270	-24.276
Normalized Destination Employment	0.11274	-6.632
ASC - Shared-Ride 2	-0.1341	7.888
ASC - Shared-3+	-1.5580	91.647
ASC –Transit	-1.3766	80.97584
ASC - Express Bus	0.1700	-10.000
ASC – BRT	0.3400	-20.000
ASC – LRT	0.6800	-40.000
ASC - Commuter Rail	0.6800	-40.000
ASC - TransitDrive	-5.7024	335.435
ASC - Transit KNR	2.7480	-161.647
ASC - 0 Autos –Walk	2.1745	-127.912
ASC - 0 Autos – Bike	0.9975	-58.676
ASC - 0 Autos - Walk-Transit	3.3941	-199.653
ASC - 0 Autos - KNR-Transit	1.6111	-94.771
ASC - Auto Sufficient - Shared-Ride 2	-0.7368	43.341
ASC - Auto Sufficient - Shared-Ride 3+	-0.5325	31.324
ASC - Auto Sufficient –Walk	-1.1604	68.259
ASC - Auto Sufficient - Walk-Transit	-1.5119	88.935
ASC - Auto Sufficient - PNR-Transit	-1.1660	68.588
ASC - Auto Sufficient - KNR-Transit	-2.3906	140.624
ASC - Auto Sufficient - Bike	-1.3224	77.788
ASC - Escort - Non-motorized	-1.2579	73.994
ASC - Escort –Transit	-5.8388	343.459

Coefficient Name	Value	Equivalent Value in IVT
ASC - Joint - Shared-Ride 3+	0.4713	-27.724
ASC - Joint - Non-motorized	-1.6395	96.441
ASC - Joint Transit	-2.8333	166.665
Shared Ride 2 Unavailable for 0 Autos	-15.0000	882.353
PNR Unavailable for Auto Sufficient Individual Tour	-15.0000	882.353
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
Walk Transit - Pseudo area type constant	-45*c_ivt	-45
PNR and KNR Transit - Pseudo area type constant	-60*c_ivt	-60
PNR – Premium – PNR_EXP/PNR_CR	-60*c_ivt	-60
PNR – Premium – PNR_BRT / PNR_LR	-30*c_ivt	-30
ASC Adjustment - Toll	20*c_ivt	20
0 Autos – Individual – Shared 3	1.41	-82.941
0 Autos – Individual – Walk	0.24	-14.118
0 Autos – Individual – Bike	-0.56	32.941
0 Autos – Individual – Walk_transit	0.53	-31.176
0 Autos – Individual – PNR_transit	-999.00	58764.706
0 Autos – Individual – KNR_transit	3.40	-200.000
Auto insufficient - individual – Shared 2	0.39	-22.941
Auto insufficient - individual – Shared 3	1.65	-97.059
Auto insufficient - individual – Walk	2.15	-126.471
Auto insufficient - individual – Bike	1.38	-81.176
Auto insufficient - individual – Walk_transit	1.97	-115.882
Auto insufficient - individual – PNR_transit	5.38	-316.471
Auto insufficient - individual – KNR_transit	3.30	-194.118
Auto sufficient - individual – Shared 2	0.72	-42.353
Auto sufficient - individual – Shared 3	2.81	-165.294
Auto sufficient - individual – Walk	1.14	-67.059
Auto sufficient - individual – Bike	1.49	-87.647

Coefficient Name	Value	Equivalent Value in IVT
Auto sufficient - individual – Walk_transit	0.36	-21.176
Auto sufficient - individual – PNR_transit	0.80	-47.059
Auto sufficient - individual – KNR_transit	2.79	-164.118
0 Autos – Joint – Shared 3	-0.23	13.529
0 Autos – Joint – Walk	-0.73	42.941
0 Autos – Joint – Bike	-999.00	58764.706
0 Autos – Joint – Walk_transit	-0.61	35.882
0 Autos – Joint – PNR_transit	-999.00	58764.706
0 Autos – Joint – KNR_transit	0.00	0.000
Auto insufficient - Joint – Shared 3	-17.42	1024.706
Auto insufficient - Joint – Walk	-18.64	1096.471
Auto insufficient - Joint – Bike	-999.00	58764.706
Auto insufficient - Joint – Walk_transit	-16.31	959.412
Auto insufficient - Joint – PNR_transit	-9.02	530.588
Auto insufficient - Joint – KNR_transit	-16.42	965.882
Auto sufficient - Joint – Shared 3	0.66	-38.824
Auto sufficient - Joint – Walk	-2.09	122.941
Auto sufficient - Joint – Bike	-1.03	60.588
Auto sufficient - Joint – Walk_transit	-3.58	210.588
Auto sufficient - Joint – PNR_transit	0.30	-17.647
Auto sufficient - Joint – KNR_transit	-2.44	143.529
Pro-bike district constant (District27==8)+(District27==9)	1.5524	-91.318

Discretionary Tour Mode Choice Model Estimation

There were 5,881 observations used for estimation of the Discretionary tour mode choice model.

The discretionary tour purpose included tours for eating out, visiting, and other discretionary purposes. This model also contains joint tours, and a set of joint tour constants were estimated, similar to the approach taken for the maintenance purpose.

Model Estimation Findings:

- In the initial model runs, the cost coefficients were split into income classes. However, the coefficients were unreasonably large. Fixing the cost coefficients to smaller values based on the wage rate of San Diego in the calibration year resulted in a more reasonable value of time. The cost coefficients were set to 35% of the average hourly wage rate by income group.

- Transit access walk and drive time were both estimated. Across the estimations, the results were negative and significant.
- Total wait time was asserted at 1.5 times the in-vehicle time, due to estimation problems encountered with wait time described above.
- The estimated coefficient for number of transfers moved from negative and significant to positive and insignificant across model estimations. It was fixed to 0 for later model runs.
- The origin MGRA land-use mix variable was interacted with non-motorized and walk-transit modes. Walk to transit had a negative coefficient, which is the opposite of the desired effect, therefore it was dropped. Walking and biking had a positive and significant coefficient so they were maintained.
- The density variables for intersection density at the origin end for walk/bike was estimated and was a very small but positive and significant coefficient.
- The employment density for the walk/bike and transit modes was estimated. It was not significant in either case and had the wrong sign for transit, so it was dropped.
- Walk and bike mode time were both negative and significant.
- Alternative specific constants were estimated for all the available modes.
- The auto sufficiency stratification on the ASCs for 0 auto households was maintained for walk and walk-transit. Both of these coefficients were positive and significant. Auto sufficient households had negative and significant coefficients on the transit modes. This shows a preference for an auto mode for Discretionary tours when an auto is available.
- The ASCs were stratified for household sizes 2, 3, and 4+ for the shared-ride modes. Shared-ride 2 was positive and significant for all household sizes, showing that people are traveling together for Discretionary purposes. Shared-ride 3+ was negative for household size 2 and for household size 3. This makes sense because two person households are not likely to take many trips with more than 2 people, and in the 3 person households not all household members are traveling together on these tours. For the largest household size, both shared-ride 2 and shared-ride 3+ were positive. In these larger households, more children likely accompany parents on trips.
- The ASCs were also stratified by gender. Females had a positive and significant coefficient on shared-ride 2. Shared-ride 3+ was not significant but was positive. A constant for females was also tested for transit, and it was negative and significant. This result shows that women are more likely to take discretionary tours with someone else in the car, and are less inclined to use transit for discretionary tours, possibly due to child-care responsibilities.
- The ASCs were also stratified by age. For the youngest age category (16 to 24), the shared-ride and non-motorized modes could not be estimated with significant or correctly signed results, therefore those constants were dropped. Constants were estimated for escorting tours; shared-ride 3+ was not significant and was dropped. Non-motorized and transit were negative and significant, which indicates that people are more likely to use auto modes for escort tours.

- Constants were estimated on non-motorized and transit modes for joint tours. The coefficients were negative and significant for all runs. This shows a preference for auto modes for joint tours, all else being equal.

Table 54: Discretionary Tour

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone		
	Shared-Ride 2	-0.58 (-2.43)	38.69
	Shared-3+	-1.59 (-4.17)	106.33
	Walk	1.47 (4.71)	-98.26
	Bike	-1.3 (-2.84)	86.81
	Transit	1.07 (4.85)	-71.09
	Express Bus	-1.55 (-13.22)	103.56
	LRT	0.31 (6.11)	-20.91
	Commuter Rail	-0.43 (-1.31)	28.82
	Transit Drive	-5.54 (-15.81)	369.21
	Drive-Express	-0.58 (-0.9)	38.87
	Drive-LRT	1.45 (5.36)	-96.91
	Drive-Commuter Rail	2.47 (5.59)	-164.52
	Transit KNR	1.25 (3.59)	-83.44
	KNR-Express	1.18 (1.65)	-78.71
	KNR-LRT	1 (4.83)	-66.37
	KNR-Commuter Rail	0.93 (1.75)	-61.78
	HOV	-2.97 (-6.19)	198.08
In-vehicle time		-0.015 (constr)	1
Cost - Low (<30k)		-0.004 (0)	0.27
Cost - Medium-Low (30-60k)		-0.002 (0)	0.13
Cost - Medium-High (60-100k)		-0.001 (0)	0.07
Cost - Very High (100k+)		-0.0004 (0)	0.03
Cost - Unknown		-0.006 (-9.05)	0.39
Transit Access Time	Walk	-0.038 (-8.81)	2.52
	Drive	-0.017 (-2.26)	1.12
Total Wait Time		-0.023 (constr)	1.53
Number of Transfers		0 (constr)	
Mix Variables - Origin MGRA	Walk	0.17 (5.29)	-11.45

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
	Bike	0.14 (2.12)	-9.02
Intersection Density	Walk/Bike	0.006 (2.98)	-0.38
Walk Mode Time	Walk	-0.053 (-11.93)	3.52
Bike Mode Time	Bike	-0.099 (-4.98)	6.59
Auto Sufficiency, Autos = 0	Walk	1.82 (4.59)	-121.35
	Walk-Transit	2.03 (8.43)	-135.17
Auto Sufficiency, Autos >=HH Size	Walk-Transit	-1.82 (-12.8)	121.38
	PNR-Transit	-1.28 (-3.86)	85.32
	KNR-Transit	-2.2 (-9.25)	146.90
Auto Sufficiency Unknown	Walk-Transit	1.88 (8.86)	-125.25
	PNR-Transit	1.28 (3.48)	-85.51
Household Size 2	Shared-Ride 2	0.35 (1.8)	-23.29
	Shared-Ride 3+	-0.93 (-2.72)	62.32
Household Size 3	Shared-Ride 2	0.41 (1.74)	-27.11
	Shared-Ride 3+	-0.8 (-1.92)	53.64
Household Size 4+	Shared-Ride 2	0.76 (3.47)	-50.46
	Shared-Ride 3+	0.57 (1.62)	-38.22
Female	Shared-Ride 2	0.26 (2.04)	-17.50
	Shared-Ride 3+	0.27 (1.36)	-18.32
	Transit	-0.23 (-1.83)	15.50
Gender Unknown	Transit	3.91 (4.1)	-260.98
Age 16 to 24	Shared-Ride 2	-0.51 (-1.91)	34.30
	Shared-Ride 3+	-1.31 (-2.77)	87.45
	Non-Motorized	-0.56 (-1.26)	37.62
	Transit	1.06 (4.35)	-70.56
Age 41 to 55	Shared-Ride 2	-1.04 (-5)	69.51
	Shared-Ride 3+	-1.21 (-3.92)	80.52
	Non-Motorized	-1.15 (-3.69)	76.80
	Transit	-0.49 (-2.47)	32.75
Age 56 to 64	Shared-Ride 2	-0.84 (-3.54)	56.16
	Shared-Ride 3+	-0.97 (-2.47)	64.57
	Non-Motorized	-0.97 (-2.93)	64.99
	Transit	-1.09 (-4.81)	72.41

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Age 65+	Shared-Ride 2	-0.9 (-4.39)	59.68
	Shared-Ride 3+	-1.13 (-3.34)	75.18
	Non-Motorized	-1.68 (-5.99)	112.32
	Transit	-2.49 (-12.24)	166.05
Age Unknown	Non-Motorized	-1.54 (-2.42)	102.62
Joint Tours	Non-Motorized	-1.9 (-8.8)	126.99
	Transit	-2.95 (-19.3)	196.77
Initial likelihood	-14952		
Final likelihood	-4542		

Final Model:

- The in-vehicle time was estimated in the first couple of model runs, and then asserted to -.015, which is what was estimated in the second to last model run. That value is fairly close to the in-vehicle time used in the other models.
- In the estimation runs, the value of time estimate was coming out unreasonably low due to the cost estimates being too large. Fixing the cost coefficients to smaller values based on the wage rate of San Diego in the calibration year resulted in a more reasonable value of time. The cost coefficients were set to 35% of the average hourly wage rate by income group.
- Density variables have an effect on discretionary tours. The mix du/emp density variable for walk and bike modes at the origin MGRA was significant and positive, as well as intersection density at the origin MGRA for walk/bike. This shows that if there are more households and employment at a trip origin makes it more likely that a person will choose to walk or bike for their discretionary tour.
- Zero auto households had positive and significant coefficients on the walk-transit modes. Auto sufficient households had negative and significant constants on transit modes.
- Larger households are more likely to use the shared-ride modes for their maintenance tours than smaller households, all else being equal.
- Women are more likely to use shared-ride modes over drive-alone then men are, implying that they are likely to take a child on a maintenance tour with them. They are less likely than men to take transit for discretionary tours, all else being equal.
- The only age group that has a preference for any mode tested is the youngest group (16 to 24) which has a positive and significant coefficient on the transit mode. All other age groups were less likely to share a ride, take non-motorized, or transit for their maintenance tours, all else being equal.
- People are less likely to take non-motorized or transit modes for joint tours, all else being equal.
- Value of time calculations are similar to the results for the maintenance tours:
    - $2.25 Low Income
    - $4.50 Medium-Low

- $9.00 Medium-High
- $22.50 Very High
- $1.53 Income Unknown

Table 55: Implemented Discretionary Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
In-vehicle time coefficient	-0.0150	1
First wait time coefficient	-0.0230	1.533333
Transfer wait time coefficient	-0.0230	1.533333
Walk access time coefficient	-0.0317	2.113
Walk egress time coefficient	-0.0317	2.113
Walk auxiliary time coefficient	-0.0317	2.113
Drive access time coefficient	-0.0166	1.104819
Transfer penalty	c_ivt*5	5
Transfer penalty - PNR	c_ivt*15	15
Express bus IVT factor	0.9000	-60.0
BRT IVT factor	0.9000	-60.0
LRT IVT factor	0.8500	-56.667
Commuter rail IVT factor	0.7500	-50.0
Bike mode time coefficient	-0.0988	6.589789
Cost coefficient for income < $30k	-0.0037	0.246667
Cost coefficient for income $30k-$60k	-0.0017	0.113333
Cost coefficient for income $60k - $100k	-0.0010	0.066667
Cost coefficient for income > $100k	-0.0004	0.026667
Origin MGRA du/emp mix coefficient, applied to walk, bike	0.17243	-11.4956
Origin MGRA intersection density coefficient, applied to walk, bike	0.00571	-0.38074
Age 16 to 24, shared-ride 2	-0.51961	34.64075
Age 16 to 24, shared-ride 3+	-1.31632	87.75462
Age 16 to 24, non-motorized	-0.55570	37.0465
Age 16 to 24, transit	1.06375	-70.9166
Age 41 to 55, shared-ride 2	-1.04157	69.43787
Age 41 to 55, shared-ride 3+	-1.21044	80.69626

Coefficient Name	Value	Equivalent Value in IVT
Age 41 to 55, non-motorized	-1.14969	76.64589
Age 41 to 55, transit	-0.48434	32.28937
Age 56 to 64, shared-ride 2	-0.84295	56.19666
Age 56 to 64, shared-ride 3+	-0.96503	64.33566
Age 56 to 64, non-motorized	-0.97814	65.20958
Age 56 to 64, transit	-1.08450	72.30029
Age 65 plus, shared-ride 2	-0.89435	59.62302
Age 65 plus, shared-ride 3+	-1.11463	74.30883
Age 65 plus, non-motorized	-1.69155	112.7698
Age 65 plus, transit	-2.49829	166.5525
Female, shared-ride 2	0.26199	-17.4659
Female, shared-ride 3+	0.27357	-18.2381
Female, transit	-0.23309	15.53908
Household size 2, shared-ride 2	0.35297	-23.5315
Household size 2, shared-ride 3+	-0.93658	62.43866
Household size 3, shared-ride 2	0.41267	-27.511
Household size 3, shared-ride 3+	-0.79896	53.26398
Household size 4+, shared-ride 2	0.76116	-50.7438
Household size 4+, shared-ride 3+	0.57813	-38.542
Destination MGRA is active beach or park, applied to bike	0.70000	-46.667
Age 41 to 55, bike	-0.77985	51.990
Age 56 to 64, bike	-0.68642	45.761
Age 65 plus, bike	-1.65192	110.128
Female, bike	-1.27322	84.881
Income 100k plus, bike	0.68414	-45.609
Normalized Landuse Variable Sum [Origin Employment + DU]	0.08882	-5.921
Bike logsum coefficient inbound	0.22000	-14.667
Bike logsum coefficient outbound	0.22000	-14.667
Miles to coast from origin MGRA	-1.51486	100.991

Coefficient Name	Value	Equivalent Value in IVT
Miles greater than 2 to coast from origin MGRA	1.42408	-94.939
Miles greater than 5 to coast from origin MGRA	0.08487	-5.658
Age under 16, walk	2.24743	-149.829
Age 16 to 24, walk	1.41776	-94.517
Age 41 to 55, walk	-0.50719	33.813
Age 56 to 64, walk	-0.60023	40.015
Age 65 plus, walk	-0.92046	61.364
Income 60k to 100k, walk	-0.23748	15.832
Normalized Landuse Variable Sum [Origin Intersection + DU]	0.46773	-31.182
Normalized Destination Employment	0.12778	-8.519
Walk Time Coefficient	-0.04530	3.020
ASC - Shared-Ride 2	-0.5420	36.13007
ASC - Shared-3+	-1.6090	107.2671
ASC –Transit	0.9922	-66.149
ASC - Express Bus	0.1500	-10.000
ASC – BRT	0.6000	-40.000
ASC – LRT	1.3500	-90.000
ASC - Commuter Rail	0.6000	-40.000
ASC - TransitDrive	-5.1561	343.7396
ASC - Transit KNR	0.8448	-56.3213
ASC - 0 Autos –Walk	-0.3082	20.547
ASC - 0 Autos - Bike	-2.1604	144.027
ASC - 0 Autos - Walk-Transit	2.0452	-136.348
ASC - Auto Sufficient - Walk	-0.2932	19.547
ASC - Auto Sufficient - Bike	-0.2690	17.933
ASC - Auto Sufficient - Walk-Transit	-1.8338	122.2561
ASC - Auto Sufficient - PNR-Transit	-1.2926	86.17664
ASC - Auto Sufficient - KNR-Transit	-2.2193	147.9532

Coefficient Name	Value	Equivalent Value in IVT
ASC - Joint - Non-motorized	-1.9129	127.5277
ASC - Joint Transit	-2.9605	197.3671
Shared Ride 2 Unavailable for 0 Autos	-15.0000	1000.0
Shared Ride 3+ Unavailable for 0 Autos	-15.0000	1000.0
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
Walk Transit - Pseudo area type constant	-60*c_ivt	-60
PNR and KNR Transit - Pseudo area type constant	-60*c_ivt	-60
PNR – Premium – PNR_EXP / PNR_CR	-60*c_ivt	-60
PNR – Premium – PNR_BRT / PNR_LR	-30*c_ivt	-30
ASC Adjustment - Toll	20*c_ivt	20
0 Autos – Individual – Shared 3	1.428	-95.200
0 Autos – Individual – Walk	1.635	-109.000
0 Autos – Individual – Bike	4.733	-315.533
0 Autos – Individual – Walk_transit	-0.782	52.133
0 Autos – Individual – PNR_transit	-999.000	66600.000
0 Autos – Individual – KNR_transit	2.470	-164.667
Auto insufficient - individual – Shared 2	-0.179	11.933
Auto insufficient - individual – Shared 3	0.549	-36.600
Auto insufficient - individual – Walk	1.319	-87.933
Auto insufficient - individual – Bike	1.972	-131.467
Auto insufficient - individual – Walk_transit	-0.809	53.933
Auto insufficient - individual – PNR_transit	0.913	-60.867
Auto insufficient - individual – KNR_transit	0.271	-18.067
Auto sufficient - individual – Shared 2	-0.142	9.467
Auto sufficient - individual – Shared 3	1.327	-88.467
Auto sufficient - individual – Walk	0.037	-2.467

Coefficient Name	Value	Equivalent Value in IVT
Auto sufficient - individual – Bike	1.591	-106.067
Auto sufficient - individual – Walk_transit	-1.185	79.000
Auto sufficient - individual – PNR_transit	1.430	-95.333
Auto sufficient - individual – KNR_transit	0.804	-53.600
0 Autos – Joint – Shared 3	0.000	0.000
0 Autos – Joint – Walk	1.466	-97.733
0 Autos – Joint – Bike	-999.000	66600.000
0 Autos – Joint – Walk_transit	-7.376	491.733
0 Autos – Joint – PNR_transit	-999.000	66600.000
0 Autos – Joint – KNR_transit	-13.864	924.267
Auto insufficient - Joint – Shared 3	0.114	-7.600
Auto insufficient - Joint – Walk	-1.252	83.467
Auto insufficient - Joint – Bike	-999.000	66600.000
Auto insufficient - Joint – Walk_transit	-1.521	101.400
Auto insufficient - Joint – PNR_transit	-0.052	3.467
Auto insufficient - Joint – KNR_transit	-1.630	108.667
Auto sufficient - Joint – Shared 3	1.775	-118.333
Auto sufficient - Joint – Walk	0.688	-45.867
Auto sufficient - Joint – Bike	0.658	-43.867
Auto sufficient - Joint – Walk_transit	-0.258	17.200
Auto sufficient - Joint – PNR_transit	0.948	-63.200
Auto sufficient - Joint – KNR_transit	-4.984	332.267
Pro-bike district constant (District27==8)+(District27==9)	1.5524	-103.493

At-Work Sub-tour Model Estimation

There were 436 observations used for estimation of the At-Work Sub-tour mode choice model.

An important predictor for the mode of the at-work sub-tour is the mode taken to work. For example, if a person drives alone to work, they have a car available at work for their tours. If a person rides a bike to work, it is unlikely that they will be able to drive for their at-work subtours. Variables were tested for mode to work to determine the effect on the at-work sub-tour mode.

Model Estimation Findings:

- The cost coefficient was tested as a single variable, as well as stratified by income groups. The income stratification did not yield reasonable results.
- In addition to a cost variable, a fare variable was also tested for the transit modes, but did not yield reasonable results so it was dropped.
- Transit access walk time was not significant in determining mode choice for at-work sub-tour mode choice.
- Drive to transit modes were disallowed for this tour purpose due to lack of observations; it is unlikely that persons would choose drive-transit for an at-work sub-tour given time constraints and the relatively short distance for most at-work sub-tour destinations.
- The total wait time was constrained to 1.5 times the IVT, as with the other purposes, due to estimation problems.
- Number of transfers was constrained to 0, due to unreasonable results.
- Mix density variables were tested for walk and walk to transit at the origin end of the trip. These did not yield significant effects.
- The mode time for walk, bike, and a combined non-motorized category were tested. The walk mode time was significant, but the bike mode time was just short of being significant, so they were combined into one coefficient which was negative and significant.
- ASCs were estimated for shared-ride 2, shared-ride 3+, walk, bike, and transit. The ASCs were negative for shared-ride and biking, but positive for walking and transit, indicating a preference for not using an auto for an at-work sub-tour, all else being equal. This may be due to parking constraints at work.
- The ASCs were stratified by age. The only mode with significance was transit, for the age groups 41 to 55 and 56 to 64. The negative sign shows that people in those age ranges are more likely to use an auto or non-motorized mode for their at-work sub-tours, compared to other age ranges.
- Constants were introduced which interact the mode to work (drive-alone, shared-ride, non-motorized, and transit) with the mode of the at-work sub-tour. Initially, a full set of constants was attempted where drive-alone was chosen as the base. Due to estimation problems, the constant terms were combined into the following:
  - Drive-alone to work interacted with drive-alone for sub-tour, which was insignificant.
  - Shared-ride to work interacted with drive-alone for sub-tour, which was negative and significant, indicating that it is unlikely that a person would have an auto available at work to enable them to drive-alone for the at-work sub-tour if they shared a ride to work.

- Shared-ride to work interacted with shared-ride for sub-tour, which was positive and significant, possibly indicating that ride-sharing to work is often made by household members who also have lunch together.
- Non-motorized/transit to work interacted with shared-ride to sub-tour, which was insignificant.

Table 56: At-Work Subtour

Variable	Mode	Coefficient & T-Stat by Choice Alternative (T-Stat)	Ratio to IVT
Constant	Drive-Alone		
	Shared-Ride 2	-0.875 (-5.71)	27.34
	Shared-3+	-2.811 (-10.52)	87.84
	Walk	-1.799 (-4.87)	56.22
	Bike	-3.032(-3.99)	94.75
	Transit	-2.847 (10.87)	88.97
In-vehicle time		-0.032 (constr)	1.00
Cost		-0.002 (constr)	0.06
Total Wait Time		-0.048 (constr)	1.50
Number of Transfers		0 (constr)	0.00
Mix Variables - Origin MGRA	Walk	0.214 (3.50)	-6.69
Non-Motorized Mode Time	Walk/Bike	-0.074 (-6.93)	2.31
Age 41 to 55	Transit	-1.166 (-2.81)	36.44
Age 56 to 64	Transit	-1.263 (-2.01)	39.47
Mode to Work Shared-Ride, DA for subtour	DA	-0.824 (-1.63)	25.75
Mode to Work Shared-Ride, SR for subtour	SR	2.435 (6.26)	-76.09
Initial likelihood	-1013.9494		
Final likelihood	-449.9865		

Final Model

- Unlike the other mode choice models, this model did not have much effect from socio-economic variables.
- In-vehicle time did not estimate at a reasonable value, so it was asserted at -0.032, or twice the in-vehicle time parameter for work tours. This was done to ensure a relatively higher value-of-time for at-work sub-tours, whose time is typically highly constrained due to the limited time windows available for this purpose. As with other models, the cost coefficient value was estimating too high. Therefore just one coefficient was asserted for cost, and it was based on the average wage rate in the San Diego area in 2007 ($9.21/hour).

- The estimation was able to pick up the effect of being in a high density area (like downtown) by including the mix density coefficients for the walk modes.

Table 57: Implemented At-Work Subtour Mode Choice Coefficients

Coefficient Name	Value	Equivalent Value in IVT
In-vehicle time coefficient	-0.0320	1
Total wait time coefficient	-0.0480	1.5
First wait time coefficient	-0.0480	1.5
Transfer wait time coefficient	-0.0480	1.5
Walk access time coefficient	-0.0533	1.666
Walk egress time coefficient	-0.0533	1.666
Walk auxiliary time coefficient	-0.0533	1.666
Drive access time coefficient	-0.0640	2.0
Transfer penalty	c_ivt*5	5
Transfer penalty - PNR	c_ivt*15	15
Express bus IVT factor	0.9000	-28.125
BRT IVT factor	0.9000	-28.125
LRT IVT factor	0.8500	-26.5625
Commuter rail IVT factor	0.7500	-23.4375
Walk and bike mode time coefficient	-0.0617	1.928
Walk mode time coefficient	-0.08494	2.654
Bike mode time coefficient	-0.0740	2. 3125
Cost coefficient	-0.0020	0.0625
Age 41 to 55, transit	-1.16600	36.43
Age 56 to 64, transit	-1.2630	39.4688
Origin MGRA du/emp mix coefficient, for walk and bike	0.21400	-6.6875
Shared Ride Mode to Work, DA for at work subtour	-0.82400	25.75
Shared Ride Mode to Work, SR for at work subtour	2.43500	-76.0938
Bike logsum coefficient inbound	0.23000	-7.188
Bike logsum coefficient outbound	0.23000	-7.188
ASC - Shared-Ride 2	-0.8750	27.3438
ASC - Shared-3+	-2.8110	87.8438
ASC - Walk	-1.7990	56.2188
ASC -Bike	-3.0320	94.7500

Coefficient Name	Value	Equivalent Value in IVT
ASC - Transit	-2.8470	88.9688
ASC - HOV	0.0000	0
ASC - Toll	0.0000	0
ASC - Express Bus	0.3200	-10.0
ASC - BRT	0.6400	-20.0
ASC - LRT	0.9600	-30.000
ASC - Commuter Rail	1.2800	-40.000
ASC - Transit Drive	-999	31218.750
ASC - Drive-Express	-999	31218.750
ASC - Drive-BRT	-999	31218.750
ASC - Drive-LRT	-999	31218.750
ASC - Drive-Commuter Rail	-999	31218.750
ASC - Transit KNR	-999	31218.750
ASC - KNR-Express	-999	31218.750
ASC - KNR-BRT	-999	31218.750
ASC - KNR-LRT	-999	31218.750
ASC - KNR-Commuter Rail	-999	31218.750
Shared Ride 2 Unavailable for 0 Autos	-30.0	937.500
Shared Ride 3+ Unavailable for 0 Autos	-30.0	937.500
PNR Transit - Distance Parameter at 5 minutes disutility per mile <10 miles	c_ivt*5*max((10-GP_DIST[outPeriod]),0)	5
KNR Transit - Distance Parameter at 3 minutes disutility per mile <10 miles	c_ivt*3*max((10-GP_DIST[outPeriod]),0)	3
PNR and KNR Transit - Pseudo area type constant	-60*c_ivt	-60
PNR – Premium – PNR_CR	-60*c_ivt	-60
PNR – Premium – PNR_EXP	-30*c_ivt	-30
ASC Adjustment - Toll	20*c_ivt	20
0 Autos - Walk	0.6083	-19.009
0 Autos - Bike	-27.0270	844.594
0 Autos - Walk_transit	-5.7026	178.206
Auto insufficient - Shared Ride 2	0.1185	-3.703

Coefficient Name	Value	Equivalent Value in IVT
Auto insufficient - Shared Ride 3+	1.8298	-57.181
Auto insufficient - Walk	2.0879	-65.247
Auto insufficient - Bike	-10.0657	314.553
Auto insufficient – Walk_transit	2.7312	-85.350
Auto sufficient - Shared Ride 2	-0.4100	12.813
Auto sufficient - Shared Ride 3	1.1512	-35.975
Auto sufficient - Walk	2.5916	-80.988
Auto sufficient - Bike	-2.0387	63.709
Auto sufficient – Walk_transit	-0.5617	17.553
Pro-bike district constant (District27==8)+(District27==9)	1.5524	-48.513

Consistently across the purposes, there were some parameters that could not be estimated and had to be asserted in the implemented model. These include the cost coefficients by income classes, wait time, transit line-haul constants, and the number of transfers. Most of these are related to transit use. Since only about 25% of the transit on-board survey was usable for this estimation, there were not very many transit observations to work with. It is possible that with more transit observations, more of these parameters could have been estimated.

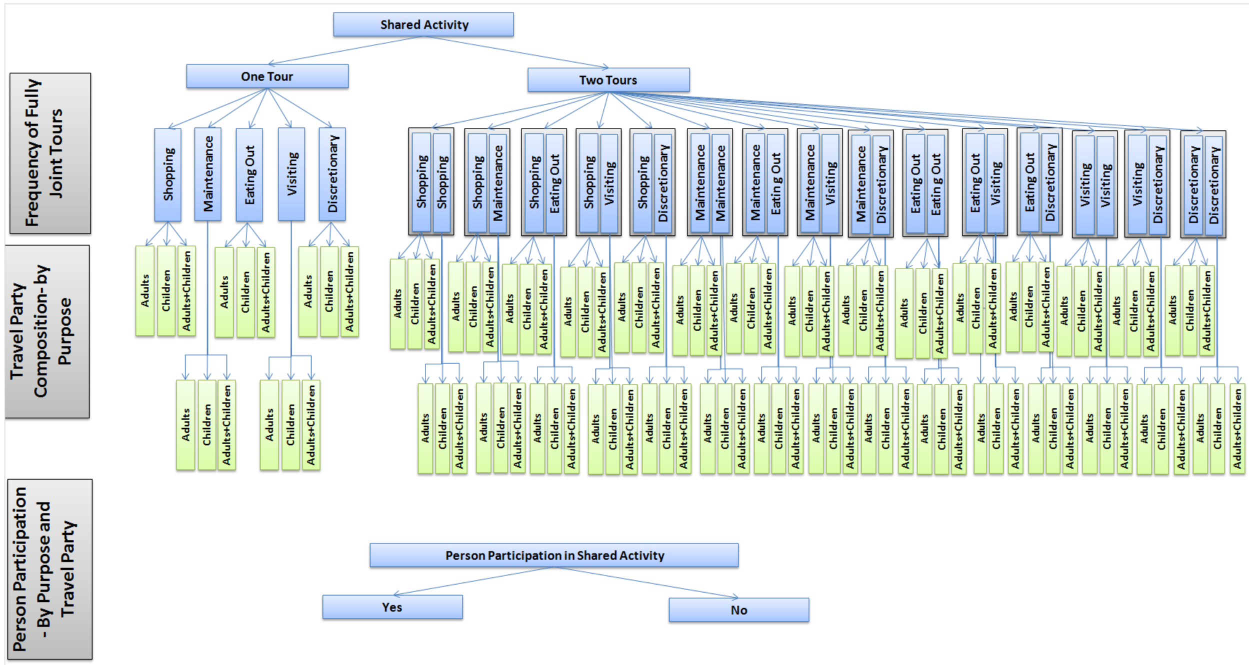
4.3 Joint Non-Mandatory Tour Modeling

In the CT-RAMP structure, joint travel for non-mandatory activities is modeled explicitly in the form of fully joint tours (where all members of the travel party travel together from the beginning to the end and participate in the same activities). This accounts for more than 50% of joint travel.

Each fully joint tour is considered a modeling unit with a group-wise decision-making process for the primary destination, mode, frequency and location of stops. Modeling joint activities involves two linked stages – see Figure 29.

- A tour generation and composition stage that generates the number of joint tours by purpose/activity type made by the entire household. This is the joint tour frequency model.
- A tour participation stage at which the decision whether to participate or not in each joint tour is made for each household member and tour.

Figure 29: Model Structure for Joint Non-Mandatory Tours



Joint tour party composition is modeled for each tour. Travel party composition is defined in terms of person categories (e.g., adults and children) participating in each tour. Person participation choice is then modeled for each person sequentially. In this approach, a binary choice model is calibrated for each activity, party composition and person type. The model iterates through household members, and applies a binary choice to each to determine if the member participates. The model is constrained to only consider members with available time-windows overlapping with the generated joint tour. The approach offers simplicity, but at the cost of overlooking potential non-independent participation probabilities across household members. The joint tour frequency, composition, and participation models are described below.

4.3.1 Joint Tour Frequency and Composition

A joint tour is a tour that involves two or more people traveling together. The joint tour travel model predicts the number of joint tours by tour purpose for the entire household. The model also predicts party composition and person participation for each joint tour. The decision to make a joint tour is included at the household level in the SANDAG Coordinated Daily Activity Pattern (CDAP) model. Only the households which have a joint tour as predicted by CDAP are considered in the joint travel model. The first model predicts tour frequency and travel party composition and was estimated as a joint logit model. The second model is the person participation model, which is a binary choice multinomial logit model. Both models were estimated using the ALOGIT software. This model is applied after mandatory activity models and before the individual non-mandatory activity models. It includes tour purpose, person characteristics, household characteristics, available window overlaps, and accessibility as explanatory variables.

Estimation Dataset

In the SANDAG 2006 household travel behavior survey, there are 833 fully joint tours (for non-mandatory tour purposes) observed for 718 households. The dataset for tour frequency and party composition is prepared at the entire household level with 718 records. It only includes households with more than 1 member and households which chose joint travel pattern in the coordinate daily activity pattern (CDAP) model.

The joint travel model includes five travel purposes: shopping, maintenance, eating out, visiting and an “other discretionary” travel purpose that may include recreation and entertainment. The model also includes three party composition types: adults only, children only, and adults with children. Table 58 and Table 59 show tour frequency by purpose and party composition.

Table 58: Observed Joint Tours by Purpose, Frequency and Party Composition

Purpose Name	Party Composition Type: Adults Only	Children Only	Adults with Children	Total
One tour				
Shopping	99	0	53	152
Maintenance	102	1	55	158
Eating Out	58	0	24	82
Visiting	29	4	20	53
Discretionary	82	3	73	158
Two tours				
Shopping/Shopping	6	0	12	18
Shopping/Maintenance	22	1	29	52
Shopping/Eating Out	9	1	2	12
Shopping/Visiting	9	1	4	14
Shopping/Discretionary	16	0	16	32
Maintenance/Maintenance	4	0	6	10
Maintenance/Eating Out	12	0	2	14
Maintenance/Visiting	9	0	5	14
Maintenance/Discretionary	12	0	16	28
Eating Out/Eating Out	6	0	0	6
Eating Out/Visiting	0	0	0	0
Eating Out/Discretionary	6	0	4	10
Visiting/Visiting	0	0	0	0
Visiting/Discretionary	3	0	5	8
Discretionary/Discretionary	4	1	7	12
Totals	**488**	**12**	**333**	**833**

In the survey sample, 72% of households took one join tour in a day while 28% of households took two joint tours in a day. The frequency of joint shopping and maintenance tours is the highest, followed by joint shopping and discretionary tours. The number of eating out and visiting joint tours are comparatively smaller.

Most of the joint tour parties either include only adults or adults with children. The number of joint tours with only children is very small in the SANDAG dataset. Children joint tours are mostly for visiting and discretionary activities. Among all purposes, only adults are likely to have eating out joint tours.

Table 59: Observed Person Participations by Purpose and Party Composition

Purpose Name	Adults		Children		Adults with Children		Total
Shopping	131	58.2%	1	0.4%	93	41.3%	225
Maintenance	135	60.8%	2	0.9%	85	38.3%	222
Eating Out	79	74.5%	0	0.0%	27	25.5%	106
Visiting	39	54.9%	5	7.0%	27	38.0%	71
Discretionary	104	49.8%	4	1.9%	101	48.3%	209
Total	**488**	**58.6%**	**12**	**1.4%**	**333**	**40.0%**	**833**

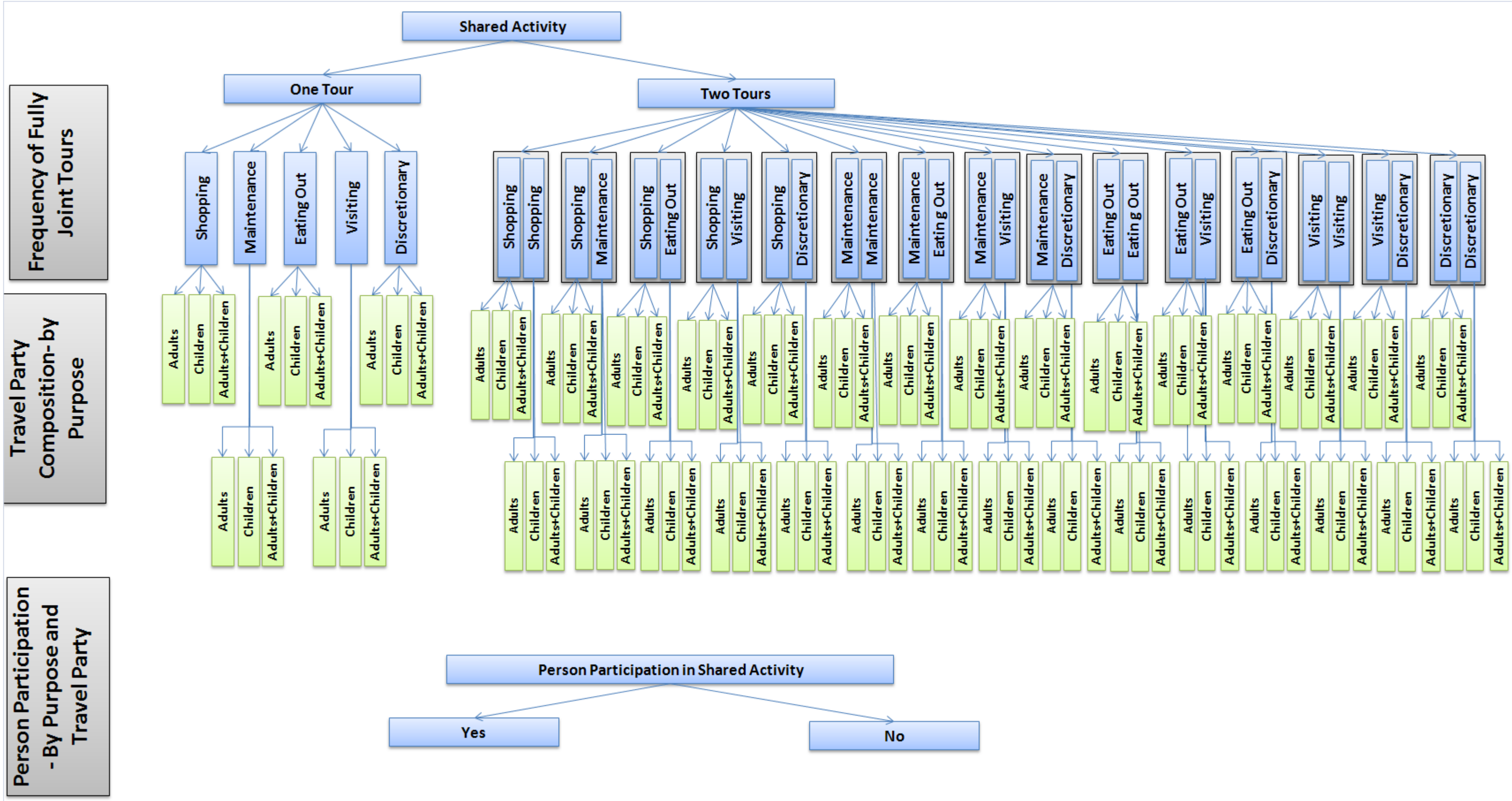
Model Structure

In the proposed model structure, choice alternatives combine five purposes and possible total frequencies (one tour, two tours) with three party compositions for each tour as shown in Figure 1. Following is a set of 20 tour purpose and frequency alternatives considered:

- One tour alternatives
    - Shopping
    - Maintenance
    - Eating Out
    - Visiting
    - Discretionary
- Two tours alternatives
    - Shopping/Shopping
    - Shopping/Maintenance
    - Shopping/Eating Out
    - Shopping/Visiting
    - Shopping/Discretionary
    - Maintenance/Maintenance
    - Maintenance/Eating Out
    - Maintenance/Visiting
    - Maintenance/Discretionary
    - Eating Out/Eating Out
    - Eating Out/Visiting
    - Eating Out/Discretionary
    - Visiting/Visiting
    - Visiting/Discretionary
    - Discretionary/Discretionary

For one tour alternative, there are 3 possible party compositions, which lead to 5 x 3 = 15 alternatives. For two tours alternatives, there are 3 party compositions for each of two tours which lead to 15 x 3 x 3 = 135 alternatives. Total number of alternatives = 15 + 135 = 150

Figure 30: Model Structure for Joint Tour Frequency, Party Composition and Person Participation



Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Household composition:
    - Number of Full-Time Workers
    - Number of Part-Time Workers
    - Number of University Students
    - Number of Non-Working Adults
    - Number of Retirees
    - Number of Driving Age School Children
    - Number of Pre-driving Age School Children
    - Number of Pre-school Children
- Household size
- Accessibility by purpose and car sufficiency: HOV Logsum (accessibility terms 10-24)
- Household income group:
    - Low income (less than $30,000)
- Medium low income ($30,000-$60,000)
- Medium income ($60,000-100,000)
- High income ($100,000 and more)
- Car ownership
    - No cars
- Cars fewer than workers
- Cars equal to workers
- Cars more than workers
- Feasibility of sharing non-mandatory activity after the mandatory activity scheduling
    - Maximum pair-wise overlap of available continuous time window for adults in hours
    - Maximum pair-wise overlap of available continuous time window for children in hours
    - Maximum pair-wise overlap of available continuous time window for adult and child in hours

Available time window is defined in number of continuous hours available to make a joint tour after accounting for mandatory activities hours during the active daily time window for the individual (excluding late night/early morning hours for sleep and other at home activities). Adults and children can have slightly different active daily time window.

Results

Table 60 and 61 show the estimated coefficients for the final adopted model.

Table 60: SANDAG Joint Tour Frequency and Travel Party Composition Model – Purpose and Frequency Component

	Shopping		Maintenance		Eating Out		Visiting		Discretionary	
Variables	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constants										
Purpose Specific Constant	0.000		-1.477	-0.6	0.580	1.6	-1.004	-4.5	-1.120	-0.4
Adjustment Constant by Purpose	0.000		0.109		0.068		0.134		0.234	
Adjustment for share of 2 Joint Tours	-1.171		-1.171		-1.171		-1.171			
Two Tours Additional Combination Constants										
1 Shopping and	-13.709	-2.0	-12.137	-3.5	-12.799	-3.7	-12.221	-3.5	-12.579	-3.6
1 Maintenance and			-13.436	-10.7	-12.189	-9.9	-11.813	-9.6	-12.289	-10.3
1 Eating Out and					-13.154	-10.0	-13.154	-10.0	-12.561	-10.1
1 Visiting and							-13.154	-10.0	-12.372	-9.7
1 Discretionary and									-13.235	-10.7
Adjustment for share of 2 Joint Tours										
Household Composition - Active Members only										
Number of Full-Time Workers	0.099	0.9	0.000		-0.306	-1.7	0.000		0.000	
Number of Part-Time Workers	0.000		0.000		0.000		0.000		0.218	1.3
Number of University Students	0.000		0.000		-0.657	-1.4	0.000		-0.611	-1.8
Number of Non-Working Adults	0.394	2.3	0.323	1.6	0.000		0.000		0.000	
Number of Retirees	0.000		0.299	1.9	-0.392	-2.0	0.000		0.000	
Number of Driving Age School Children	0.000		0.504	1.8	0.000		0.000		0.359	1.3
Number of Pre-driving Age School Children	-0.313	-2.4	0.000		-0.251	-1.4	0.162	1.1	0.000	
Number of Pre-school Children	-1.214	-3.7	-1.161	-3.4	-1.701	-4.2	-0.970	-2.7	-1.244	-3.7

Variables	Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Car Ownership										
Cars More than Workers			-0.336	-1.6						
Household Income										
$29,999 or Less					-1.282	-2.6			-0.353	-1.3
$30,000 to $59,999					-0.275	-1.0			-0.192	-0.9
$60,000 to $99,999										
$100,000 and more			-0.476	-2.3						
HOV Accessibilities by purpose and car ownership										
By Purpose			0.128	0.7					0.090	0.5
For 2 tours only	0.040	0.2								

Table 61: SANDAG Joint Tour Frequency and Travel Party Composition Model – Composition Component

Variables	Adults Only		Children Only		Mixed (Adults w/children)	
	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Constants						
Shopping			-5.375	-2.0	0.576	0.4
Maintenance			-5.145	-2.0	0.516	0.4
Eating Out			-4.098	-1.6	0.169	0.1
Visiting			-4.098	-1.6	0.078	0.1
Discretionary			-4.098	-1.6	0.856	0.7
Adjustment Constants						
Shopping			1.349		0.717	
Maintenance			1.288		0.636	
Eating Out			0.000		0.786	
Visiting			1.908		0.809	
Discretionary			0.936		0.785	
Household Composition - Active Members only						
Number of Full-Time Workers	0.599	2.4				
Number of Part-Time Workers	1.114	3.4			0.522	1.8
Number of University Students	0.231	0.5				
Number of Non-Working Adults	0.341	1.0				
Number of Retirees	0.657	2.1				
Number of Driving Age School Children			0.580	1.8	0.217	0.7
Number of Pre-driving Age School Children			0.580	1.8	0.314	2.2
Number of Pre-school Children					0.898	3.0
Household Composition – No Active Members						
Number of Active Adults<2	-999					
Number of Active Children<2			-999			
No travel-active pair adult-child in HH					-999	
Log of Window Overlaps*						
Maximum Continuous Time Window Overlap	2.969	7.1	4.674	5.0	3.524	7.8
Car Ownership						
Zero Cars					-2.921	-1.3

Cars Less than Workers					-0.546	-1.0
Household Income						
$100,000 and more			-1.189	-1.4	-0.303	-1.0

Number of Observations	718
Log Likelihood Constants only	-1784.7765
Final Log Likelihood	-1555.9659
Rho-squared wrt zero	.4239
Rho-squared wrt constants	.1282

Findings

Tour Frequency and Purpose

1. Non-working adults have a strong positive constant for shopping and maintenance tours which reflects of the practice of non-workers taking children with them on out-of-home maintenance activities. Joint maintenance activities are also shared by retirees and driving age school students.
2. Retirees are less likely to have joint eating out tours with household members.
3. University students have negative constants for joint eating out and discretionary activities. This could be explained by adult students having more eating-out and discretionary activities with friends as compared to household members.
4. Preschool children have negative coefficients for all the activities. But, relatively, they are more likely to accompany someone on visiting or maintenance tours.
5. Higher car ownership is not strongly correlated with joint maintenance tours. This would reflect on the fact that non-working adults might undertake maintenance activities (with children) if there is a car available for the non-worker during the day.
6. Low-income households are less likely to engage in joint eating-out and discretionary tours. Since these activities are directly related to discretionary expenditure, it is consistent with our expectation. High income households are less likely to engage in joint maintenance activities.
7. There are some positive (although very weak) effects of accessibilities on shopping, maintenance and discretionary locations.

Travel Party Composition

1. The constants for travel party are segmented by purpose. The constants are all negative for children only parties, particularly for shopping and maintenance tours. The constants for mixed party are slightly positive but insignificant.
2. Part-time workers, retirees, and full-time workers are more likely to form an adult only party. Part-time workers also participate in mixed parties. Surprisingly, non-workers proved to be less frequently involved in mixed parties. The coefficient of zero for non-workers in mixed parties may be compensated by the wider window availability for non-workers and children for shared activities, compared to other person types. Preschool children are more likely to be part of mixed parties as compared to other children in the household.
3. Zero or low car ownership is not strongly correlated with mixed travel parties. People usually prefer traveling in a car when they have children with them.
4. High income groups do not tend to have “children only” or “mixed” parties.

4.3.2 Joint Tour Participation

Along with joint tour frequency, and composition, the joint tour model also predicts person participation for each joint tour. This model is a binary choice multinomial logit model. The model was estimated using the ALOGIT software. This model is applied after mandatory activity models and before the individual non-mandatory activity models. It includes tour purpose, person characteristics, household characteristics, available window overlaps, and accessibility as explanatory variables.

Estimation Dataset

For person participation, each household member (from 718 households) relevant for the observed party composition for the specific tour is included in the dataset. This full dataset has 2,451 records representing relevant person-tours pairs. Then, the observations with mandatory person participation in the tour were excluded reducing the dataset to 1,535 person-tour pairs. For example, consider a household with two adults and one child having an adult only joint tour. In such a case, both adults in the household have to participate in the tour and it does not leave any choice for the individuals.

Tables 62 and 63 show the frequency of person participations by purpose and person type. Pure travel parties (i.e. adults only or children only) have very high degree of mandatory participation. Only households with 3+ adults or 3+ children have flexible participation in joint tours.

Table 62: Observed Person Participations by Purpose and Party Composition

Purpose	Travel Party Composition		
	Adults	Children	Adults w/ children
Shopping Tours:			
All Cases	294	3	364
Participation	264	2	232
Mandatory	210	0	47
Non-Mandatory	84	3	317
Non-Mandatory Participation	54	2	185
Maintenance Tours:			
All Cases	317	10	324
Participation	276	5	226
Mandatory	198	0	34
Non-Mandatory	119	10	290
Non-Mandatory Participation	78	5	192
Eating Out Tours:			
All Cases	171	0	104
Participation	161	0	77
Mandatory	130	0	11
Non-Mandatory	41	0	93
Non-Mandatory Participation	31	0	66
Visiting Tours:			
All Cases	88	15	113
Participation	79	11	71
Mandatory	62	4	9
Non-Mandatory	26	11	104
Non-Mandatory Participation	17	7	62
Discretionary Tours:			
All Cases	236	14	398
Participation	211	9	268
Mandatory	162	2	47
Non-Mandatory	74	12	351
Non-Mandatory Participation	49	7	221

Table 63: Observed person participations by person type and party composition

Purpose	Travel Party Composition		
	Adults	Children	Adults w/ children
Full-Time Worker			
All Cases	351	0	368
Participation	284	0	157
Mandatory	200	0	8
Non-Mandatory	151	0	360
Non-Mandatory Participation	84	0	149
Part-Time Worker			
All Cases	113	0	92
Participation	91	0	69
Mandatory	67	0	3
Non-Mandatory	46	0	89
Non-Mandatory Participation	24	0	66
University Student			
All Cases	30	0	27
Participation	18	0	17
Mandatory	4	0	0
Non-Mandatory	26	0	27
Non-Mandatory Participation	14	0	17
Non-working Adults			
All Cases	125	0	166
Participation	115	0	150
Mandatory	83	0	6
Non-Mandatory	42	0	160
Non-Mandatory Participation	32	0	144
Retiree			
All Cases	487	0	9
Participation	483	0	4
Mandatory	408	0	0
Non-Mandatory	79	0	9
Non-Mandatory Participation	75	0	4

Purpose	Travel Party Composition		
	Adults	Children	Adults w/ children
Driving Age School Child			
All Cases	0	3	50
Participation	0	2	30
Mandatory	0	0	13
Non-Mandatory	0	3	37
Non-Mandatory Participation	0	2	17
Pre-driving Age School Child			
All Cases	0	27	278
Participation	0	13	175
Mandatory	0	3	27
Non-Mandatory	0	24	251
Non-Mandatory Participation	0	10	148
Pre-school Child			
All Cases	0	12	313
Participation	0	12	272
Mandatory	0	3	91
Non-Mandatory	0	9	222
Non-Mandatory Participation	0	9	181

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Household composition:
    - Number of Full-Time Workers
- Person Type Definitions
    - Full-Time Worker
    - Part-Time Worker
    - University Student
    - Non-Working Adult
    - Retiree
    - Driving Age School Child
    - Pre-driving Age School Child
    - Pre-school Child

- Competition: Number of household members of the same category
    - Number of other adults in the household
    - Number of other children in the household
- Household income group:
    - Low income (less than $30,000)
    - Medium low income ($30,000-$60,000)
    - Medium income ($60,000-100,000)
    - High income ($100,000 and more)
- Car Ownership
    - No Cars
    - Cars fewer than Workers
    - Cars equal to Workers
    - Cars more than Workers
- Feasibility of sharing non-mandatory activity after the mandatory activity scheduling
    - Maximum pair-wise overlap of available continuous time window with other adults in hours
    - Maximum pair-wise overlap of available continuous time window with other children in hours
- Number of joint tours made by the household

Model Structure

The person participation model has a binary logit form with two alternatives: to participate or not to participate. The availability of the "participate" alternative is based on person type match to the travel party composition. This model is applied after the joint tour frequency and party composition model. Therefore, the purpose of the tour and party type is known when making a decision for this model. Figure 1 shows the structure of this model and model chain for joint tours.

Results

The final adopted model coefficients for person participation in the joint tours are shown in Table 64. Since this is a binary choice model, all utility components are added in the utility for the "participate" alternative and the other utility is set to zero.

Findings

The first sets of coefficients in Table 64 are the constants stratified by eight detailed person types in combination with party composition type and purpose. Shopping purpose is the reference case. Here are the findings:

1. Retirees exhibit the highest propensity (followed by non-workers) to participate in adult parties. It could be because of retirees and non-workers (from older households) undertaking joint activities. While part-time workers, surprisingly, show the lowest propensity to participate in adult parties.
2. Preschool children are more likely to be part of mixed parties as compared to the other two school children categories because they are frequently accompanied by adults.

3. Workers (especially part-time workers) and pre-driving age school children show inclination for eating out tours.
4. Driving age school children are not inclined to participate in visiting or discretionary tours. They probably like to hang out more with friends for discretionary activities.
5. Non-working adults are more likely to participate in mixed parties and take part in joint maintenance or visiting activities.
6. Logically, adults can only participate in an adult or mixed party, and children can only participate in a children or mixed party. Income over $100,000 (for adults and children) proved to be a negative factor for participating in mixed parties. Income less than $30,000 proved to be a negative factor for adult party.
7. The coefficient for high car ownership proved to be negative for adults in a mixed party which means it would make fewer adults participate in the mixed party. Zero car ownership proves to be a strong negative for children participating in a mixed party. Low car ownership proved to be positive for adults only party.
8. Number of joint tours in the household proves to be negative for both adult and children. It has a stronger effect for adults in adult party, which reflects that chances of forming parties with more adults or children are lower with more tours in the household.
9. The coefficients for competition (i.e. number of other adults or children to substitute this person on the joint tour) are logically negative for both adults and children.

Table 64: SANDAG Person Participation Model for Joint Tours

Variables	Adults Only		Children Only		Mixed		Maintenance		Eating Out		Visiting		Discretionary	
	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Person Specific Constants														
Full-Time Worker	-0.845	-0.9			0.453	1.1	0.000		0.536	1.6	0.000		0.000	
Part-Time Worker	-1.838	-1.7			1.263	2.2	0.766	1.3	1.233	1.6	1.076	1.5	0.539	1.1
University Student	-0.970	-1.0			1.562	2.5	0.000		0.000		0.000		0.000	
Non-Working Adult	-0.758	-0.7			2.900	5.5	0.971	1.7	0.000		1.076	1.5	0.000	
Retiree	1.197	0.9			1.043	1.1	0.000		0.000		-1.930	-1.7	1.105	0.9
Driving Age School Child			-12.089	-1.3	-1.916	-2.3	0.000		0.000		-1.335	-1.0	-1.151	-1.5
Pre-driving Age School Child			-16.170	-1.6	-1.916	-2.6	0.000		1.536	2.6	0.000		0.799	2.6
Pre-school Child			-16.170	-1.6	-0.934	-1.1	-0.528	-1.3	0.000		1.553	1.4	0.000	
Party Specific Variables														
Car Ownership														
Cars Less than Workers/Adults	1.293	2.7												
Cars More than Workers/Adults					-0.391	-2.0								
Zero Cars/Child					-1.547	-1.6								
Household Income														
$29,999 or Less/ Adult	-0.681	-1.3												
$100,000 and more/ Adult					-0.203	-1.0								
$100,000 and more/ Child					-0.742	-3.0								
Number of Joint Tours for the Household														
Adult	-0.599	-2.6			-0.219	-1.4								
Child			-0.314	-0.3	-0.242	-1.4								
Competition														
# of Other Adults for Adult	-0.748	-3.0			-0.286	-2.1								

# of Other Children for Child			-2.306	-2.4	-0.472	-4.6								
Adults cannot participate in children party			-999.0											
Children cannot participate in adult party	-999.0													
One of the two available adults - must participate in adult party	999													
The only available adult - must participate in mixed party					999									
One of the two available children - must participate in children party			999											
The only available child - must participate in mixed party					999									
Maximum Pair-wise Window Overlaps*														
Maximum Continuous Window Overlap														
With Adults	1.634	4.5			0.057	0.3								
With Child			10.703	2.2	1.617	4.7								
*Log(1+Window Overlap)														

Number of Observations	1535
Log Likelihood Constants only	-1006.6214
Final Log Likelihood	-806.3254
Rho-squared wrt zero	0.2422
Rho-squared wrt constants	0.199

4.3.3 Joint Tour Primary Destination Choice

- See Section 4.4.2 (Individual non-mandatory tours destination choice). The destination choice for joint non-mandatory tours were estimated with those of the individual non-mandatory tours.

4.3.4 Joint Tour Time of Day Choice

- See Section 4.2.2 (Individual mandatory tours time of day choice).

4.3.5 Joint Tour Mode Choice Model

- See Section 4.2.3 (Individual mandatory tour mode choice).

4.4 Individual Non-Mandatory Tour Modeling

4.4.1 Individual Non-Mandatory Tour Frequency

The individual non mandatory tour frequency model predicts the number of non-mandatory (escorting, shopping, maintenance, eating out, visiting and discretionary) tours by purpose for each household member. The model was estimated in a multinomial logit form using the ALOGIT software. 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.

In this model, the combination of non-mandatory tours is used as an independent variable derived on mandatory tour frequency, person and household characteristics, and accessibilities (to both mandatory activities (at a person level) and non-mandatory activities (at a household level)) as explanatory variables.

Estimation Dataset

The estimation dataset included 7,796 observed persons with active travel patterns from the SANDAG 2006 Household Travel Behavior Survey. Among these observed persons, there were 3,180 full-time workers (FW), 711 part-time workers (PW), 226 university students (US), 582 non-workers (NW), 1,141 retirees (RT), 285 driving age school child (SD), 1,102 pre-driving age school child (SP), 569 pre-school Child (PS). Table 65 shows the observed frequency of non-mandatory tours by person type and purpose.

Table 65: Non-Mandatory Tours by Person type and Purpose

Person Type	Frequency						
	Total	Escorting	Shopping	Maintenance	Eating Out	Visiting	Discretionary
Full-time worker	1552	388	326	307	111	109	311
Part-time worker	706	201	127	138	44	53	143
University student	160	51	33	26	4	16	30
Non-worker	982	319	233	212	48	53	117
Retiree	1705	105	489	492	132	108	379
Driving age school child	105	4	14	16	5	15	51
Pre-driving age school child	356	44	34	60	24	40	154
Pre- school child	523	175	100	95	20	41	92
Total	**6089**	**1287**	**1356**	**1346**	**388**	**435**	**1277**

Table 66 shows the observed non-mandatory tour frequency for each person type. The survey observations were joined with MGRA-based mandatory and non-mandatory accessibilities to create the estimation file. Mandatory and non-mandatory activity accessibilities are the logsum/utility measures calculated using asserted mode and destination choice models. Mandatory accessibilities reflect the actual workplace and/or school location for each worker and student in the household, while non-mandatory accessibilities reflect the general accessibility of the household to all potential non-mandatory destinations.

Table 66: Number of Non-Mandatory Tours by Person type

Person Type	Frequency of Non-Mandatory Tours						
	Total	No tours	1 Tour	2 Tours	3 Tours	4 Tours	5+ Tours
Full-time worker	3180	2032	837	229	71	11	0
Part-time worker	711	275	249	125	43	17	2
University student	226	112	78	28	7	0	1
Non-worker	582	3	284	207	68	20	0
Retiree	1141	1	700	337	81	22	0
Driving age school child	285	196	76	10	3	0	0
Pre-driving age school child	1102	780	293	24	5	0	0
Pre- school child	569	223	211	105	18	12	0
Total	**7,796**	**3622**	**2728**	**1065**	**296**	**82**	**3**

Choice and Model Structure

The IDAP model is a multinomial logit model with a total of 197 alternatives based on combination of number of tours by each purpose with total maximum number of 5 tours. Based on observed data, the number of tours modeled explicitly varied by purpose. For escorting, shopping, maintenance and discretionary, 0, 1 and 2 tours were modeled. Only 0 and 1 tours were modeled explicitly for eating out and visiting because there were not enough observations for 2 or more tours category.

The current choice structure includes all combinations of tours by the six purposes after truncation of total number of tours to 5. The choice structure includes the following alternatives:

- Total number of tours = 0, 1 alternatives
- Total number of tours = 1, 6 (by each purpose) alternatives
- Total number of tours = 2, 19 alternatives
- Total number of tours = 3, 40 alternatives
- Total number of tours = 4, 61 alternatives
- Total number of tours = 5, 70 alternatives
- Total = 197 alternatives

Availability of Alternatives

Since this model is only applied for persons with an active (M or N) travel pattern, the choice alternative of making "no non-mandatory tours" is only available to persons who have made at least one mandatory tour. In the survey, 5 or more tours are only observed for part-time workers and university students. Therefore, the 70 alternatives based on 5 tours are only available for these two person types.

Main Explanatory Variables and Utility Structure

For each person type, a separate IDAP model is estimated therefore these models are fully segmented by person type. The following are the explanatory variables used in the utility functions:

- Alternative specific
  - Total number of tours category – 0 to 5
  - Tour purpose – escorting, shopping, maintenance, eating out, visiting, discretionary
  - More than two tours of same purpose - escorting, shopping, maintenance, discretionary
- Presence of mandatory tours
- Household income group
  - Low income (less than $30,000)
  - Low-medium income ($30,000-60,000)
  - Medium income ($60,000-100,000)
  - High-medium income ($100,000 -150,000)
  - High income ($150,000 and more)
- Car sufficiency with respect to workers
  - No cars

    - Cars less than workers
    - Cars equal to workers
    - Cars more than workers
- Gender
- Education level
    - College educated - undergraduate or higher
    - Low educated – not completed high school
- Number of household members by person type
- Number of pre-driving school kids and pre-school kids not at home
- Household type
    - With only retirees and non-workers
- Zonal accessibility indices from residential zones to Non-Mandatory activity destinations
- Work and school location accessibilities (specific to person)
- Household residence type
    - Detached dwelling unit
    - Non-detached dwelling unit
- Population density at home location

The zonal accessibility indices for non-mandatory activities take the form of destination choice logsums and represent a result of the summation of attractions across all destinations. The auto accessibilities are non-mandatory accessibilities with SOV logsums (destination accessibility terms 4-6) attached by household auto ownership. The non-mandatory transit (destination accessibility term 2) and walk (destination accessibility term 3) accessibilities are also used. Off-peak skims are used for creation of non-mandatory accessibilities. In addition to generic non-mandatory accessibilities, purpose specific HOV logsums (destination accessibility terms 10-27) were also used. The Auto Logsum to work (mandatory accessibility term 7) and school location (mandatory accessibility term 18) are accessibilities to person's specific work or school location calculated using peak skims.

Results and Findings

The non-mandatory tour frequency estimation results are summarized in Tables 67 to 69.

Here are the findings from the estimation results:

- *Constants:* All the constants by tour purpose are negative. The constants for tour frequency are in addition to constants by purpose.
- *More than two tours of same purpose:* The likelihood of making more than one tour of same purpose is positive for escorting (which may indicate that dropping off and pick up is usually done by same person) and negative for other purposes (shopping, maintenance and discretionary) which shows that a person is less likely to make multiple tours for same purpose on a given day.
- *Persons with mandatory patterns:* Persons with mandatory patterns (work or school tour) are less likely to make more than one non-mandatory tour. This indicates scheduling constraints due to time spent performing mandatory activities.

- *Household income:* The impact of household income is quite consistent across most of the person types. Members of high income households are less likely to have escorting and maintenance tours than lower income households. High income households might have nannies for escorting young children or have other methods to take care of maintenance activities. Tours for shopping, eating out and other discretionary activities increase with respect to household income. Visiting tours are more popular among full-time workers, non-workers and children from high income households than lower income households. However, the impacts are opposite for retirees.
- *Female:* Females are more likely to have escorting, shopping and visiting tours than males. However, retired females are less likely to have non-escorting tours than males.
- *Household members:* the type of tours made by a person is affected by the number of household members by person type in two ways –
    - Other persons who share responsibility (escorting, shopping and maintenance needs). For example, non-workers in the household will reduce the number of escorting, maintenance or shopping tours for workers.
    - Other persons who produce need for non-mandatory tours or reduce changes of a tour. For example, pre-driving age children need escorting to school and other locations; whereas, pre-school children reduces the chances of eating out activities.
    - Persons who may participate in joint activities – participation in discretionary activities by children in the household
- *Households with only retirees and non-workers:* this variable is only used for the Retiree model, where it was important to differentiate between households with old members only (e.g., a retired couple) and mixed households (e.g., grandparents living in an extended family). Retirees in a household with only old members are less likely to make an escorting tour (because there are no children in the household). But they might be needed to escort another retiree, and they are more likely to make shopping or eating out tours compared to a retiree in a mixed household.
- *Car sufficiency:* Fewer or no cars reduce the chances of making more non-mandatory tours. It particularly affects escorting tours where the availability of car is important. Young children (age<16) in households with more cars than workers are more likely to have non-mandatory tours. It reflects that a non-working adult has access to car and therefore it is easier to participate in joint travel with younger kids.
- *Education level:* Persons with a college degree are more likely to undertake discretionary activities. This behavior probably reflects lifestyle differences across educational backgrounds.
- *Accessibilities to non-mandatory destinations by purpose:* It proved to be significant and positive for most person types. In some cases, walk accessibilities also proved significant for discretionary and eating out tours.
- *Workers, students and preschoolers with mandatory activity pattern:* They are likely to make higher number of non-mandatory tours with better work/school accessibility. Full-time workers with usual work place at home are more likely to make higher number of non-mandatory tours.

- *Population density at the home location:* It showed a positive effect on visiting tours for part-time workers and pre-driving age school children.
- *Persons living in detached homes:* They are more likely to make an escorting tour and less likely to make a eating out or discretionary tour.

Table 67: Individual Non-Mandatory Tour Frequency Estimation Results for Workers and University Students

	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
Utility Terms	**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

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
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				
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						

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
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				
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

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
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

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Escorting						
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 accessibility	0.2644	1.62	0.2044	0.87		
Shopping accessibility	0.3637	2.30	0.0415	0.15		
Maintenance accessibility	0.2144	1.41	0.3990	1.63		
Eating out accessibility	0.7319	2.45	0.3121	0.70		
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				

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
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
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	

Table 68: Individual Non-Mandatory Tour Frequency Estimation Results for Non-Workers and Retirees

Utility Terms	Non-Worker (NW)		Retiree (RT)	
	Coeff	T-Stat	Coeff	T-Stat
Constant by tour frequency				
Number of non-mandatory tours =0	-0.1904	-0.24	-1.5783	-1.47
Number of non-mandatory tours =1	0.0000		0.0000	
Number of non-mandatory tours =2	0.0000		0.0000	
Number of non-mandatory tours =3	-0.5622	-2.79	-0.3002	-1.88
Number of non-mandatory tours =4	-0.9607	-2.74	-0.3002	-1.88
Number of non-mandatory tours =5+	-999		-999	
Constant by tour purpose				
Escorting tour	-6.3906	-2.19	-10.5002	-3.12
Shopping tour	-2.1117	-0.80	-5.4307	-3.16
Maintenance tour	-1.6380	-0.69	-4.2681	-2.97
Eating out tour	-4.6829	-3.47	-1.9035	-6.58
Visiting	-4.7069	-1.10	-4.2256	-1.69
Discretionary	-5.7493	-1.71	-6.8970	-3.96
More than 2 tours of same purpose				
Escorting tours	1.5833	5.79	2.0805	5.73
Shopping tours	-0.7666	-2.88	-1.2721	-6.20
Maintenance tours	-0.6449	-2.29	-0.8517	-4.57
Discretionary tours	-0.8749	-1.98	-0.1133	-0.58
Household income				
Shopping, low income (<30K)	-0.3126	-1.67		
Shopping, medium income (30-60K)	-0.3126	-1.67		
Shopping, medium income (60-100K)				
Shopping, high income (100-150K)			0.2909	1.78
Shopping, high income (>150K)			0.2909	1.78
Maintenance, low income (<30K)			-0.3492	-2.97
Maintenance, medium income (30-60K)			-0.3492	-2.97
Maintenance, medium income (60-100K)				
Maintenance, high income (100-150K)	-0.2307	-1.06		
Maintenance, high income (>150K)	-0.2307	-1.06		
Eating Out, low income (<30K)	-0.5484	-1.20	-1.3358	-4.26
Eating Out, medium income (30-60K)	-0.3580	-0.72	-0.5816	-2.45

Utility Terms	Non-Worker (NW)		Retiree (RT)	
	Coeff	T-Stat	Coeff	T-Stat
Eating Out, medium income (60-100K)				
Eating Out, high income (100-150K)				
Eating Out, high income (>150K)	1.5359	3.56		
Visiting, low income (<30K)				
Visiting, medium income (30-60K)				
Visiting, medium income (60-100K)				
Visiting, high income (100-150K)	0.3139	0.88		
Visiting, high income (>150K)	0.3139	0.88	-1.6146	-1.58
Discretionary, low Income (<30K)	-0.4233	-1.72	-0.2020	-1.26
Discretionary, medium income (30-60K)	-0.4233	-1.72		
Discretionary, medium income (60-100K)				
Discretionary, high income (100-150K)			0.1602	0.98
Discretionary, high income (>150K)			0.1602	0.98
Gender				
Female, escorting tour	0.5115	2.33		
Female, shopping tour	0.3453	1.82	-0.1100	-0.91
Female, maintenance tour			-0.2449	-2.13
Female, eating out tour			-0.2451	-1.26
Female, visiting	0.4643	1.22		
Female, discretionary			-0.0780	-0.66
Household interactions				
Escorting				
Number of full-time workers	0.2407	1.62	-0.1531	-0.79
Number of part-time workers	0.1210	0.46	-0.1531	-0.79
Number of university students	0.3437	1.27		
Number of non-workers	-0.4871	-1.84	-0.1531	-0.79
Number of retirees	0.3039	1.40		
Number of driving age school children	0.7440	4.36	0.4547	1.38
Number of pre-driving school children not at home	0.9082	9.43	0.7495	4.42
Number of pre-school children not at home	0.7481	7.39		
Shopping				
Number of non-workers	-0.3184	-1.20		
Number of retirees			-0.3556	-3.06
Maintenance				

Utility Terms	Non-Worker (NW)		Retiree (RT)	
	Coeff	T-Stat	Coeff	T-Stat
Number of workers	0.1511	1.27		
Number of retirees			-0.2134	-1.99
Discretionary				
Number of school and pre-school children	0.1440	1.66		
Eating out				
Number of pre-driving school children	-0.2690	-1.39		
Number of pre-school children	-0.2690	-1.39		
Visiting				
Number of retirees			-0.1703	-0.86
Number of pre-driving age children (SP,PS)	0.0928	0.67		
Households with only retirees and non-workers				
Escorting tour			-0.8345	-2.91
Shopping tour			0.2697	1.84
Eating out tour			0.1788	0.76
Discretionary tour			0.1204	0.84
Car sufficiency				
No cars				
Number of non-mandatory tours =1				
Number of non-mandatory tours =2	-0.5768	-1.58		
Number of non-mandatory tours >=3	-0.5768	-1.58		
Cars less than workers				
Number of non-mandatory tours =1				
Number of non-mandatory tours =2	-0.5519	-0.57		
Number of non-mandatory tours >=3	-0.5519	-0.57		
Escorting				
No cars	-0.8482	-1.48		
Cars less than workers				
Cars more than workers	0.2428	1.01		
Education				
College education				
Escorting tour			0.1896	1.02
Shopping tour	0.2522	1.40	0.1008	0.84
Maintenance tour	0.5068	2.87		
Eating out tour	0.8590	3.65		

Utility Terms	Non-Worker (NW) Coeff	Non-Worker (NW) T-Stat	Retiree (RT) Coeff	Retiree (RT) T-Stat
Visiting tour	0.7077	1.97	0.3146	1.51
Discretionary tour	0.3391	1.06	0.3550	2.93
Less than high school				
Escorting tour	0.1973	0.87	-0.9186	-1.79
Shopping tour	-0.3009	-1.09	-0.6426	-2.07
Maintenance tour			-0.6417	-2.14
Eating out tour	-0.9680	-1.94		
Visiting tour	-0.8165	-1.05		
Discretionary tour	-0.9874	-1.55	-0.5424	-1.61
Accessibilities				
Escorting accessibility	0.1994	1.02	0.5184	2.25
Shopping accessibility	0.0633	0.34	0.3052	2.50
Maintenance accessibility	0.0102	0.05	0.2808	2.46
Eating out accessibility	0.0000			
Visiting accessibility	0.1332	0.38	0.1222	0.59
Discretionary accessibility	0.2836	1.09	0.3990	3.02
Walk accessibility				
Eating out tour	0.2237	1.51		
Dwelling type - detached home				
Escorting tour	0.1495	0.87	0.3369	1.47
Eating out tour			-0.3271	-1.60
Discretionary tour			-0.1194	-1.00

	Non-Worker (NW)	Retiree (RT)
Number of observations	582	1,141
Likelihood with constants only	-1817.43	-3300.45
Final likelihood	-1676.32	-3283.80
ρ^2 w.r.t. zero	0.4045	0.4049
ρ^2 w.r.t. constants	0.0776	0.005

Table 69: Individual Non-Mandatory Tour Frequency Estimation Results for Driving Age School Children, Pre-Driving Age School Children and Pre-School Children

Utility Terms	Driving Age School Child (SD)		Pre-Driving Age School Child (SP)		Pre-School Child (PS)	
	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	-1.0467	-1.46				
Number of non-mandatory tours =2	-1.2747	-0.80	0.0734	0.11	1.6723	4.31
Number of non-mandatory tours =3	-1.2747	-0.80	0.0734	0.11	2.4044	3.11
Number of non-mandatory tours =4	-999		-999		4.8035	4.20
Number of non-mandatory tours =5+	-999		-999		-999	
Constant by tour purpose						
Escorting tour	-4.2078	-3.91	-11.5449	-1.91	-9.3585	-2.91
Shopping tour	-25.7696	-2.04	-17.9811	-2.34	-15.5285	-3.28
Maintenance tour	-5.2937	-0.69	-3.9966	-0.88	-6.9819	-1.93
Eating out tour	-27.8652	-1.41	-11.9893	-1.52	-3.2276	-5.46
Visiting	-2.1746	-2.82	-3.6720	-5.72	-4.7963	-9.70
Discretionary	-1.2022	-1.61	-2.3740	-0.68	-8.5943	-1.88
More than 2 tours of same purpose						
Escorting tours			0.6375	0.79	1.0152	3.37
Maintenance tours					-0.4714	-1.07
Discretionary tours	-0.6777	-0.97	-1.3768	-2.41	-1.1747	-2.26
For persons with mandatory DAP						
Number of non-mandatory tours =0			-0.9073	-1.67		
Number of non-mandatory tours =1	-2.0484	-2.16	-3.2999	-3.07	-1.775	-2.35
Number of non-mandatory tours =2	-2.0484	-2.16	-3.2999	-3.07	-1.775	-2.35
Number of non-mandatory tours =3	-2.0484	-2.16	-3.2999	-3.07	-1.775	-2.35
Number of non-mandatory tours =4	-2.0484	-2.16	-3.2999	-3.07	-1.775	-2.35
Household income						
Escorting, low income (<30K)	0.3707	0.36				
Escorting, medium income (30-60K)	0.3707	0.36				
Escorting, medium income (60-100K)						
Escorting, high income (100-150K)						
Escorting, high income (>150K)					-0.3290	-0.79
Shopping, low income (<30K)					-0.1204	-0.40

Utility Terms	Driving Age School Child (SD)		Pre-Driving Age School Child (SP)		Pre-School Child (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Shopping, medium income (30-60K)					0.0000	
Shopping, medium income (60-100K)						
Shopping, high income (100-150K)					0.4067	1.31
Shopping, high income (>150K)			0.4616	0.83	0.6540	1.56
Maintenance, low income (<30K)					0.5314	1.62
Maintenance, medium income (30-60K)					0.3992	1.26
Maintenance, medium income (60-100K)					0.0000	
Maintenance, high income (100-150K)			-0.1727	-0.58	-0.4070	-1.04
Maintenance, high income (>150K)	-0.6754	-0.65	-0.1727	-0.58	-0.5562	-0.86
Eating Out, low income (<30K)					-1.695	-1.59
Eating Out, medium income (30-60K)						
Eating Out, medium income (60-100K)						
Eating Out, high income (100-150K)						
Eating Out, high income (>150K)			1.5516	3.24		
Visiting, low income (<30K)			-1.4377	-1.90		
Visiting, medium income (30-60K)			-0.5833	-1.15		
Visiting, medium income (60-100K)						
Visiting, high income (100-150K)	0.4310	0.74			0.1394	0.34
Visiting, high income (>150K)	0.4310	0.74	1.1100	2.57	0.6184	1.03
Discretionary, low income (<30K)	-0.9039	-1.48	-1.5275	-3.68	-1.5323	-3.42
Discretionary, medium income (30-60K)			-0.8207	-2.85	-0.5407	-1.74
Discretionary, medium income (60-100K)						
Discretionary, high income (100-150K)	0.3838	0.99				
Discretionary, high income (>150K)	0.5217	1.18	0.2576	0.99		
Gender						
Female, shopping tour	0.9536	1.56				
Household interactions						
Escorting						

Utility Terms	Driving Age School Child (SD)		Pre-Driving Age School Child (SP)		Pre-School Child (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Number of part-time workers					0.6322	3.68
Number of university students					0.7389	2.78
Number of non-workers					0.6322	3.68
Number of pre-driving school Children not at home	0.6772	1.69	0.4049	2.71	0.5762	6.35
Number of pre-school children not at home					0.5384	3.98
Shopping						
Number of workers and non-workers	-0.2018	-0.51				
Number of driving age school children			0.2095	1.34		
Number of pre-driving age children	0.4796	2.11	0.2095	1.34		
Discretionary						
Number of full-time workers					-0.6727	-2.70
Number of part-time workers	0.4407	1.89				
Number of university students	0.5808	1.67				
Number of non-workers	0.4407	1.89				
Number of school and pre-school children			0.2187	2.51	0.3147	3.02
Eating out						
Number of part-time workers					-0.5894	-1.29
Number of non-workers					-0.5894	-1.29
Number of pre-driving age school children			0.3604	1.64	-0.7081	-2.03
Number of pre-school children			-1.5888	-1.63	-0.7081	-2.03
Visiting						
Number of driving age school children			0.4509	3.13		
Number of pre-driving age children (SP,PS)			0.4509	3.13	0.2651	1.75
Car sufficiency						
No cars						
Number of non-mandatory tours =1	-0.2385	-0.21	-0.9863	-1.56		
Number of non-mandatory tours =2	-0.2385	-0.21	-0.9863	-1.56		
Number of non-mandatory tours >=3	-0.2385	-0.21	-0.9863	-1.56		
Cars more than workers						

Utility Terms	Driving Age School Child (SD)		Pre-Driving Age School Child (SP)		Pre-School Child (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Number of non-mandatory tours =1	0.0388	0.12			0.6952	2.30
Number of non-mandatory tours =2	0.0388	0.12			0.6952	2.30
Number of non-mandatory tours >=3	0.0388	0.12			0.6952	2.30
Escorting						
No cars					-1.0637	-2.30
Cars less than workers					-1.0637	-2.30
Shopping						
No cars			-1.0265	-0.97		
Cars less than workers			-1.0265	-0.97		
Cars more than workers			0.2305	0.61	0.4196	1.78
Maintenance						
Cars more than workers			0.6580	2.30		
Visiting						
Cars more than workers					0.5361	1.47
Discretionary						
Cars more than workers			0.0243	0.13		
Accessibilities						
Escorting accessibility			0.5917	1.41	0.3520	1.57
Shopping accessibility	1.6148	1.85	1.0369	1.91	0.8434	2.50
Maintenance accessibility	0.2615	0.44	0.1013	0.29	0.2777	0.97
Eating out accessibility	1.8894	1.26	0.6412	1.05		
Visiting accessibility						
Discretionary accessibility			0.0767	0.29	0.4620	1.31
Work/school accessibility for persons with mandatory pattern						
Number of non-mandatory tours =1			0.5143	2.13	0.1146	0.29
Number of non-mandatory tours =2	0.8484	0.86	1.2078	1.18	0.5810	0.67
Number of non-mandatory tours >=3	0.8484	0.86	1.2078	1.18	0.5810	0.67
Population density at home location						
Visiting tour			0.0365	1.72		
Dwelling type - detached home						
Eating out tour					-0.8693	-1.79
Number of observations		285		1,102		569

Utility Terms	Driving Age School Child (SD)		Pre-Driving Age School Child (SP)		Pre-School Child (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Likelihood with constants only	-339.64		-1260.55		-1232.72	
Final likelihood	-327.26		-1193.99		-1110.74	
ρ^2 w.r.t. zero	0.763		0.7765		0.5967	
ρ^2 w.r.t. constants	0.0364		0.0536		0.0989	

Final Model:

The final adopted model is a mix of estimated and asserted coefficients. Table 70 ~ Table 72 show the Implemented coefficients for the final non-mandatory tour frequency adopted model.

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Constants by tour frequency						
Total Number of Tours = 0 (No Prior Tours)	-999.0000		-999.0000		-999.0000	
Total Number of Tours = 0 (1 or more Prior Tours)	0.0000		0.0000		0.0000	
Total Number of Tours = 1+					-0.2573	
Total Number of Tours = 1	0.0000		0.0000			
Total Number of Tours = 2	1.3287		1.3477			
Total Number of Tours = 3	3.0274		1.9587			
Total Number of Tours = 4	3.5474		3.4069			
Total Number of Tours >= 5	-999.0000		3.4069			
Tour frequency with purpose						
One or more Mandatory tour & tour frequency =2	-1.1224		-1.3838		-1.0721	
One or more Mandatory tour & tour frequency =3	-2.0576		-1.3838		-1.0721	
One or more Mandatory tour & tour frequency =4+	-2.0576		-2.3081		-1.0721	
One or more Joint tour & tour frequency =1					-0.3362	
One or more Joint tour & tour frequency =2+					-0.3886	

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	**Full-time Worker (FW)**		**Part-time Worker (PW)**		**University Student (US)**	
	Coeff	**T-Stat**	**Coeff**	**T-Stat**	**Coeff**	**T-Stat**
One or more Joint tour & tour frequency =3+	-0.4776					
One or more Joint tour & tour frequency =4+			-0.8510			
Number of Shopping Joint Tours >0	-0.1709					
Number of Discretionary Joint Tours >0	-1.1637		-0.1399			
Number of Escorting tours >0	-8.0056		-6.8259		-3.1515	
Number of Shopping tours >0	-6.0932		-2.5857		-2.7727	
Number of Maintenance tours >0	-4.4508		-4.8768		-2.2626	
Number of Eating Out tours >0	-12.6249		-8.0920		-14.6919	
Number of Visit tours >0	-3.8699		-4.7879		-4.2126	
Number of Discretionary tours >0	-4.1919		-3.1037		-4.5482	
Escorting tours >=2	0.6139		0.6887		2.7225	
Shopping tours >=2			-0.8070			
Discretionary tours >=2	-0.2367		-1.1236			
Household Income and Tour Purpose						
Low Income group (<30K) & Escorting tour					0.2021	
Medium low Income group (30K-60K) & Escorting tour					0.2021	
High Income group (100-150K) & Escorting tour					-0.0608	
High Income group (>150K) & Escorting tour	-0.0665		-0.1887		-0.0608	
low Income group (<30K) & shopping tour			-0.5846			
Medium low Income group (30K-60K) & shopping tour			-0.1915			
High Income group (100-150K) & shopping tour	0.0637		0.3024		0.6855	
High Income group (>150K) & shopping tour	0.0637		0.3024		0.7028	
Low Income group (<30K) &	0.2513					

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Maintenance tour						
Medium low Income group (30K-60K) & Maintenance tour	0.1889					
High Income group (100-150K) & Maintenance tour					-0.2526	
High Income group (>150K) & Maintenance tour	-0.2319				-0.2526	
Low Income group (<30K) & Eating Out tour	-1.8102		-1.7096			
Medium low Income group (30K-60K) & Eating Out tour			-1.0189			
High Income group (100-150K) & Eating Out tour					1.5850	
High Income group (>150K) & Eating Out tour	0.3147				1.5850	
Low Income group (<30K) & Visiting tour	-0.5656				0.7094	
Medium low Income group (30K-60K) & Visiting tour					0.7094	
High Income group (>150K) & Visiting tour					-0.1746	
Low Income group (<30K) & Discretionary tour	-0.2310		-0.6980		-0.1746	
High Income group (100-150K) & Discretionary tour	0.1072		0.4411		0.6155	
High Income group (>150K) & Discretionary tour	0.1790		0.4411		0.6155	
Gender and Tour Purpose						
Female & Escorting Tour	0.1374		0.8279		0.1879	
Female & Shopping Tour			0.6502		0.9870	
Female & Eating Out Tour			-1.2544			
Female & Maintenance Tour					0.2033	
Female & Visiting Tour					1.0640	
Car sufficiency and Tour Frequency						
zero car ownership & tour frequency =2+	-0.9358		-2.2135			

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Cars Less than Workers & tour frequency =2+	-0.3610		-0.4902			
Cars more than Workers & tour frequency =1+					0.4271	
Cars more than Workers & tour frequency =3+	0.0726					
Car sufficiency and Tour Purpose						
Zero Car ownership, Escorting	-0.8733					
Cars Less than Workers, Escorting	0.4126		0.2450			
Cars more than Workers, Escorting			-0.2735			
Cars Less than Workers, Shopping			0.3779			
Cars more than Workers, Shopping			-0.5799			
Household interactions with Tour Purpose						
Number of Non-Workers (other than modeled person) & Escorting tour	-0.3234		-0.2647		-0.4576	
Number of Full time Workers (other than modeled person) & Escorting tour	0.2121		0.0977		-0.3011	
Number of Part time Workers (other than modeled person) & Escorting tour	-0.0731		-0.1351		-0.4576	
Number of Driving School Kids (other than modeled person) & Escorting tour	0.5794		0.5923			
Number of University Students (other than modeled person) & Escorting tour	0.2751		0.3244		0.4201	
Number of Retirees (other than modeled person) & Escorting tour	-0.5589				-0.6370	
Number of "Not at home" Pre-Driving School Kids & Escorting tour	0.6397		0.8074		0.7678	
Number of "Not at home" Pre-School Kids & Escorting tour	0.3850		0.5840		0.5786	
Number of Non-Workers (other than modeled person) & Shopping tour			-0.5717			
Number of Full time Workers (other than modeled person) & Shopping tour			-0.5717		-0.5009	
Number of Part time Workers (other			-0.5717		-0.7607	

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
than modeled person) & Shopping tour						
Number of University Students (other than modeled person) & Shopping tour					-1.4410	
Number of Pre-School Kids (other than modeled person) & Shopping tour	-0.2187					
Number of Pre-Driving School Kids (other than modeled person) & Shopping tour	-0.2187					
Number of Driving School Kids (other than modeled person) & Shopping tour	-0.2187					
Number of Non-Workers(other than modeled person) & Maintenance tour	-0.2191		-1.1734		-0.5407	
Number of Full time Workers (other than modeled person) & Maintenance tour	-0.2191		-0.2425		-0.5407	
Number of Part time Workers (other than modeled person) & Maintenance tour	-0.2191		-0.2425		-0.5407	
Number of University Students (other than modeled person) & Maintenance tour	-0.2191				-1.0480	
Number of Non-Workers (other than modeled person) & Eating Out tour	-0.7640					
Number of Full time Workers (other than modeled person) & Eating Out tour	-0.7640		-0.2733			
Number of Part time Workers (other than modeled person) & Eating Out tour	-0.7640					
Number of Pre-School Kids (other than modeled person) & Eating Out tour	-0.3556					
Number of Pre-Driving School Kids (other than modeled person) & Eating Out tour	-0.3556					
Number of University Students (other	-0.7640					

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
than modeled person) & Eating Out tour						
Number of Retirees (other than modeled person) & Eating Out tour	-0.7640					
Number of Part time Workers (other than modeled person) & Visiting tour			0.8878			
Number of Pre-School Kids (other than modeled person) & Visiting tour			0.0239			
Number of Pre-Driving School Kids (other than modeled person) & Visiting tour			0.0239			
Number of Driving School Kids (other than modeled person) & Visiting tour			0.0239			
Number of Non-Workers (other than modeled person) & Visiting tour	-0.4449					
Number of University Students (other than modeled person) & Visiting tour	-0.4449					
Number of Retirees (other than modeled person) & Visiting tour	-0.4449		0.8854			
Number of Pre-School Kids (other than modeled person) & Discretionary tour	-0.1570		-2.4317			
Number of Pre-Driving School Kids (other than modeled person) & Discretionary tour	-0.0215		0.2574			
Number of Driving School Kids (other than modeled person) & Discretionary tour	-0.0215		0.2574			
Number of University Students (other than modeled person) & Discretionary tour					0.0894	
Work Accessibility & Tour Frequency						
Work Accessibility & Tour Frequency =1	0.3287		0.6287			
Work Accessibility & Tour Frequency	0.7186		0.8426			

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
=2						
Work Accessibility & Tour Frequency =3	0.7186		0.8143			
Work Accessibility & Tour Frequency =4	0.7186					
Work Accessibility & Tour Frequency =5+	0.7186					
Work From Home & Tour Frequency						
Work From Home & Tour Frequency =1	0.9159					
Work From Home & Tour Frequency =2	1.1003					
Work From Home & Tour Frequency =3	1.1003					
Work From Home & Tour Frequency =4	1.1003					
Work From Home & Tour Frequency =5+	1.1003					
School Accessibility & Tour Frequency						
School Accessibility & Tour Frequency =1+					0.5130	
Retail Accessibility & Tour Purpose						
Retail Accessibility for Escorting	0.2913		0.1997			
Retail Accessibility for Shopping	0.2052					
Retail Accessibility for Maintenance	0.0974		0.1896			
Retail Accessibility for Eating Out	0.6780		0.3876			
Retail Accessibility for Discretionary					0.1461	
Walk Accessibility and Tour Purpose						
Walk Accessibility for Discretionary	0.0456		0.0322			
Walk Accessibility for Eating Out					1.0022	
Population Density and Tour Purpose						
Population Density & Visiting tour			0.0488			

Table 70: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Workers and University StudentsUtility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Education and Tour Purpose						
College Education & Visiting tour	-0.6720					
College Education & Discretionary tour	0.6219		0.2565			
Less than High School Education & Visiting tour	0.4548					
Less than High School Education & Discretionary tour			-0.9742			
Household type and Tour Purpose						
Detached Household & Escorting tour	0.2202		0.2904			
Detached Household & Eating Out tour			-0.2279			
Detached Household & Discretionary tour					-0.3303	
Alternative Specific Constant Adjustment						
Escorting Tours =1	0.2607		0.3266		0.2352	
Shopping tours = 1	0.1457		0.0853		0.1896	
Maintenance tours = 1	-0.1937		-0.1883		0.2582	
Eating Out tours > 0	-1.2656		-0.8929		-0.5106	
Visit tours > 0	-0.1556		-0.6522		-0.3531	
Discretionary tours = 1	-0.1157		0.0021		-0.6134	
Escorting tours >=2	0.6093		1.3575		0.9980	
Shopping tours >=2	0.1032		0.0471		0.3228	
Maintenance tours >=2	-0.2369		-0.2445			
Discretionary tours >=2	-0.0455		0.1753		-0.1513	

Table 71: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Non-Workers and Retiree

Utility Terms	Non-Worker (NW)		Retiree(RT)	
	Coeff	T-Stat	Coeff	T-Stat
Constant by tour frequency				
Total Number of Tours = 0 (No Prior Tours)	-999.0000		-999.0000	
Total Number of Tours = 0 (1 or more Prior Tours)	0.0000		-1.1407	
Total Number of Tours = 3	-0.7939			
Total Number of Tours = 4	-1.1179			
Total Number of Tours >= 5	-999.0000		-999.0000	
Constant by tour frequency with purpose				
One or more Joint tour & tour frequency =1	-0.9686		-1.6010	
One or more Joint tour & tour frequency =2	-1.8085			
One or more Joint tour & tour frequency =2+			-2.1055	
One or more Joint tour & tour frequency =3+	-2.5920			
Number of Shopping Joint Tours >0	-0.4668		-0.6377	
Number Maintenance Joint Tours	-0.5753		-0.4348	
Number Eating Out Joint Tours			-0.7839	
Number of Discretionary Joint Tours >0			-0.0850	
Number of Escorting tours >0	-5.5709		-10.4405	
Number of Shopping tours >0	-1.5833		-4.6661	
Number of Maintenance tours >0	-2.0214		-2.4724	
Number of Eating Out tours >0	-8.9856		-2.5648	
Number of Visit tours >0	-6.6293		-3.6770	
Number of Discretionary tours >0	-3.1828		-6.1189	
Escorting tours >=2	1.3605		2.0794	
Shopping tours >=2	-0.7454		-1.1624	
Maintenance tours >=2	-0.1194		-0.5943	

Utility Terms	Non-Worker (NW)		Retiree(RT)	
	Coeff	T-Stat	Coeff	T-Stat
Discretionary tours >=2	0.1253			
Household income & Tour Purpose				
low Income group (<30K) & shopping tour	-0.2599			
Medium low Income group (30K-60K) & shopping tour	-0.2599			
High Income group (100-150K) & shopping tour			0.4056	
High Income group (>150K) & shopping tour			0.4056	
Low Income group (<30K) & Maintenance tour			-0.2202	
Medium low Income group (30K-60K) & Maintenance tour			-0.2202	
Low Income group (<30K) & Eating Out tour	-0.2857		-1.0384	
Medium low Income group (30K-60K) & Eating Out tour			-0.4217	
High Income group (100-150K) & Eating Out tour				
High Income group (>150K) & Eating Out tour	2.2230			
High Income group (100-150K) & Visiting tour	0.2695			
High Income group (>150K) & Visiting tour	0.2695		-1.1040	
Low Income group (<30K) & Discretionary tour	-0.5775		-0.3758	
Medium low Income group (30K-60K) & Discretionary tour	-0.5775			
High Income group (100-150K) & Discretionary tour			0.1222	
High Income group (>150K) & Discretionary tour			0.1222	
Gender				
Female & Escorting Tour	0.6769			

Utility Terms	Non-Worker (NW) Coeff	Non-Worker (NW) T-Stat	Retiree(RT) Coeff	Retiree(RT) T-Stat
Female & Shopping Tour	0.5108		-0.0455	
Female & Eating Out Tour			-0.2472	
Female & Maintenance Tour			-0.2926	
Female & Visiting Tour	0.7494			
Female & Discretionary Tour			-0.0647	
Car sufficiency & tour frequency				
zero car ownership & tour frequency =2+	-1.0038			
Cars Less than Workers & tour frequency =2+				
Cars more than Workers & tour frequency =1+				
Cars more than Workers & tour frequency =3+				
Zero Car ownership, Escorting	-0.8907			
Cars Less than Workers, Escorting				
Cars more than Workers, Escorting	0.1802			
Cars Less than Workers, Shopping				
Cars more than Workers, Shopping				
Household interactions with tour frequency				
Number of Non-Workers (other than modeled person) & Escorting tour	-0.3489		-0.1294	
Number of Full time Workers (other than modeled person) & Escorting tour	0.2514		-0.1294	
Number of Part time Workers (other than modeled person) & Escorting tour	0.2512		-0.1294	
Number of Driving School Kids (other than modeled person) & Escorting tour	0.7483		0.6054	
Number of University Students (other than modeled person) & Escorting tour	0.4583			
Number of Retirees (other than modeled person) & Escorting tour	0.2841			
Number of "Not at home" Pre-Driving School Kids & Escorting tour	0.9378		0.7285	
Number of "Not at home" Pre-School	0.9374			

Utility Terms	Non-Worker (NW) Coeff	Non-Worker (NW) T-Stat	Retiree(RT) Coeff	Retiree(RT) T-Stat
Kids & Escorting tour				
Number of Non-Workers (other than modeled person) & Shopping tour	-0.4780			
Number of Retirees (other than modeled person) & Shopping tour			-0.4462	
Number of Full time Workers (other than modeled person) & Maintenance tour	0.0904			
Number of Part time Workers (other than modeled person) & Maintenance tour	0.0904			
Number of Retirees (other than modeled person) & Maintenance tour			-0.4112	
Number of Pre-School Kids (other than modeled person) & Eating Out tour	-0.6629			
Number of Pre-Driving School Kids (other than modeled person) & Eating Out tour	-0.6629			
Number of Pre-School Kids (other than modeled person) & Visiting tour	-0.4021			
Number of Pre-Driving School Kids (other than modeled person) & Visiting tour	-0.4021			
Number of Retirees (other than modeled person) & Visiting tour			-0.2327	
Number of Pre-School Kids (other than modeled person) & Discretionary tour	-0.2039			
Number of Pre-Driving School Kids (other than modeled person) & Discretionary tour	-0.2039			
Number of Driving School Kids (other than modeled person) & Discretionary	-0.2039			

Utility Terms	Non-Worker (NW) Coeff	Non-Worker (NW) T-Stat	Retiree(RT) Coeff	Retiree(RT) T-Stat
tour				
All Retirees and Non-workers only, Escorting			-0.8133	
All Retirees and Non-workers only, Shopping			0.2715	
All Retirees and Non-workers only, Eating out			0.2011	
All Retirees and Non-workers only, Discretionary			0.2624	
Retail Accessibility by Purpose				
Retail Accessibility for Escorting	0.1609		0.5109	
Retail Accessibility for Shopping			0.2262	
Retail Accessibility for Maintenance	0.0194		0.1154	
Retail Accessibility for Visiting/visit	0.2883		0.0533	
Retail Accessibility for Discretionary	0.0632		0.3252	
Walk Accessibility by Purpose				
Walk Accessibility for Eating Out	0.6073			
Education				
College Education & Escorting tour			0.1522	
College Education & Shopping tour	0.3677		0.2046	
College Education & Maintenance tour	0.5982			
College Education & Eating Out tour	0.7979			
College Education & Visiting tour			0.2179	
College Education & Discretionary tour	0.9810		0.3046	
Less than High School Education & Escorting tour	0.1748		-0.8443	
Less than High School Education & Shopping tour	-0.3525		-0.5676	
Less than High School Education & Eating Out tour	-0.4838			
Less than High School Education & Visiting tour	-1.6201			

Utility Terms	Non-Worker (NW)		Retiree(RT)	
	Coeff	T-Stat	Coeff	T-Stat
Less than High School Education & Maintenance tour			-0.6861	
Less than High School Education & Discretionary tour	-0.8370		-0.8504	
Household type and purpose				
Detached Household & Escorting tour			0.3809	
Detached Household & EatingOut tour			-0.3389	
Detached Household & Discretionary tour			-0.3286	
Alternative Specific Constant Adjustment				
Escorting Tours =1	-2.5926		-2.6765	
Shopping tours = 1	-2.7528		-2.6195	
Maintenance tours = 1	-2.9488		-3.0911	
Eating Out tours > 0	-3.0827		-3.0181	
Visit tours > 0	-2.9418		-2.9249	
Discretionary tours = 1	-2.6656		-2.7533	
Escorting tours >=2	-2.0666		-2.6408	
Shopping tours >=2	-3.0643		-2.3634	
Maintenance tours >=2	-3.1290		-3.3222	
Discretionary tours >=2	-2.7486		-2.5989	

Table 72: Implemented coefficients for Individual Non-Mandatory Tour Frequency for Driving Age School Children, Pre-Driving Age School Children and Pre-School Children

Utility Terms	Driving Age School Children (SD)		Pre-Driving Age School Children (SP)		Pre-School Children (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Constant by tour frequency						
Total Number of Tours = 0 (No Prior Tours)	-999.0000		-999.0000		-999.0000	
Total Number of Tours = 0 (1 or more Prior Tours)	0.0000				0.0000	
Total Number of Tours = 1+	-0.4825					
Total Number of Tours = 2			-0.7045		-0.7216	
Total Number of Tours = 3			-0.7045		-0.9586	
Total Number of Tours = 4+			-999.0000		-999.0000	
Constant by tour frequency with purpose						
One or more Mandatory tour & tour frequency =1			-1.8596			
One or more Mandatory tour & tour frequency =2+	-2.5161		-6.1247		-2.1108	
One or more Joint tour & tour frequency =1+			-1.0154			
Number of Discretionary Joint Tours >0	-0.2308		-1.2257			
Number of Escorting tours >0	-5.0011		-10.3136		-7.2688	
Number of Shopping tours >0	-16.7785		-17.8882		-43.4464	
Number of Maintenance tours >0	-3.2583		-14.5925		-3.3790	
Number of Eating Out tours >0	-18.1598		-42.1591		-5.2924	
Number of Visit tours >0	-2.6366		-2.9744		-4.0352	
Number of Discretionary tours >0	-2.0687		-8.0543		-4.2006	
Escorting tours >=2			0.3358		2.3269	
Shopping tours >=2						
Discretionary tours >=2	-1.1938		-0.8724			
Household income						
Low Income group (<30K) & Escorting tour	1.1208					
Medium low Income group (30K-60K) & Escorting tour	1.1208					

Utility Terms	Driving Age School Children (SD)		Pre-Driving Age School Children (SP)		Pre-School Children (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
High Income group (>150K) & Escorting tour					-0.6921	
Low Income group (<30K) & Visiting tour			-1.6227			
Medium low Income group (30K-60K) & Visiting tour			-1.6227			
High Income group (100-150K) & Visiting tour	0.5513					
High Income group (>150K) & Visiting tour	0.5513		1.1424			
Low Income group (<30K) & Discretionary tour	-0.8053		-1.6227			
Medium low Income group (30K-60K) & Visiting tour			-1.6227			
High Income group (100-150K) & Discretionary tour	0.5225					
High Income group (>150K) & Discretionary tour	0.8604		1.1424			
Gender						
Female & Shopping Tour	0.9646					
Car sufficiency						
Zero Car ownership, Escorting					-0.9936	
Cars Less than Workers, Escorting					-0.9936	
Cars more than Workers, Maintenance			0.4721			
Cars more than Workers, Discretionary			0.1531			
Household interactions						
Number of Non-Workers (other than modeled person) & Escorting tour					0.7831	
Number of Part time Workers (other than modeled person) & Escorting tour					0.7831	
Number of University Students (other than modeled person) & Escorting tour					0.8044	
Number of "Not at home" Pre-Driving School Kids & Escorting tour	0.4901		0.4372		0.5152	

Utility Terms	Driving Age School Children (SD)		Pre-Driving Age School Children (SP)		Pre-School Children (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Number of "Not at home" Pre-School Kids & Escorting tour					0.6072	
Number of Non-Workers (other than modeled person) & Shopping tour	0.3173					
Number of Full time Workers (other than modeled person) & Shopping tour	0.3173					
Number of Part time Workers (other than modeled person) & Shopping tour	0.3173					
Number of Pre-School Kids (other than modeled person) & Shopping tour	0.3133		-0.1631			
Number of Pre-Driving School Kids (other than modeled person) & Shopping tour	0.3133		-0.1631			
Number of Driving School Kids (other than modeled person) & Shopping tour			-0.1631			
Number of Pre-School Kids (other than modeled person) & Visiting tour			0.3656			
Number of Pre-Driving School Kids (other than modeled person) & Visiting tour			0.3656			
Number of Driving School Kids (other than modeled person) & Visiting tour			0.3656			
Number of Non-Workers (other than modeled person) & Discretionary tour	0.3202					
Number of Part time Workers (other than modeled person) & Discretionary tour	0.3202					
Number of University Students (other than modeled person) & Discretionary tour	0.5522					
Number of Pre-School Kids (other than modeled person) & Discretionary tour			0.2287			
Number of Pre-Driving School Kids			0.2287			

Utility Terms	Driving Age School Children (SD)		Pre-Driving Age School Children (SP)		Pre-School Children (PS)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
(other than modeled person) & Discretionary tour						
Number of Driving School Kids (other than modeled person) & Discretionary tour			0.2287			
School Accessibility & Tour Frequency						
School Accessibility & Tour Frequency =1			0.6512			
School Accessibility & Tour Frequency =2+	1.9398		3.8532			
Retail Accessibility by Purpose						
Retail Accessibility for Escorting			0.5583		0.2739	
Retail Accessibility for Shopping	0.7809		0.9818		2.7431	
Retail Accessibility for Maintenance			0.8866			
Retail Accessibility for Eating Out	1.0093		2.8733			
Retail Accessibility for Discretionary			0.5082			
Alternative Specific Constant Adjustment						
Escorting Tours =1	0.1831		-0.4416		-8.8413	
Shopping tours = 1	1.3627		1.4818		-4.9117	
Maintenance tours = 1	-0.2971		-1.3168		-8.3014	
Eating Out tours > 0	-1.3136		-4.3127		-8.2128	
Visit tours > 0	-0.0383		-0.4585		-8.1567	
Discretionary tours = 1	-0.3194		-0.2932		-8.0038	
Escorting tours >=2			-0.7947		-9.7945	
Maintenance tours >=2					-7.7026	
Discretionary tours >=2	-1.0597		-0.4554		-15.0000	

4.4.2 Individual Non-Mandatory Tour Primary Destination Choice

The non-mandatory purpose destination choice model was estimated using SANDAG's 2006 household interview survey. Non-mandatory purposes are those other than work and school. A number of explanatory variables were tested in the destination choice models, including mode choice logsums (as a measure of accessibility), travel distance, household and person attributes (such as household income, auto ownership, number of adults, person age), and land-use or urban form variables (such as population-to-employment ratio, employment density, and intersection density). The models were estimated in ALOGIT software as a multinomial logit model.

Utility Specification

The tour destination choice model predicts the primary destination for the tour at the level of the Master Geographic Reference Area (MGRA). There are a total of 23002 MGRAs in the San Diego regional travel demand model. There are two stages involved in both the estimation and application of the model. In the first phase, a list of sampled MGRAs is created by the sampling procedure described below. In the second phase, the full model is applied to each sampled alternative and a destination MGRA is selected. The two-stage procedure is necessary in order to minimize the computational burden associated with computing mode choice logsums for each tour to each of 23002 MGRAs. In estimation, 600 destination MGRAs were sampled. In application, the model considers 30 sampled MGRAs.

The utility (U_{ijn}^{k}) of choosing a destination MGRA (j) for an individual (n) for purpose (k) from origin MGRA (i) is given by Equation 1.

$$U_{ijn}^{k} = S_{j}^{k} + \alpha^{k} \times L_{ij} + \sum_{p} \beta^{pk} \times D_{ij}^{p} + \sum_{q} \gamma^{qk} \times D_{ij} N_{n}^{q} + C_{jn}$$

Where:

Segment (*k*) = the tour purpose

S_{j}^{k} = the size function for destination zone *j* and tour purpose *k*

L_{ij} = the mode choice logsum between zone pair *ij* (see below for a more complete description of how this logsum is calculated). Note that the term on mode choice logsum is expected to be between 0 and 1. A negative term would be counter-intuitive as it would suggest that the probability of selecting a destination is inversely proportional to the accessibility of the destination. A term between 0 and 1 ensures that cross-elasticities with respect to mode choice alternatives are higher than between destinations.

D_{ij}^{p} = the various distance terms (p = linear, log, squared, and cubed)

N_{n}^{q} = the q[th] person /household characteristics (such as income, age group, person type) for individual n. Used for creating interaction variables with linear distance (D_{ij}),

C_{jn} = a correction term to compensate for the sampling error in the model estimation (i.e. represent the difference between the sampling probability and final estimated probability for each alternative). The appendix explains how this correction factor is calculated.

The size function (S_{j}^{k}) for destination j, purpose k is a combination of different (*d*) size variables (S_{jd}^{k}) such as enrollment, employment by class, households, and their interaction with person/household characteristics. It is included in the utility function as a log term, as shown in Equation 2. The coefficients (γ_{d}^{k}) on the size terms are constrained as positive in the estimation process. Note that the implied value of the coefficient on the first size term variable (d=1) is 1. This is to ensure that the size term is not over-specified; all other parameter values are interpreted as ratios of the impact of their corresponding independent variable to the first size term variable.

Size term parameters can be estimated using multiple linear regressions where employment types, enrollment, and/or households by MGRA are used as independent variables and total tours attracted to each destination MGRA are dependent variables. Alternatively, size term parameters can be simultaneously estimated with other destination choice parameters in ALOGIT. Size terms were initially estimated using a regression analysis as documented in the Accessibility Measures for the SANDAG ABM paper. The results of that analysis informed the size terms that should be used for each purpose in this estimation, but new size term parameters were estimated simultaneously with other destination choice model terms in the estimation process. The results of this estimation then replaced the size term values for the purposes estimated in the original regressions (which did not consider spatial separation or other variables).

Equation 2

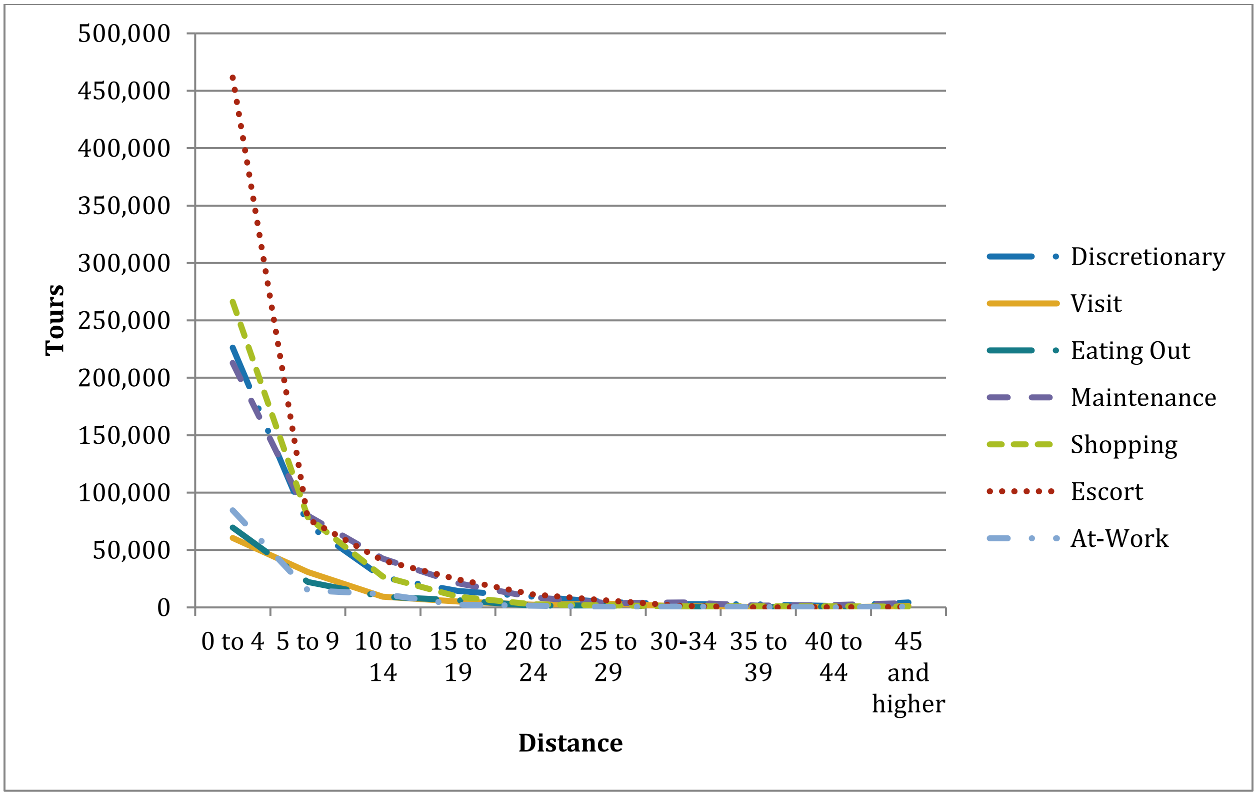
$$S_j^k = \log(S_{j1}^k + \sum_{d>1} \gamma_d^k \times S_{jd}^k)$$

A combination of distance terms is used in the utility such that the composite distance utility function is monotonically decreasing within the maximum chosen distance range. Table 70 shows observed expanded non-mandatory tours by purpose and distance range, and Figure 31 shows the trip length frequency distribution for non-mandatory tours.

Table 70: Expanded Observed Tours by Distance to Primary Destination and Tour Purpose

Miles	Discretionary	Visit	Eating Out	Maintenance	Shopping	Escort	At-Work
0 to 4	226,296	60,478	69,547	212,924	266,169	461,465	84,574
5 to 9	72,057	30,893	22,284	79,860	78,386	76,760	15,034
10 to 14	26,002	9,453	9,394	42,502	26,990	40,788	11,470
15 to 19	14,296	5,062	6,206	20,963	9,418	24,434	2,270
20 to 24	9,251	2,350	1,610	8,727	2,759	11,258	1,430
25 to 29	4,596	3,115	1,873	3,688	1,683	6,087	548
30 to 34	2,803	1,072	303	4,243	844	1,121	563
35 to 39	2,728	324	0	1,570	888	0	288
40 to 44	1,268	0	794	2,160	890	246	0
45 and higher	4,215	1,327	0	3,822	665	275	714
Total	**363,512**	**114,074**	**112,011**	**380,459**	**388,692**	**622,434**	**116,891**

Figure 31: Observed Tour Length Frequency Distribution to Primary Destination by Tour Purpose



A probability sampling procedure was used to select MGRAs as alternatives for estimation. The same procedure is also used in model application. The sampling procedure applies a simple multinomial logit model to create a probability distribution of 23002 MGRAs for every sample record. The sampling model considers only the distance from origin MGRA to destination MGRA and the size term of the destination MGRA for the sample record tour purpose[2]. Each destination MGRA is assigned a probability computed from this simple model and a Monte Carlo selection is made according to the probability distribution to obtain the sampled MGRAs. The full destination choice model is then applied (or estimated) on the sampled MGRAs. The full destination choice model includes a mode choice logsum term, distance terms, and other significant variables. The model also includes a correction factor that accounts for the frequency of selection of the sampled alternative and the selection probability according to the sampling model. The correction factor is described more fully in the appendix. Note that distance terms are required in addition to the mode choice logsum term in order to match the non-linear shape of the trip length frequency distribution. The distance terms include distance, the square of distance, distance cubed, and the log of distance.

In model estimation, we tested household and person variables that interact with one-way tour distance, mode choice logsum, and size terms and measure the quantity of activity opportunities in the destination MGRA. Size terms include number of households in the destination MGRA and number of employees by different occupation categories.

[2] For a description of size terms used for sampling, see the paper Accessibility Measures for the SANDAG ABM, dated May 20, 2010.

Estimation Dataset

The 2006 SANDAG household interview survey was utilized for this estimation. In order to estimate a choice from the 600 destinations, each survey record was replicated 20 times in the estimation file, and 30 destinations were sampled for each observation. A weight was used in estimating the model to account for the replication of each observed tour record (equal to 0.05, or 1/20). These weights have the effect of reducing the size of T-Statistics accordingly. For each sampled MGRA, the data appended to the estimation file included the MGRA number, the parent TAZ number, the frequency of selection, the sampling probability, the distance from the tour origin to the sampled MGRA, the size term characteristics of the sampled MGRA (number of households, employment by type, enrollment by school grade level), and a mode choice logsum term based on the tour purpose and person and household attributes.

Calculation of Mode Choice Logsums

It would be preferable to transfer logsums from the full time-of-day choice model to the destination choice model. However, this would be computationally burdensome because it would require applying the mode choice model for each of 15 time-period combinations (outbound/return) for each of 30 sampled destinations for every tour[3]. As an alternative, a simplified time-of-day choice model utilizing only three outbound/return time period combinations of mode choice logsums is used. The logsum of this simplified model, which is essentially a weighted average mode choice logsum, is used as a representative mode choice logsum for use in destination choice. Three time periods were chosen as representative for each non-mandatory purpose based on the observed departure/arrival frequency distribution. Alternative-specific constants were then calculated for each of the three time period combinations according to the observed frequency, as shown in Equation 3.

Equation 3

$$C_{o,r}^{k} = \left(\frac{Obs_o^k}{\sum_o Obs_o^k} \times 0.5 \right) + \left(\frac{Obs_r^k}{\sum_r Obs_r^k} \times 0.5 \right)$$

Where:

$C_{o,r}^{k}$ is the alternative-specific constant (C) for purpose (*k*), representative outbound period (*o*) and representative inbound period (*r*)

Obs_o^k is the number of expanded tours for purpose (*k*) departing in representative outbound period (*o*), and

Obs_r^k is the number of expanded tours for purpose (*k*) arriving back at the tour origin in representative inbound period (r).

The mode choice logsum across all time-periods is calculated as shown in Equation 4.

[3] See Technical Memorandum: Time of Day Choice Estimation Results, Dated October 29, 2010.

Equation 4

$$L^k = \ln[\sum_{o,r}(M^k_{o,r} + C^k_{o,r})]$$

Where:

L^k is the mode choice logsum used for destination choice for purpose (k)

$M^k_{o,r}$ is the mode choice logsum for outbound period (o) and inbound period (r) and purpose (k)

Note that household and person level attributes, as well as tour origin (i) and sampled destination (j), are implied and are not included in the denotation of the mode choice logsum formula.

Representative time periods were chosen based on the highest frequency outbound and inbound periods as observed in the expanded data by purpose. It was also important to minimize repetition of time periods already considered in previously chosen representative periods. For example, if "midday outbound-midday inbound" was chosen as the first representative logsum, "midday outbound-P.M. inbound" was unlikely to be chosen for the second representative logsum. Table 71 shows the frequency of non-mandatory tours by outbound and inbound time periods. Table 72 shows the constants of the logit model used to calculate a time-of-day/mode logsum for each purpose. The highlighted cells indicate the three representative time periods used for each purpose.

Table 71: Observed Non-Mandatory Tours by Outbound and Inbound Time Periods and Tour Purpose

Outbound Percent							
Period	Escorting	Shopping	Maintenance	Eating Out	Visit	Discretionary	At-Work
1-Early	0.4%	0.1%	0.6%	0.8%	0.0%	2.4%	0.0%
2-AM Peak	34.5%	5.8%	18.0%	4.9%	9.9%	19.3%	6.4%
3-Midday	39.8%	64.5%	59.0%	36.3%	37.4%	31.0%	90.6%
4-PM Peak	20.1%	20.4%	19.9%	49.1%	37.4%	40.5%	2.3%
5-Evening	5.2%	9.3%	2.5%	8.8%	15.4%	6.7%	0.7%
Inbound Percent							
Period	Escorting	Shopping	Maintenance	Eating Out	Visit	Discretionary	At-Work
1-Early	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
2-AM Peak	29.9%	1.8%	3.8%	0.9%	2.7%	6.1%	2.1%
3-Midday	38.5%	56.1%	57.3%	34.3%	26.2%	33.1%	88.1%
4-PM Peak	24.2%	26.5%	26.5%	24.3%	23.7%	27.2%	8.6%
5-Evening	7.3%	15.6%	12.3%	40.5%	47.4%	33.6%	1.2%

Table 72: Simplified Time-of-Day Choice Model Alternative-Specific Constants

Outbound Time Period	Return Time Period	Escorting	Shopping	Maintenance	Eating Out	Visit	Discretionary	At-Work
2-AM Peak	2-AM Peak	-1.0658	0.0000	0.0000	0.0000	0.0000	0.0000	-3.1453
2-AM Peak	3-Midday	0.0000	0.0000	-0.9419	0.0000	0.0000	-1.2589	0.0000
3-Midday	3-Midday	-0.8711	-0.4672	0.0000	-1.0073	-1.0815	0.0000	-0.1029
3-Midday	4-PM Peak	0.0000	0.0000	-0.8140	0.0000	0.0000	-1.1551	0.0000
4-PM Peak	4-PM Peak	-1.4395	-1.4114	0.0000	-0.9689	-1.1213	0.0000	-2.9056
4-PM Peak	5-Evening	0.0000	0.0000	-1.7897	0.0000	0.0000	-0.9138	0.0000
5-Evening	5-Evening	0.0000	-2.0448	0.0000	-1.3654	-1.0935	0.0000	0.0000

Home Based Shop Model Estimation

The first model estimated was the home-based shop purpose. This purpose had 19,262 records with an available chosen destination in the survey set.

Model Estimation Findings:

- The initial model runs tested just the mode choice logsum and the distance size terms. After several runs, distance was capped at 10 miles to ensure that the non-linear terms on distance result in a monotonically decreasing probability distribution. For MGRAs over 10 miles from the origin MGRA, the mode choice logsum will continue to decrease in size, such that the utility will monotonically decrease over 10 miles. Size terms for retail and restaurant and bar employment were included in this estimation. Both of these variables were significant in the original regression analysis of SANDAG's accessibilities. In the original regression, the restaurant and bar term came out larger in magnitude than the retail employment term, meaning that restaurant and employment was a better predictor of shopping location choice. This was a surprising result since it would be expected that retail employment is a better predictor of shopping choice. The same result occurred in initial estimation runs for the destination choice estimation. However, when the accessibility term was included, the restaurant and bar term became smaller than the retail term, as expected. In this case, restaurant and bar employment had some explanatory power for locations with many activity choices in one place.
- The effect of distance on travelers by income class was tested. These results were not significant, although the highest income group and the unknown income class were close to significance. Those were maintained for a few more model runs before they were dropped because the significance was not improving.
- The effect of distance on travelers of different age groups was tested. These results were not significant. The lowest age group and unknown age group were close to being significant so these were maintained for several additional runs, but were eventually dropped because the significance was not improving.
- The effects of distance were tested on gender, with a positive and significant effect on females. That means that women are more likely than men to travel farther on their shopping tours.

- Density variables were tested. The mixed density (a combination of employment and dwelling units) was tested at the origin end of the tour. The density of intersections was also tested at the origin end of the tour. These variables are an attempt to measure the effects of urban design on tour length. In the estimation, the density measures tested yielded positive coefficients when interacted with distance, which is the opposite of what was expected. These measures were dropped on the basis that density effects are likely already being measured sufficiently through the tour mode choice logsum, which includes density effects, particularly for non-motorized modes.
- The effects of distance were also tested on 0 auto households. One would reasonably expect that 0 auto households would travel shorter distances, as they do not have easy access to a vehicle. However, the estimated result was positive and so it was not used. Again, it is likely that the effects of auto sufficiency are already taken into account by the mode choice logsum term.
- A time pressure variable was created and interacted with distance. Time pressure is the amount of time a person has left to schedule their remaining tours for the day, after all higher-importance (according to tour purpose hierarchy) tours have been scheduled. The variable is created by dividing the maximum remaining continuous time window by the number of remaining tours according to the tour hierarchy. The resulting number of remaining tours includes all types of tours with the same or lower priorities which are not scheduled before the tour in question. The remaining tours include the current tour, and so it is never 0. Time pressure was tested in both logged and unlogged form. The logged version was maintained, as it was both positive and significant. A positive coefficient means that if there is more time to allow for the remaining tours, the person will be more likely to travel further.
- The non-motorized and non-mandatory accessibility of each destination was also tested. This was not interacted with distance, meaning that a destination is more attractive if it has more accessibility to non-mandatory purposes such as shopping and eating. The interpretation is that a person may be more likely to choose a destination for a shop tour where there is accessibility to places to eat. In the estimation, the accessibility term was positive and very significant, which means that destinations with a higher accessibility will be more attractive to travelers.

Table 73: Shop Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.5
Distance	-0.25581 (-3.78)
Distance Squared	-0.00310 (-1.66)
Log of Distance	-0.22941 (-1.47)
Log of Time Pressure	0.02945 (1.84)
Accessibility - Non-motorized, non-mandatory	0.37732 (5.68)
Retail Exponentiated Size Term	1
Initial Likelihood	-4948
Final Likelihood	-4071

Final Model:

- For the final model estimation, only the retail employment size term was included. The restaurant/bar size term has mixed results across all estimations, and retail employment is a good predictor of shopping opportunities. The non-motorized accessibility term to non-mandatory activities is also significant (see below) and is likely accounting for the attractiveness of certain shopping locations to other, non-shopping activities (such as eating a meal as an intermediate stop on a shopping tour). The final values of the size terms are contained inTable 87.
- The mode choice logsum was asserted at .5. When tested by itself, the mode choice logsum estimated at 1.106, but when distance terms were included, the logsum term became insignificant. Since 1 is the maximum expected value for a mode choice logsum, the coefficient was set approximately halfway between the estimate and the minimum of 0.
- Distance terms for distance, distance squared, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.
- The female coefficient became insignificant in later estimations and was dropped from the final.
- Time pressure was maintained in the final estimation, as it was a positive and significant value.
- Accessibility was also maintained, as it was positive and significant.

The final implemented coefficients for the selected variables are shown in

Table 74.

Table 74: Implemented Destination Choice Model for Shopping

Variable	Coefficient
Sample of alternatives correction factor	1.000000
Mode choice logsum	0.50000
Distance	-0.255811
Distance squared	-0.003099
Distance logged	-0.229414
Distance - Time Pressure calculated as the log of the maxtime over tours left	0.029451
Accessibility	0.377323
Size Term - Shopping	1.000000
Size Term variable – shopping = 0	-999.0
Calibration - Distance	0.581621
Calibration - Distance_squared	-0.135740
Calibration - Distance_cubed	0.009042
Calibration - Distance_logged	-1.332207
Calibration - 0-1 miles	-0.347721
Calibration - 1-2 miles	-0.234057
Calibration - 2-5 miles	-0.020812
Mission Valley Mall Constant	-0.500000
Mission Valley Mall Constant	-0.500000

Home Based Discretionary Model Estimation

The home based discretionary purpose had 5,414 records with an available chosen destination in the dataset.

Model Estimation Findings:

- The initial model run was based on the final shop model, although it only included the linear distance terms. Non-linear distance terms were tested in later model runs. As with the shopping purpose, distance was capped at 10 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.
- Size terms included for this purpose were the number of households, religious employment, restaurant/bar employment, amusement employment, hotel employment, and retail employment. These variables were all significant in the original regression analysis of SANDAG's accessibilities. Religious employment was used as the base for estimation, since it had the highest value in the regression analysis.
- The effects of distance on travelers of different genders were tested. Females had a negative and significant effect, meaning that they travel shorter distances for their discretionary tours than males do.

- The effects of distance on travelers of different income classes were also tested. The income variables were not significant. The very low and very high income categories were close, and therefore maintained for a few runs, but were dropped when they did not become significant.
- The effect of distance on travelers of different age groups was also tested, with no significant results.
- The mixed use variable was tested at the origin MGRA location and did not yield reasonable results. The value came out as positive and should have been negative, as explained in the shopping purpose section.
- The logged time pressure variable was included in this estimation and was both positive and significant for most model runs. This is the expected result, as explained in the shopping purpose section. It means that people are more likely to travel further if they have more time left for their tours.

Table 75: Discretionary Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.4
Distance	0.54342 (1.52)
Distance Squared	-0.0653 (-2.28)
Distance Cubed	0.00172 (2.14)
Log of Distance	-1.52485 (-3.02)
Log of Time Pressure	0.054 (1.85)
Religious Activity Exponentiated Size Term	1
Restaurant/Bar Exponentiated Size Term	0.159
Amusement Exponentiated Size Term	0.203
Hotel Exponentiated Size Term	0.035
Retail Exponentiated Size Term	0.047
Households Exponentiated Size Term	0.043
Initial Likelihood	-915
Final Likelihood	-874

Final Model:

- For the final model estimation, all of the tested size terms were maintained. Religious activity employment (the base) had the largest magnitude at 1 when exponentiated. The final values of the size terms are contained inTable 87.
- The mode choice logsum was asserted at 0.4, which is halfway between 0 (the estimated logsum term when distance terms were included) and the estimated mode choice logsum value of 0.8 (in the absence of distance terms).

- The linear distance terms of distance and distance squared were maintained, as were the non-linear terms of distance cubed and the log of distance. The inclusion of the distance cubed and the log of distance makes this a non-linear distance expression.

The final implemented coefficients for the selected variables are shown in Table 76.

Table 76: Implemented Destination Choice Model for Discretionary

Variable	Coefficient
Sample of alternatives correction factor	1.0000
Mode choice logsum	0.40000
Distance	0.543421
Distance squared	-0.065311
Distance cubed	0.001720
Distance logged	-1.524852
Distance - Time Pressure calculated as the log of the maxtime over tours left	0.054074
Size Term - Other Discretionary	1.000000
Size Variable - Other Discretionary = 0	-999.0
Distance - Calibration Adjustment	0.0066
Calibration - Distance	0.218090
Calibration - Distance_squared	-0.052328
Calibration - Distance_cubed	0.002659
Calibration - Distance_logged	-0.188325

Home Based Maintenance Model Estimation

The home based maintenance purpose had 14,380 records with an available chosen destination in the data set.

Model Estimation Findings:

- The initial model run was based on the final shop model, although it only included the linear distance terms. Non-linear distance terms were tested in later model runs. Similar to the shopping purpose, distance was capped at 8 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.
- The size terms tested for this purpose were employment in retail, federal non-military, personal services retail based, and professional and business services. These were all significant in the original regression analysis of SANDAG's accessibilities. Retail was used as the base for estimation since it had the highest value in the regression analysis.
- The effects of distance on travelers of different genders were tested. Females had a positive and significant effect, meaning that they travel longer distances for their discretionary tours than males do. In later model runs, this variable became insignificant as non-linear distance terms were included.
- The effects of distance on travelers of different income classes were also tested. The results were not significant. The very low income category was close, and it fluctuated around significance in several model runs.
- The effects of distance on travelers of different ages were also tested. The lowest age group was close to significance in the initial model run, and became significant in later runs. The sign on the coefficient was negative, meaning that persons aged 16 to 24 travel shorter distances for their maintenance tours than people in the base age group of 25 to 40.
- The effects of distance were also tested on 0 auto households. One would reasonably expect that 0 auto households would travel shorter distances, as they do not have easy access to a vehicle. That would mean the coefficient would be negative. However, the estimated result was positive and so it was not used.
- The mix density was tested at the origin MGRA location and did not yield reasonable results. The value came out as a positive, and it should have been negative, as previously explained.
- The logged time pressure variable was included in this estimation and was both positive and significant for most model runs. This is the expected result, as explained in the shopping purpose section. It means that people will travel further if they have more time left for their tours.
- The non-motorized and non-mandatory accessibility of each destination was also tested. As with the shop purpose, it was not interacted with distance, meaning that a destination is more attractive if it has more accessibility. The expected result is therefore a positive coefficient. In this case, the estimation resulted in a negative value, so it was dropped from estimation.

Table 77: Maintenance Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.5
Distance	-0.035 (-0.54)
Distance Squared	-0.008 (-4.45)
Log of Distance	-0.504 (-3.30)
Age 16 - 24	-0.086 (-1.79
Log of Time Pressure	0.026 (1.72)
Retail Exponentiated Size Term	1
Federal Non-Military Exponentiated Size Term	0.720
Personal Services Retail Based Exponentiated Size Term	2.456
Professional and Business Services Exponentiated Size Term	0.845
Initial Likelihood	-4630
Final Likelihood	-4616

Final Model:

- For the final model estimation, all of the tested size terms were maintained. The largest size term was Personal Services Retail Based Employment, which makes sense for the maintenance purpose. Second largest was the Rail Activity employment, followed by the Professional and Business Services employment and Federal Non-Military employment. The final values of the size terms are contained in Table 87.
- The mode choice logsum was constrained to 0.5. In the run where the logsum was tested by itself, it resulted in a value of 0.998. Therefore 0.5 was chosen as it is halfway between 0 and the estimated value.
- Distance terms for distance, distance squared, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.
- The youngest age group (ages 16 to 24) did have a significant and negative value in the final run. This means that younger travelers are likely to go shorter distances for this purpose.
- The logged time pressure was positive and significant, meaning that if there is more time, a traveler may choose to go further.

The final implemented coefficients for the selected variables are shown in

Table 78.

Table 78: Implemented Destination Choice Model for Maintenance

Variable	Coefficient
Sample of alternatives correction factor	1.000000
Mode choice logsum	0.50000
Distance	-0.035327
Distance squared	-0.007959
Distance - age 16-24	-0.503857
Distance - Time Pressure calculated as the log of the maxtime over tours left	0.025736
Size Term – Maintenance	1.000000
Size variable – Maintenance =0	-999.0
Calibration - Distance	0.2641
Calibration - Distance_squared	-0.0396
Calibration - Distance_cubed	0.0023
Calibration - Distance_logged	-1.4297
Calibration - 0-1 miles	-0.0214
Calibration - 1-2 miles	-0.1938
Calibration - 2-5 miles	0.0000

Home-Based Eating Out Model Estimation

The home based eating out purpose had 3612 records with an available chosen destination in the data set.

Model Estimation Findings:

- The initial model run was based on the final shop model, although it only included the linear distance terms. Non-linear distance terms were tested in later model runs. As with the shopping purpose, distance was capped at 10 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.
- Size terms tested for this purpose included both employment in the restaurant/bar sector, as well as households, which are the two attractors of eating out tours.
- The effects of distance on gender were tested, with no significant results.
- The effects of distance on travelers of different income classes were also tested. The very low income category was significant in the very first test, but then became insignificant and was dropped.
- The effects of distance on travelers of different age groups were also tested, with no significance in any age group.
- The effects of distance were also tested on 0 auto households, with no significance.
- The mix density was tested at the origin MGRA location, both by itself as one value and also as split into three bins. The intersection density was also tested at the origin MGRA location. There was some significance, but the values came out as a positive. As explained in previous

sections, these should have been negative in order to be reasonable, therefore they were dropped.

- The logged time pressure variable was included in this estimation and was positive but not significant. This is the expected result, as explained in the shopping purpose section. It means that people will travel further if they have more time left for their tours.
- The non-motorized and non-mandatory accessibility of each destination was also tested. As with the shop purpose, it was not interacted with distance, meaning that a destination is more attractive if it has more accessibility. In this case, the estimation resulted in a negative value, so it was dropped.

Table 79: Eating Out Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.5
Distance	0.09472 (0.26)
Distance Squared	-0.0.02912 (-0.95)
Distance Cubed	-0.00065 (0.74)
Log of Distance	-0.66460 (-1.44)
Time Pressure Logged	0.028 (0.90)
Restaurant/Bar Exponentiated Size Term	1
Households Exponentiated Size Term	0.551
Initial Likelihood	-871
Final Likelihood	-601

Final Model:

- For the final model estimation, the tested size term was maintained. The final values of the size terms are contained in Table 87.
- The mode choice logsum was constrained to 0.5. In the run where the logsum was tested by itself, it resulted in a value of 0.938. Therefore 0.5 was chosen as it is halfway between 0 and the estimated value.
- The linear distance terms of distance and distance squared were included, as well as the non-linear terms of distance cubed and the log of distance. The inclusion of the distance cubed and the log of distance makes this a non-linear distance expression.
- Although the logged time pressure was not significant, it was positive as expected. This coefficient has potential policy applications and therefore was maintained in the final estimation.

The final implemented coefficients for the selected variables are shown in

Table 80.

Table 80: Implemented Destination Choice Model for Eating Out

Variable	Coefficient
Sample of alternatives correction factor	1.000000
Mode choice logsum	0.50000
Distance	0.094725
Distance squared	-0.029121
Distance cubed	0.000648
Distance logged	-0.664601
Distance - Time Pressure calculated as the log of the maxtime over tours left	0.027648
Size Term – Eating Out	1.000000
Size variable – eating out = 0	-999
Calibration - Distance	-0.1900
Calibration - Distance_squared	0.0333
Calibration - Distance_cubed	-0.0010
Calibration - Distance_logged	-0.2569
Calibration - 0-1 miles	0.1074

Home-Based Visiting Model Estimation

The home-based visiting purpose had 1238 records with an available chosen destination in the data set.

Model Estimation Findings:

- The initial model run was based on the final shop model, although it only included the linear distance terms. Non-linear distance terms were tested in later model runs. As with the shopping purpose, distance was capped at 10 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.
- The size terms tested for this purpose were employment in the restaurant/bar sector and the number of households in the destination zone. These were both significant in the original regression analysis of SANDAG's accessibilities. Restaurant/bar employment was used as the base for this estimation.
- The effects of distance on travelers of different gender were tested, with no significant results.
- The effects of distance on travelers of different income classes were also tested. The two lowest income categories (0 to 30K and 30K to 60K) were positive and significant. In later estimation runs, the second lowest group became insignificant and was dropped. This result means that travelers with lower incomes will travel longer distances for their visiting tours than people in the base income category (60K to 100K).
- The effect of distance on travelers of different age groups was also tested, with no significance in any age group.

- The effects of distance were also tested on 0 auto households, with no significance.
- The mix density was tested at the origin MGRA location, for the highest density bin. The coefficient was positive and significant, and therefore the variable was dropped since this is the opposite of the reasonable value.
- The logged time pressure variable was included in this estimation and was negative and not significant, therefore it was dropped.
- The non-motorized and non-mandatory accessibility of each destination was also tested, and this variable was positive and insignificant. Although the direction of the sign was correct (implying that travelers are more likely to choose a location with high accessibility), it had such low significance that it was dropped.

Table 81: Visiting Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.4
Distance	-0.08237 (-1.55)
Distance Squared	-0.00305 (-1.83)
Log of Distance	-0.43026 (-2.99)
Income 0-30K	0.039 (1.67)
Restaurant/Bar Exponentiated Size Term	1
Initial Likelihood	-2940
Final Likelihood	-2883

Final Model:

- For the final model estimation, the tested size terms were maintained. The number of households had a lower exponentiated size term than the restaurant/bar employment. The final values of the size terms are contained inTable87.
- The mode choice logsum was constrained to 0.4. In the run where the logsum was tested by itself, it resulted in a value of 0.78. Therefore 0.4 was chosen as it is halfway between 0 and the estimated value.
- The linear distance terms of distance and distance squared were included, as well as the non-linear term of the log of distance. The inclusion of the log of distance makes this a non-linear distance expression.
- The lowest income category of 0-30K was positive and significant and was maintained in the final run. No other groups had significance in the later runs. This coefficient is interpreted as meaning that lower income people are likely to travel farther for visiting tours; this may be making up for the mode choice logsum parameter in which low income households are more sensitive to travel cost and therefore likely to engage in shorter tours, all else being equal.

The final implemented coefficients for the selected variables are shown in Table 82.

Table 82: Implemented Destination Choice Model for Visiting

Variable	Coefficient
Sample of alternatives correction factor	1.0000
Mode choice logsum	0.40000
Distance	-0.082372
Distance squared	-0.003052
Distance logged	-0.430261
Distance - low income	0.038684
Size Term – Visiting	1.000000
Size variable – Visiting = 0	-999.0
Calibration - 0-1 miles	1.0697
Calibration - 1-2 miles	0.5699

Home Based Escorting Model Estimation

The escorting purpose had 21810 records with an available chosen destination in the data set. The escorting purpose used different size terms than the other purposes. While the other purposes used size terms based on employment in different sectors, escorting tours are often due to dropping off or picking up children at school. Therefore, size terms were created based on the enrollment in K-8 and 9-12 schools, and households were used as a proxy for pre-school enrollment due to lack of data on pre-school enrollment. The size terms also include number of households, as escorting is also often due to dropping off/picking up children at other households.

Size terms were constructed based on household characteristics, such that enrollment by grade level was weighted based on number of children by grade level. For example, if a household had two K-8 students, then the K-8 size term was multiplied by 2. If a household has a K-8 student and a 9-12 student, then both the K-8 and 9-12 size terms were applied. The size term for a household with no students would default to total households.

Model Estimation Findings:

- The initial model run included the linear distance terms. Non-linear distance terms were tested in later model runs. As with other non-mandatory purposes, distance was capped at 20 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.
- The size terms tested for this purpose were number of households, preschool employment, K-8 enrollment, 9-12 enrollment and a combined K-12 enrollment. Throughout the model runs, the exponentiated size terms for enrollment were extremely large. The effects of distance on travelers of different genders were tested. Initially the result was negative and significant, which would imply that female travelers have shorter escort trips, but in later runs the coefficient became insignificant.
- The effects of distance on travelers of different income classes were also tested. The lowest income category (0 to 30K) was positive and significant, but all other categories were

dropped. The positive sign of the coefficient means that low income travelers have longer escort trips than people in the base income category (60K to 100K).

- The effect of distance on travelers of different age groups was also tested. The two highest age categories (56 to 64 and 65+) had positive and significant distance effects. The other categories were dropped. This result means that older travelers are more likely to travel farther distances for escorting tours than people in the base age category of 25 to 40 years old.
- The effects of distance were also tested on 0 auto households, with no significance.
- The mix density was tested at the origin MGRA location, for the highest density bin. The coefficient was positive and significant, and therefore dropped since this is the opposite of the reasonable value.
- The logged time pressure variable was included in this estimation and was negative and not significant; therefore it was dropped.
- The non-motorized and non-mandatory accessibility of each destination was not tested for this purpose as it does not seem reasonable that it has an effect on escorting tours.

Table 83: Escorting Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.5
Distance	-1.033 (-23.06)
Distance Squared	0.022 (10.23)
Income 0-30K	0.157 (4.35)
Age 56-64	0.190 (3.96)
Age 65+	0.309 (8.43)
Households Exponentiated Size Term	1
K-12 Enrollment Exponentiated Size Term	320
Initial Likelihood	-2238
Final Likelihood	-1597

Final Model:

- The size term for the preschool employment was dropped because the modeling team determined that it included too much employment that was not likely related to preschools. The size term for the three enrollment categories (pre-school, K-8, and high school) were combined into one size term whose parameter value was very large (320). In application, the estimated enrollment size term parameter was capped at 0.437.The final values of the size terms are contained inTable87.
- When the mode choice logsum was estimated by itself, it resulted in a very high value of 4.472, which is unreasonable. Even when estimated with distance coefficients, it was higher than one, so it was asserted at 0.5 to be consistent with other models.

- The linear distance terms of distance and distance squared were included, as well as the non-linear term of the log of distance.
- The lowest income category of 0-30K was positive and significant and was maintained in the final run. No other groups had significance in the later runs.
- The two highest age categories were positive and significant and maintained in the final run.

The final implemented coefficients for the selected variables are shown in Table 84.

Table 84: Implemented Destination Choice Model for Escorting

Variable	Coefficient
Sample of alternatives correction factor	1.00000
Mode choice logsum	0.50000
Distance	-1.033377
Distance squared	0.022131
Distance - Low income	0.157497
Distance - Age 56 to 64	0.189508
Distance - Age 65+	0.309310
Size Term – escort size is non-zero for escort tour	1
Size Term – escort size is zero for escort tour	-999
Calibration - Distance	-0.2321
Calibration - Distance_squared	0.0733
Calibration - Distance_cubed	-0.0027
Calibration - Distance_logged	-0.0801

At-Work Sub-tours Model Estimation

The at-work sub-tour purpose had 6861 observations in the data set. The at-work sub-tours were estimated differently than the other purposes. Since each sub-tour has a specific purpose of the at-work sub-tour (i.e., eating out, work-related, or other), the size term was pre-calculated based on the estimated size terms for the sub-tour purpose:

- Eating out: If the sub-tour purpose was eating out, the size term for the eating out purpose was used (restaurant/bar employment and households)
- Work-related: The size term was total employment.
- Other: The size term estimated using regression analysis for the original accessibility calculations for at-work sub-tours was used, and it includes employment in Retail, Personal Services, and Professional Services as well as Restaurant employment in the size term.

Model Estimation Findings:

- The initial model run included linear distance terms. Non-linear distance terms were tested in later model runs. Distance was capped at 20 miles to ensure that the non-linear terms on distance resulted in a monotonically decreasing probability distribution.

- Limited socio-economic related variables were tested for this purpose, as most are not relevant for destination choice for at-work sub-tours.
- The mix density was tested at the origin MGRA location, for the highest density bin. The coefficient was positive and significant, and therefore dropped since this is the opposite of the reasonable value.
- The non-motorized and non-mandatory accessibility of each destination was also tested, and, as with the other purposes, it was not interacted with distance. In this case, the estimation resulted in a negative value, so it was dropped from estimation.
- Whether or not the person is a full time worker was tested, resulting in a positive value that was close to being significant. The positive coefficient means that full time workers are likely to travel further distances for their at-work sub-tours.

Table 85: At-Work Sub-tour Destination Choice Estimation

Variable	Coefficient & T-Stat by Choice Alternative (T-Stat)
Mode choice logsum	.5
Distance	-0.706 (-7.68)
Distance Squared	0.015 (6.59)
Distance - Full Time Worker	0.119 (1.38)
At-work subtour Exponentiated Size Term	1
Initial Likelihood	-1271
Final Likelihood	-848

Final Model:

- Linear distance terms were originally maintained in the final model estimation: distance and distance squared. In addition, the non-linear term of the log of distance were added in the calibration process. The mode choice logsum was asserted at 0.5. When it was estimated in the model runs, the value was close to 1.
- Although the distance-full time worker coefficient was not quite significant, the positive sign was a reasonable result. This coefficient was very close to significance and has potential policy applications, so it was maintained in the final estimation.

The final implemented coefficients for the selected variables are shown in

Table 86.

Table 86: Implemented Destination Choice Model for At-Work Sub-tours

Variable	Coefficient
Mode choice logsum	0.50000
Distance	-0.7058
Distance squared	0.0150
Distance - full time worker	0.1190
Size Term - At-Work Sub-Tour	1.000000
Size Variable - At-Work Sub-Tour = 0	-999
Calibration - Distance	-0.5666
Calibration - Distance_squared	0.1300
Calibration - Distance_cubed	-0.0047
Calibration - Distance_logged	-0.3494

Table 87: Implemented Size Term Coefficients for Non-mandatory Tour

Size Term	Escort	Shop	Maint	Eat-out	Visit	Discr	AtWork	Total
Retail Activity		1	1			0.047	0.154	3.970
Professional and Business Services			0.845			0.009	0.029	0.087
Amusement Services						0.203		0.407
Hotels Activity (479, 480)						0.035		
Restaurants and Bars				1.000	0.100	0.159	0.367	8.123
Personal Services Retail Based			2.456			0.037	0.054	0.999
Religious Activity						1		7.786
Federal Non-Military Activity			0.720			0.009		1.313
State and Local Non-Education Activity_gov_blue						0.009		0.214
State and Local Non-Education Activity_gov_white						0.009		0.214
Total number of households	1			0.551	0.301	0.043		0.489
Enrollment K-6	0.437					0.032		
Enrollment 7-12	0.437					0.051		
Adult school enrollment	0.437							
Other college enrollment	0.437							
University/College enrollment	0.437					0.023		
Acres of active park						3.717		
Acres of active beach						0.600		
Acres of open space						0.100		

Findings

In most cases, the model estimation did not find reasonable and significant results for the socio-economic variables tested. That is likely because the effects of those variables are explained by the tour mode choice logsum, which included many socio-economic coefficients. By the same token, the density measures tested were not significant for any of these purposes, as they were also included in the mode choice model and therefore influence trip distribution through the use of logsums.

The inclusion of the maximum time window coefficient had very good results, as it was significant and correctly signed for most of the purposes. It is a reasonable result that travelers with more time left for scheduling their tours would be more likely to take longer tours than people with a smaller time window. The accessibility coefficient also had significance for a few of the purposes, and it helps to explain the additional attractiveness of zones that have many potential trip destinations clustered together. While most of the purposes were estimated the same way, the unique size term structure for escorting and at-work tours provided more explanatory power than using the same estimation as the other purposes. Including education-specific size terms for the escort purposes and changing the way the coefficients were applied allowed more accuracy in predicting destination choice based on whether or not a household has students. The use of purpose-specific size terms for at-work sub-tours is also more accurate than using generic size terms for all at-work tours.

4.4.3 Individual Non-Mandatory Tour Time of Day Choice

- See Section 4.2.2 (Individual mandatory tours time of day choice).

4.4.4 Individual Non-Mandatory Tour Mode Choice Model

- See Section 4.2.3 (Individual mandatory tours mode choice).

4.5 At-Work Sub-Tour Modeling

4.5.1 At-Work Sub-Tour Frequency

The at-work sub-tour frequency model predicts the number of tours for each person who has at least one work tour. The model is applied after the mandatory tour frequency model. The model has seven alternatives: None, 1 eating out tour, 1 business tour, 1 other tour, 2 business tours, 2 other tours, 1 eating out tour and 1 business tour. It was estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 3,526 observations of work subtours. In order to evaluate the potential impact of varying accessibilities at the home and work locations (by MGRA), the data set was appended with work and home location accessibilities, as well as the non-motorized accessibilities at the work location. In order to evaluate the potential impact of urban form on work tours, the data was also appended with the density variables for employment, retail employment, and a density mix variable (combines dwelling units, employment, and intersection density) at the work location.

Table 88: Observed Frequency of Mandatory Tours and Model Formulation

Choice	# Eating Out Subtours	# Work Subtours	# Other Subtours	Frequency
No tours	0	0	0	3097
1 eat out subtour	1	0	0	190
1 work subtour	0	1	0	75
2 work subtours	0	2+	0	6
1 other subtour	0	0	1	141
2+ other subtours	0	0	2+	5
1 eat out and 1 work subtour	1+	1+	0	4
Total				**3518**

Main Explanatory Variables

The following variables have been examined in the estimation process:

Income stratified by tour purpose:

- Low, medium low, medium high, high income

Employment type stratified by tour purpose:

- full time
- part time

Household characteristics stratified by tour purpose:

- Number of non-workers
- Number of children (non-driving)
- Household size
- Number of adults
- Female, with pre-school children

Accessibility at work location stratified by tour purpose and auto ownership:

- At work accessibility, car available
- At work accessibility, no car available

Accessibility at home location stratified by auto ownership:

- Home access SOV to eat, eat purpose
- Home access HOV to eat, eat purpose
- Home access SOV to shop, other purpose
- Home access HOV to shop, other purpose
- Home access SOV to maintenance, other purpose
- Home access HOV to maintenance, other purpose

Tour characteristics

- Total number of eat tours during the day, eat purpose
- Total number of other tours during the day, other purpose

Density at work location stratified by tour purpose:

- Low, medium, high employment density
- Low, medium, high retail employment density
- Low, medium low, medium high, high mix index density

Some variables, such as distance to work, duration of work tour, and mode choice for primary work tour are not available at this phase of model development. While those variables will likely have an impact on the work based subtours, they could not be evaluated at this time.

Due to the small number of observations for the alternatives, many of the variables did not have a significant effect. Most of these were dropped from the estimation, but some important indicators, such as the impact of low income on business tours, were kept in the estimation even though they were not significant, because the sign of their effect was intuitively correct and they do help describe the model. The model was specified with certain variables interacted with purpose type.

Results

The final estimation results are presented in Table 89.

Table 89: Estimation Results for At-Work Sub-Tour Frequency Model

Variable	Purpose	Coefficient & T-Stat by Choice Alternative (T-Stat)
Constant	0= No at-work subtours	0 (reference)
	199= 1 eat tour	-3.73 (-8.76)
	919=1 work tour	-4.72 (-10.72)
	929=2 work tours	-8.36 (-8.56)
	991=1 other tour	-3.12 (-7.53)
	992=2+ other tours	-6.64 (-7.14)
	119=1 eat and 1 work tour	-7.96 (-9.73)
Full time worker	1 eat tour	0.69 (2.59)
	1 business tour	1.10 (2.44)
	1 other tour	0.65 (2.44)
	2 business tours	2.20
	2+ other tours	1.30
	1 eat and 1 business tour	1.79
Low income household	1 business tour	-0.51 (-1.18)
	2 business tours	-1.02
	1 eat and 1 business tour	-0.51
Medium high income	1 eat tour	0.74 (3.56)
	1 eat and 1 business tour	0.74

High income	1 eat tour	1.01 (5.12)
	1 other tour	0.59 (3.86)
	2+ other tours	1.18
	1 eat and 1 business tour	1.01
Number of adults	1 eat tour	-0.30 (-2.79)
	1 other tour	-0.37 (-3.32)
	2+ other tours	-0.74
	1 eat and 1 business tour	-0.30
Female, with preschool children	1 other tour	0.69 (2.81)
	2+ other tours	1.38
Work accessibility, non-motorized	1 eat tour	0.06 (1.72)
	1 eat and 1 business tour	0.06
Low employment density	1 eat tour	-1.12 (-2.19)
	1 eat and 1 business tour	-1.12
High Mix density	1 business tour	0.50 (2.07)
	2 business tours	1.00
	1 eat and 1 business tour	0.50
Total number of Eat tours in day	1 eat tour	-0.58 (-1.14)
	1 eat and 1 business tour	-0.58
Total number of Other tours in the day	1 other tour	-0.22 (-1.23)
	2+ other tours	-0.44
Alternative Specific Constant Adjustment (ASCA)		
ASCA for Full time Worker	1 eat tour	0.5563
	1 business tour	0.1070
	1 other tour	0.3006
	2 business tours	-0.4349
	2+ other tours	0.3584
	1 eat and 1 business tour	0.8336
ASCA for Part time Worker	1 eat tour	0.6813
	1 business tour	-0.4549

	1 other tour	0.2015
	1 eat and 1 business tour	3.3560
ASCA for university Students	1 eat tour	0.5830

Initial likelihood (zero coefficients)	-8045.23
Likelihood with constants only	-1846.7914
Final likelihood	-1789.4061
Rho-squared w.r.t. Zero	.7776
Rho-squared w.r.t. Constants	.0311

Findings

The following section summarized the most important findings and impacts on at-work tour frequency.

- Being a full-time worker has a significant and positive impact for all three purposes. It is likely that this variable is acting a proxy for the work tour duration, which is not available to estimate at this time. A longer work day realistically would result in more likelihood of tours.
- A medium-high or high income has a significant and positive effect on the number of eat tours and a high income has a significant and positive effect on the number of other tours. This is intuitively correct, since workers with more money will make more tours to purchase food and other goods and services.
- A low income is not statistically significant but does have a negative sign for the work purpose. This variable was left in the model even though it is not significant, because it is likely that lower income workers do not attend as many business meetings as their higher income counterparts.
- The number of adults in the household has a negative and significant effect on the frequency of eat and other tours. This is presumably because another adult could take the necessary other tours (for example, shopping). Another adult could also perhaps prepare a lunch for a working adult.
- Females with a preschool child have a positive and significant coefficient for other tours. This is an expected result, because they presumably have errands to run and take care of those while their child is in daycare.
- The variable for work accessibility for the eat out purpose, non-motorized, is not statistically significant, but it has a positive coefficient as expected. Although the coefficient is small, it was left in the estimation because workers in more accessible locations are more likely to take tours.
- Low density employment has a negative and significant effect on eat tours. This makes sense, because low density employment means fewer options for eating out, since eating locations would cluster near employment centers.
- High mix density has a positive and significant effect on the frequency of work tours. In this case, the mix index variable is probably acting as a proxy for a particular type of

employment location, such as downtown, where inter-related firms would cluster. For example, law firms may cluster near a county courthouse, and lawyers would have business trips in between during the day.

- The total number of tours for eat and other during the day has a negative effect on the respective purposes. While it is not significant, the negative sign is as expected because if people are running errands outside of the work day, they do not need to do them during the work day.

4.5.2 At-Work Sub-Tour Primary Destination Choice

- See Section 4.4.2 (Individual non-mandatory tours destination choice).

4.5.3 At-Work Sub-Tour Time of Day Choice

- See Section 4.2.2 (Individual mandatory tours time of day choice).

4.5.4 At-Work Sub-Tour Mode Choice Model

- See Section 4.2.3 (Individual mandatory tours mode choice).

5.0 Intermediate Stop Modeling

5.1 Intermediate Stop Frequency Model

The stop frequency model predicts the number of stops for each person by primary tour purpose (work, school, university, shopping, escorting, maintenance, discretionary, visiting, and eating). A stop frequency model was also estimated for the at-work sub tour purpose (507 records). The number of stops is predicted by tour direction – outbound (stops made between home and the primary destination) versus inbound (stops made on the way back home). Thus the models have 16 alternatives: the number of inbound (0 through 3+) combined with the number of outbound (0 through 3+) stops. It was estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 11,665 observations from the SANDAG 2006 Household Travel Behavior Survey (if income was included as an explanatory variable, and the household reported income as N/A, they were dropped from the estimation set). In order to evaluate the potential impact of workplace and school location on the number of stops, the survey observations were appended with distance, travel time by auto and transit, and mode choice logsums to work and school locations. Non-motorized accessibilities at the work location (MGRA) and accessibilities for the other purposes from the residence location (MGRA) were also included in the estimation dataset. Off peak trip distance from home to destination was also included on the estimation dataset.

Table 90: Observed Frequency of Stops by Primary Tour Purpose

Inbound Stops	Outbound Stops	Primary Tour Purpose									Total
		Work	University	School	Escorting	Shopping	Maintenance	Eating Out	Visiting	Discretionary	
0	0	2,061	174	1,162	1,038	726	869	336	318	968	**7,652**
1	0	511	22	203	151	141	165	26	35	118	**1,372**
2	0	124	6	40	36	34	66	2	3	26	**337**
3	0	85	2	31	18	18	27	0	11	10	**202**
0	1	294	23	84	84	216	95	17	41	64	**918**
1	1	154	8	73	25	62	43	11	19	30	**425**
2	1	47	3	19	5	20	13	0	5	15	**127**
3	1	32	1	7	2	14	10	0	0	2	**68**
0	2	78	5	6	23	56	22	3	12	15	**220**
1	2	27	0	7	11	22	18	4	1	9	**99**
2	2	22	0	3	0	14	5	2	1	8	**55**
3	2	15	0	0	2	2	2	0	1	2	**24**
0	3	17	0	3	10	20	11	3	7	6	**77**
1	3	13	1	0	6	11	8	0	2	2	**43**
2	3	9	0	0	1	1	5	0	0	7	**23**
3	3	5	0	0	1	5	1	0	0	1	**13**
Total		**3,494**	**245**	**1,638**	**1,413**	**1,362**	**1,360**	**404**	**456**	**1,283**	**11,655**

Table 91: Observed Frequency of Stops for At Work Sub-Tour Purpose

Inbound Stops	Outbound Stops	At-Work Sub Tour Purpose
0	0	441
1	0	25
2	0	2
3	0	1
0	1	26
1	1	8
2	1	2
3	1	0
0	2	1
1	2	0
2	2	0
3	2	0
0	3	1
1	3	0
2	3	0
3	3	0
Total		**507**

Main Explanatory Variables

The following variables have been examined in the estimation process:

Personal characteristics stratified by person type:

- Full-time worker
- Part-time worker
- Non-worker
- Driving age school child
- Pre-driving age school child
- Preschool child
- Number of tours by purpose per person

Household composition stratified by total number of stops (inbound plus outbound):

- Number of full time workers
- Number of part time workers
- Number of non-workers
- Household income group

- Number of children (driving age, non-driving age, pre-school)
- Number of vehicles
- Zero Auto ownership household
- Number of tours made by other members of the household

Usual work and school location variables:

- SOV time
- SOV Distance
- SOV Logsum

Accessibility from home:

- Non-work accessibility by car ownership
- Shopping accessibility by car ownership
- Maintenance accessibility by car ownership
- Eating out accessibility by car ownership
- Visiting accessibility by car ownership
- Discretionary accessibility by car ownership
- Escorting accessibility by car ownership
- SOV off-peak trip distance to destination

Tour variables:

- Tour duration
- General tour mode
- Joint tour indicator

Results

The final estimation results are presented in the tables on the next pages. There are 9 estimation sets for each primary tour purpose.

Table 92: Stop Frequency Model Estimation Results by Primary Tour Purpose

		Primary Tour Purpose											
		Work		School		Shopping		Escorting		Maintenance		Discretionary	
Explanatory Variable	Dependent Variable Interaction	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constants	outbound trip = 1	-1.748	-5.566	-5.541	-6.647	-1.863	-4.572	-5.774	-8.496	-5.843	-7.331	-6.628	-4.894
	outbound trip = 2	-3.979	-7.509	-13.603	-8.591	-4.153	-6.205	-10.204	-9.590	-11.220	-7.438	-13.612	-5.174
	outbound trip = 3	-6.068	-7.475	-18.069	-8.202	-6.586	-6.543	-14.464	-9.275	-16.256	-7.181	-20.665	-5.236
	return trip = 1	-1.542	-7.135	-3.419	-5.774	-2.236	-8.120	-4.257	-9.987	-4.684	-6.570	-6.394	-5.009
	return trip = 2	-3.426	-6.939	-8.514	-6.447	-4.640	-7.380	-9.739	-9.639	-10.142	-6.880	-12.930	-4.982
	return trip = 3	-4.679	-6.177	-12.661	-6.074	-6.699	-7.032	-13.918	-9.243	-15.309	-6.882	-20.392	-5.211
	total number of stops = 1	-0.355	-1.479	0.240	0.400	0.053	0.165	0.930	1.701	0.607	1.601	-0.425	-0.886
	total number of stops = 2	0.900	1.845	1.263	1.200	0.427	0.871	3.346	4.576	4.032	4.705	4.618	3.256
	for total number of stops = 3	1.615	2.200	4.889	2.758	1.765	2.232	7.212	5.965	8.366	5.253	10.667	3.930
	total number of stops = 4	2.696	2.695	8.038	3.104	3.516	3.164	10.655	6.262	12.892	5.523	16.553	4.122
	total number of stops = 5	3.989	3.175	-999	N/A	3.659	2.383	14.937	6.493	17.433	5.617	23.605	4.430
	total number of stops = 6	5.005	3.172	-999	N/A	7.127	3.927	18.751	6.451	21.315	5.381	29.384	4.377
Number of full-time workers other than traveler in household	total number of stops = 1	-0.237	-3.471			-0.260	-2.579			-0.350	-3.618		
	total number of stops = 2+	-0.382	-4.753			-0.454	-3.575			-0.350	-3.618		
Number of part-time workers	total number of stops = 1	-0.323	-2.806										
	total number of stops = 2	-0.446	-3.025										
	0 out & 3 return stops	-0.446											
	for total number of stops = 3+ (except 0 out & 3 return stops)	-0.465	-2.916										
Number of part-time workers other than traveler in household	total number of stops = 1+									-0.549	-2.920		
Number of total workers in household	total number of stops = 1			-0.351	-2.200								
	total number of stops = 2+			-0.285	-1.423								
Number of non-workers	total number of stops = 1	-0.533	-4.068										
	total number of stops = 2+	-0.851	-5.425										
Number of non-workers other than traveler in household	total number of stops = 1					-0.301	-1.808						
	total number of stops = 2+					-1.226	-4.822						
Number of children in household	total number of stops = 1	0.171	4.002	-0.050	-0.641							0.230	3.973
	total number of stops = 2	0.331	6.135	0.386	4.919							0.230	3.973
	0 out & 3 return stops	0.331											

		Primary Tour Purpose											
		Work		School		Shopping		Escorting		Maintenance		Discretionary	
Explanatory Variable	Dependent Variable Interaction	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
	for total number of stops = 3+ (except 0 out & 3 return stops)	0.351	5.928	0.386	4.919							0.230	3.973
Traveler a full -time worker	total number of stops = 1	-0.670	-4.039			0.000							
	total number of stops = 2+	-1.249	-7.060			-0.222	-0.911						
Traveler a preschool child	total number of stops = 1			0.400	2.223								
	total number of stops = 2			0.852	3.536								
	for total number of stops = 3+			1.012	3.449								
Number of school tours per person	total number of stops = 1+			0.478	1.443								
Number of shopping tours (individual + joint) per person	total number of stops = 1+					-0.177	-0.967						
Number of maintenance tours (individual + joint) per person	total number of stops = 1									0.000			
	total number of stops = 2+									-0.132	-1.126		
Number of other tours besides Maintenance tours per person	total number of stops = 1+									0.010	0.125		
Number of other tours besides work and discretionary tours per person	total number of stops = 1											0.000	
	total number of stops = 2+											-0.114	-0.672
Number of escorting tours per person	total number of stops = 1							-0.148					
	total number of stops = 2+							-0.229					
Number of tours made by other household members	total number of stops = 3+							-0.081	-1.530				
Household income (<30K)	total number of stops = 1+	-0.344	-2.378	-0.386	-1.969	-0.488	-2.720	-0.574	-2.595				
Household income (30-100K)	total number of stops = 1+	-0.135	-1.723			-0.198	-1.260						
Tour distance to destination	total number of stops = 1	0.090										-0.019	-1.466
	total number of stops = 2+	0.090										0.005	0.375
SOV travel distance to usual school location	total number of stops = 1			0.029	2.257								
	total number of stops = 2			0.029	2.257								
	total number of stops = 3			0.051	2.442								
	total number of stops = 4+			0.079	2.143								
SOV maintenance accessibility from home (destination accessibility terms 31-33)	total number of stops = 1+									0.140	2.626		

		Primary Tour Purpose											
		Work		School		Shopping		Escorting		Maintenance		Discretionary	
Explanatory Variable	Dependent Variable Interaction	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
SOV Discretionary Accessibility from Home (destination accessibility terms (40-42)	total number of stops = 1+											0.186	2.145
Tour duration in hours	total number of stops = 1	0.103	7.267	0.184	4.962	0.570	9.533	0.989	10.412	0.241	7.384	0.547	9.737
	total number of stops = 2+	0.116	7.297	0.425	9.413	0.916	14.079	1.346	13.152	0.374	11.607	0.666	11.137
Tour mode is transit	total number of stops = 1	-0.652	-3.244	-0.589	-1.283	-0.390	-1.213					-0.851	-1.068
	total number of stops = 2+	-0.856	-3.598	-0.933	-1.489	-2.404	-4.976					-0.851	-1.068
Tour mode is school bus	total number of stops = 1			-1.035	-3.985								
	total number of stops = 2+			-1.035	-3.985								
Tour mode is non-motorized	total number of stops = 1	-1.357	-3.406	-2.151	-5.068	0.000							
	total number of stops = 2+	-1.471	-3.147	-3.441	-3.388	-1.592	-2.651						
Tour mode is auto/taxi	total number of stops = 1							1.939	4.779	0.857	3.758		
	total number of stops = 2+							1.939	4.779	0.857	3.758		
Tour mode is school bus	total number of stops = 1+			-999									
Joint tour indicator	total number of stops = 1					0.172	0.639	-0.399	-2.320	-0.225	-1.353	-0.206	-1.097
	total number of stops = 2+					0.172	0.639	-0.399		0.000		-0.555	-2.158
Alternative specific constant adjustment	0 out & 1 return stops	0.1792		0.7067		0.5465		-0.4374		-0.4378		0.8484	
	0 out & 2 return stops	0.0900		0.1256		1.4444		0.9797		0.2433		0.3053	
	0 out & 3 return stops	0.2078		0.3126		1.3849		0.9276		0.2372		0.9766	
	1 out & 0 return stops	-0.1053		1.9252		0.4924		0.5119		0.2921		0.5756	
	1 out & 1 return stops	0.2289		1.2067		1.6290		0.9995		0.2108		0.5531	
	1 out & 2 return stops	0.2040		1.2729		1.6257		1.3887		0.1170		0.6003	
	1 out & 3 return stops	0.0177		0.9244		1.3848		1.0409		0.6771		0.1778	
	2 out & 0 return stops	0.3531		3.4223		1.6522		0.9275		0.2133		0.7039	
	2 out & 1 return stops	0.0422		3.2945		1.2304		0.9249		0.2776		0.3569	
	2 out & 2 return stops	0.7377		4.0808		1.6876				-0.0558		0.9309	
	2 out & 3 return stops	0.1473				2.5795		1.0715		-1.9166		0.2266	
	3 out & 0 return stops	0.0670		3.2167		1.4070		0.7691		0.3357		0.9462	
	3 out & 1 return stops	-0.1629				1.6420		0.9984		0.0715		0.1921	
	3 out & 2 return stops	0.6078				1.9658		-0.3309		-0.0911		1.2246	
	3 out & 3 return stops	-0.1646				1.8964		0.7576		0.1979		0.6755	

		Primary Tour Purpose											
		Work		School		Shopping		Escorting		Maintenance		Discretionary	
Explanatory Variable	**Dependent Variable Interaction**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Alternative specific constant for Joint Tours	total number of stops = 1					-0.2908				-0.4314		0.3622	
	total number of stops = 2					-1.3963				-0.0899		0.5031	
	total number of stops = 3					-1.2368				-0.1327		0.2014	
	total number of stops = 4					-1.5445				-0.9574		0.0577	
	total number of stops = 5					-1.8935				-0.9794		-0.3204	
	total number of stops = 6					-1.8935				0.0000		0.0000	
ALOGIT statistics	Observations:	3266		1619		1362		1413		1360		1237	
	Likelihood – Constants only	-4905.933		-1775.5823		-2237.001		-1505.7981		-1892.6766		-1291.3926	
	Final value of likelihood:	-4773.245		-1596.1248		-2022.272		-1328.9545		-1785.9138		-1156.8387	
	Rho-Squared (0):	0.4729		0.6033		0.4645		0.6608		0.5264		0.6627	
	Rho-Squared (constant):	0.027		0.1011		0.096		0.1174		0.0564		0.1042	

Table 93: Stop Frequency Model Estimation Results by Primary Tour Purpose

Explanatory Variable	Dependent Variable Interaction	Primary Tour Purpose					
		University		Eating		Visiting	
		Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constants	outbound trip = 1+	-1.248	-2.873	-1.888	-1.578	-1.323	-3.999
	return trip = 1+	-2.187	-8.227			-2.212	-10.801
	return trip = 1+ (and out trip = 1+)			-3.440	-5.851		
	total number of stops = 1,2,3	-1.819	-4.553			-1.579	-4.674
	total number of stops = 2,3 (and out trip=1+)			-1.783	-1.550		
	total number of stops = 4	-999		-999		-1.579	
	total number of stops = 5+	-999		-999		-999	
Number of children in Household	total number of stops = 1+					0.032	0.388
Traveler a Non Worker	total number of stops = 1+	1.152	1.169				
Traveler a non-traditional college student (age > 30)	total number of stops = 1+	0.643	2.184				
Number of other tours besides eating out tours per person	total number of stops = 1+			-0.890	-2.281		
Number of other tours besides visiting tours per person	total number of stops = 1+					-0.511	-3.064
Household Income (<30K)	total number of stops = 1+					-0.935	-1.969
SOV Off peak trip distance to destination	total number of stops = 1					0.000	
	total number of stops = 2+					0.029	2.224
Tour duration	total number of stops = 1+	0.022	0.555	0.537	3.511	0.202	4.610
Tour mode is transit	total number of stops = 1+	-0.523	-1.259			-0.244	-0.385
Tour mode is non-motorized	total number of stops = 1+	-1.238	-1.521			-1.250	-1.992
Tour mode is auto/taxi	total number of stops = 1			0			
	total number of stops = 2+			-1.194	-1.999		
Joint tour indicator	total number of stops = 1					0	
	total number of stops = 2+					-1.045	-3.224
Alternative specific constant adjustment	0 out & 1 return stops	0.6724		-2.2085		1.8601	
	0 out & 2 return stops	-1.1706		-2.9036		-0.0347	
	0 out & 3 return stops	-1.7753		-8.3845		0.5637	
	1 out & 0 return stops	-0.1884		-0.6712		1.1355	
	1 out & 1 return stops	1.0696		5.2881		2.4633	
	1 out & 2 return stops	0.0130				1.0728	
	1 out & 3 return stops						

	2 out & 0 return stops	-2.1955		0.9152		-0.0945	
	2 out & 1 return stops			4.1709		-0.3051	
	2 out & 2 return stops					0.7151	
	2 out & 3 return stops						
	3 out & 0 return stops			0.4962		-0.8469	
	3 out & 1 return stops					-0.6922	
	3 out & 2 return stops						
	3 out & 3 return stops						
Alternative specific constant for Joint Tours	total number of stops = 1			-1.4651		-0.2660	
	total number of stops = 2			-2.1723		0.3406	
	total number of stops = 3			-1.40522		0.4338	
ALOGIT statistics	Observations:	245		149		392	
	Likelihood – Constants only	-269.8979		-85.4224		-452.9304	
	Final value of likelihood:	-298.7963		-84.4816		-469.0782	
	Rho-Squared (0):	0.5601		0.7955		0.5684	
	Rho-Squared (constant):	-0.1071		0.011		-0.0357	

Table 94: Stop Frequency Model Estimation Results for At Work Sub Tours

Explanatory Variable	Dependent Variable Interaction	At Work Sub Tour	
		Coefficient	T-statistic
Constants	outbound trip = 1	-0.17885	-0.16795
	outbound trip = 2+	-5.16744	-3.25726
	return trip = 1	-3.05041	-6.09947
	return trip = 2+	-4.71338	-3.61773
	total number of stops = 1	-2.82842	-2.40508
	total number of stops = 2	-0.08937	-0.07614
	total number of stops = 3	-0.5222	-0.29135
	total number of stops = 4+	-999	
Number of children in household	total number of stops = 1+	0.319218	2.161725
Traveler a full-time worker	total number of stops = 1+	-0.84489	-1.81274
Household income (<30K)	total number of stops = 1+	-1.36445	-1.27518
Household income (30-100K)	total number of stops = 1+	-0.59745	-1.94763
Number of non-work tours per person	total number of stops = 2+	-1.20226	-1.19347
Number of tours made by other household members	total number of stops = 2+	-0.33813	-1.8269
Sub tour purpose is work	total number of stops = 1+	0.667781	1.959614
Tour duration in hours	total number of stops = 1+	0.471195	4.689953
Alternative specific constant adjustment	0 out & 1 return stops	4.7315	
	0 out & 2 return stops	0.7441	
	1 out & 0 return stops	1.9743	
	1 out & 1 return stops	1.2098	
	1 out & 2 return stops	2.1822	
	2 out & 0 return stops	1.0469	
	3 out & 0 return stops	1.6337	
ALOGIT statistics	Observations:	507	
	Likelihood – Constants only	-287.996	
	Final value of likelihood:	-260.538	
	Rho-Squared (0):	0.8147	
	Rho-Squared (constant):	0.0953	

Findings

The following section summarizes the most important findings and impacts on stop frequency by primary tour purpose: (1) Person-type constants are very significant showing that person type itself and (2) the number of tours the person makes explains the stop frequencies on tours.

- Work Tours:
  - *Number of full-time/part-time workers:* The number of full-time workers in the household other than the traveler is a very significant variable for explaining variation in the number of stops on the tour. I.e. the more full time workers in the household, the less likely that there are multiple stops on the work tour. This is likely due to sharing of household maintenance responsibilities across multiple household members. Number of part-time workers in the household has this same effect.
  - *Number of children:* If the number of children in the household increases, there are more stops on work tours; likely due to the increase in travel related to child-care responsibilities.
  - *Household income:* As the household income in the family grows, they are more likely to make one or more stops on the work tour.
  - *Trip distance:* As the trip distance from home to the final destination of the tour increases, the person is more likely to have multiple stops on the work tour.
  - *Tour duration:* As the tour duration gets longer, the more likely a person is to make multiple stops on the work tour.
  - *General tour mode:* If the general tour mode is transit or non-motorized, the person is less likely to make multiple stops on the work tour.
- School Tours:
  - *Number of workers:* As the number of workers in the household increases, the less likely the person will make multiple stops on school tours.
  - *Number of children:* If there are more children in the household, there is a higher likelihood that the person makes multiple stops on the school tour.
  - *Person type of pre-school child:* If the traveler is a pre-school child, she has an even higher likelihood to be on school tours with multiple stops.
  - *Household income:* As the household income grows, the more likely the person makes multiple stops on the school tour.
  - *Trip distance:* As the trip distance to the usual school location increases, the more likely the person is to make multiple stops on the school tour.
  - *Tour duration:* As the tour duration gets longer, the more likely a person is to make multiple stops on a school tour.

General tour mode: If the general tour mode is transit or non-motorized, the person is less likely to make multiple stops on a school tour. If the general tour mode is school bus, there is no possibility to make multiple stops on a school tour.Shopping Tours:

  - *Number of non-workers:* As the number of non-workers in the household other than the traveler increases, the less likely it is that the traveler will make multiple stops on the shopping tour.

- *Person type of full-time worker:* If the traveler is a full-time worker, they are less likely to make multiple stops on the shopping tour.
- *Number of shopping tours:* The more shopping tours a person makes, the less likely there are to make multiple stops on the shopping tour.
- *Household income:* Number of stops on shopping tours is directly related to household income. If the household makes more than $30,000 but less than $100,000, they are less likely to make multiple stops on shopping tours. If the household makes less than $30,000, they are even less likely to make multiple stops on shopping tours.
- *Tour duration:* As the tour duration gets longer, the more likely a person is to make multiple stops on a shopping tour.
- *General tour mode:* If the general tour mode is transit or non-motorized, the person is less likely to make multiple stops on a shopping tour.
- *Joint tour indicator*: If the shopping tour is a joint tour, the person is more likely to make one or more stops on the tour.

- Escorting Tours:
  - *Number of escort tours:* As the number of escort tours made by a person increases, the less likely they are to make multiple stops on an escorting tour.
  - *Household income:* If the household makes less than $30,000, the less likely the person is to make one or more stops on the escorting tour.
  - *Tour duration:* As the tour duration gets longer, the more likely a person is to make multiple stops on an escorting tour.
  - *General tour mode:* If the general mode is auto or taxi, the person is more likely to make multiple stops on an escorting tour.
  - *Joint tour indicator:* If the escorting tour is a joint tour, the person is less likely to make 2 or more stops on the tour.
- Maintenance Tours:
  - *Number of part-time workers:* As the number of part time workers in the household other than the traveler increases, the less likely the person is to make multiple stops on the maintenance tour.
  - *Number of tours:* As the number of tours made by a person increases, the less likely they are to make multiple stops on a maintenance tour.
  - *Accessibility to maintenance activities:* As the accessibility to maintenance activities from the home location increases, the chance that a person makes multiple stops on maintenance tours is increased slightly.
  - *Tour duration:* As the tour duration gets longer, the person is more likely to make multiple stops on a maintenance tour.
  - *General tour mode:* If the general tour mode is auto or taxi, the person is more likely to make multiple stops on a maintenance tour.
  - *Joint tour indicator:* If the maintenance tour is a joint tour, the person is less likely to make 2 or more stops on the tour.

- Discretionary Tours:
    - *Number of children:* As the number of children increases, the more likely the traveler is to make multiple stops on discretionary tours.
    - *Number of tours:* As the number of tours made by the person increases, the less likely they are to make multiple stops on discretionary tours.
    - *Accessibility to discretionary activities:* As the accessibility to discretionary activities from the home location increases, the more likely the traveler makes multiple stops on a discretionary tour.
    - *Off peak trip distance to the destination:* As the off peak trip distance to the destination increases, the person is more likely to make multiple stops on a discretionary tour.
    - *Tour duration:* As the tour duration increases, the person is more likely to make multiple stops on a discretionary tour.
    - *General tour mode:* If the general tour mode is transit, the person is less likely to make multiple stops on a discretionary tour.
    - *Joint tour indicator:* If the discretionary tour is a joint tour, the person is less likely to make multiple stops on a discretionary tour.
- University Tours:
    - *Person type of non-worker:* If the traveler is a non-worker, he is more likely to make multiple stops on university tours.
    - *Non-traditional college students:* If the traveler is a non-traditional college students (aged > 30 years old), he is more likely to make multiple stops on university tours.
    - *Tour duration:* As the tour duration becomes longer, the more likely a person is to make multiple stops on a university tour.
    - *General tour mode:* If the general tour mode is transit or non-motorized, the person is less likely to make multiple stops on a university tour.
- Eating Tours:
    - *Number of tours:* The more tours besides eating tours that a person makes, the less likely they are to make multiple stops on eating out tours.
    - *Tour duration:* As the tour duration gets longer, the more likely the person is to make multiple stops on an eating tour.
    - *General tour mode:* If the general tour mode is auto, the person is less likely to make 2 or more stops on an eating tour.
- Visiting Tours:
    - *Number of children:* The more children in the household, the more likely the traveler makes multiple stops on visiting tours.
    - *Number of tours:* The more tours besides visiting tours that the person makes, the less likely they are to make multiple stops on the visiting tour.
    - *Household income:* If the household income is less than $30,000, the less likely the traveler is to make multiple stops on visiting tours.

- *Tour duration:* As the tour duration becomes longer, the more likely the person is to make multiple stops on a visiting tour.
  - *General tour mode:* If the general tour mode is transit or non-motorized, the person is less likely to make multiple stops on a visiting tour.
  - *Joint tour indicator:* If the visiting tour is a joint tour, the person is less likely to make multiple stops on the tour.
- At-Work Sub-Tours:
  - *Number of children:* The more children in the household, the more likely the traveler makes multiple stops on at work sub-tours.
  - *Person type of full-time worker:* If the traveler is a full time worker, she is less likely to make multiple stops on at work sub-tours.
  - *Household income:* Number of stops on at-work sub tours is directly related to household income. If the household makes more than $30,000 but less than $100,000, they are less likely to make multiple stops on at work sub-tours. If the household makes less than $30,000, they are even less likely to make multiple stops on at work sub-tours.
  - *Number of non-work tours:* As the number of non-work tours made by the person increases, the less likely the person is to make two or more stops on at work sub-tours.
  - *Sub-purpose on the at-work sub-tour:* If the sub-purpose on the at-work sub-tour is working, the person is more likely to make multiple stops on the tour.
  - *Tour duration:* As the tour duration becomes longer, the more likely the person is to make multiple stops on an at-work sub tour.

5.2 Intermediate Stop Purpose Choice Model

The stop purpose choice model is a lookup table of probabilities based upon tour purpose, stop direction, departure time, and person type. See Table 95 below.

Table 95: Stop Purpose Lookup Proportions

Primary Purpose	Direction	Departure Range Start Time	Departure Range End Time	Person Type	Work	University	School	Escort	Shop	Maintenance	Eating Out	Visiting	Discretionary
Work	Outbound	430	830	FT Worker	0.092	0	0	0.646	0.047	0.099	0.066	0.02	0.03
Work	Outbound	430	830	PT Worker	0	0	0	0.65	0.122	0.134	0	0	0.094
Work	Outbound	430	830	University Student	0	0	0	0.65	0.122	0.134	0	0	0.094
Work	Outbound	900	2400	FT Worker	0.26	0	0	0.066	0.176	0.374	0.005	0.064	0.055
Work	Outbound	900	2400	PT Worker	0.033	0	0	0.163	0.353	0.334	0.117	0	0
Work	Outbound	900	2400	University Student	0	0	0	0	0	0	0	0	1
Work	Outbound	430	2400	Driving-age Child	0	0	0	0.65	0.122	0.134	0	0	0.094
University	Outbound	430	2400	FT Worker	0	0	0	0.364	0.152	0	0.484	0	0
University	Outbound	430	2400	PT Worker	0	0	0	0.364	0.152	0	0.484	0	0
University	Outbound	430	2400	University Student	0	0	0	0.364	0.152	0	0.484	0	0
School	Outbound	430	2400	Driving-age Child	0	0	0	0.505	0.036	0	0.078	0.278	0.103
School	Outbound	430	2400	Pre-Driving Child	0	0	0	0.505	0.036	0	0.078	0.278	0.103
School	Outbound	430	2400	Preschool	0	0	0	0.111	0.134	0.509	0.246	0	0
Escort	Outbound	430	2400	FT Worker	0	0	0	0.177	0.24	0.195	0.201	0.179	0.008
Escort	Outbound	430	2400	PT Worker	0	0	0	0.319	0.242	0.123	0.116	0.2	0
Escort	Outbound	430	2400	University Student	0	0	0	0	0.343	0.657	0	0	0
Escort	Outbound	430	2400	Homemaker	0	0	0	0.423	0.144	0.161	0.216	0	0.056
Escort	Outbound	430	2400	Retired	0	0	0	0.07	0.174	0.287	0.096	0.233	0.14
Escort	Outbound	430	2400	Driving-age Child	0	0	0	0	0	1	0	0	0
Escort	Outbound	430	2400	Pre-Driving Child	0	0	0	0	0	1	0	0	0
Escort	Outbound	430	2400	Preschool	0	0	0	0.352	0	0.506	0	0	0.142
Shop	Outbound	430	2400	FT Worker	0	0	0	0.124	0.202	0.459	0.119	0.096	0
Shop	Outbound	430	2400	PT Worker	0	0	0	0.127	0.3	0.515	0	0.058	0
Shop	Outbound	430	2400	University Student	0	0	0	0	0	0	0	0	1
Shop	Outbound	430	2400	Homemaker	0	0	0	0.277	0.296	0.105	0.113	0.035	0.174
Shop	Outbound	430	2400	Retired	0	0	0	0.066	0.216	0.533	0.115	0.05	0.02
Shop	Outbound	430	2400	Driving-age Child	0	0	0	0	0	0	0	0	1
Shop	Outbound	430	2400	Pre-Driving Child	0	0	0	0	0.329	0	0.343	0	0.328
Shop	Outbound	430	2400	Preschool	0	0	0	0.124	0	0	0.165	0.248	0.463
Maintenance	Outbound	430	2400	FT Worker	0	0	0	0.121	0	0.469	0.295	0.05	0.065
Maintenance	Outbound	430	2400	PT Worker	0	0	0	0	0.224	0.639	0.137	0	0

Maintenance	Outbound	430	2400	University Student	0	0	0	0	0	1	0	0	0
Maintenance	Outbound	430	2400	Homemaker	0	0	0	0.31	0	0.301	0.326	0.063	0
Maintenance	Outbound	430	2400	Retired	0	0	0	0.047	0.041	0.489	0.196	0.227	0
Maintenance	Outbound	430	2400	Driving-age Child	0	0	0	1	0	0	0	0	0
Maintenance	Outbound	430	2400	Pre-Driving Child	0	0	0	0.254	0.492	0	0.254	0	0
Maintenance	Outbound	430	2400	Preschool	0	0	0	0.762	0.238	0	0	0	0
Eating Out	Outbound	430	2400	FT Worker	0	0	0	0.15	0	0	0	0.85	0
Eating Out	Outbound	430	2400	PT Worker	0	0	0	0.238	0.252	0	0.51	0	0
Eating Out	Outbound	430	2400	University Student	0	0	0	0.241	0.484	0	0.275	0	0
Eating Out	Outbound	430	2400	Homemaker	0	0	0	0.241	0.484	0	0.275	0	0
Eating Out	Outbound	430	2400	Retired	0	0	0	0	0	0.405	0	0.595	0
Eating Out	Outbound	430	2400	Driving-age Child	0	0	0	0.246	0.754	0	0	0	0
Eating Out	Outbound	430	2400	Pre-Driving Child	0	0	0	0.246	0.754	0	0	0	0
Eating Out	Outbound	430	2400	Preschool	0	0	0	0.246	0.754	0	0	0	0
Visiting	Outbound	430	2400	FT Worker	0	0	0	0.098	0.213	0.107	0.278	0.108	0.196
Visiting	Outbound	430	2400	PT Worker	0	0	0	0.32	0	0.325	0	0.355	0
Visiting	Outbound	430	2400	University Student	0	0	0	0	0	0.516	0.484	0	0
Visiting	Outbound	430	2400	Homemaker	0	0	0	0	0	0.386	0	0.264	0.35
Visiting	Outbound	430	2400	Retired	0	0	0	0.402	0	0.347	0.026	0.199	0.026
Visiting	Outbound	430	2400	Driving-age Child	0	0	0	0	0	0	1	0	0
Visiting	Outbound	430	2400	Pre-Driving Child	0	0	0	0	0	0	0.333	0.334	0.333
Visiting	Outbound	430	2400	Preschool	0	0	0	0	0	0	0.333	0.334	0.333
Discretionary	Outbound	430	2400	FT Worker	0	0	0	0.044	0	0.443	0.27	0.072	0.171
Discretionary	Outbound	430	2400	PT Worker	0	0	0	0.714	0	0.286	0	0	0
Discretionary	Outbound	430	2400	University Student	0	0	0	0.714	0	0.286	0	0	0
Discretionary	Outbound	430	2400	Homemaker	0	0	0	0	0.128	0.287	0.228	0	0.357
Discretionary	Outbound	430	2400	Retired	0	0	0	0.034	0.221	0.194	0.132	0.275	0.144
Discretionary	Outbound	430	2400	Driving-age Child	0	0	0	0	0.128	0.287	0.228	0	0.357
Discretionary	Outbound	430	2400	Pre-Driving Child	0	0	0	0.598	0	0	0.402	0	0
Discretionary	Outbound	430	2400	Preschool	0	0	0	0.227	0	0.127	0.355	0	0.291
Work-Based	Outbound	430	2400	All	0.263	0	0	0.042	0.048	0.191	0.427	0	0.029
Work	Inbound	430	1430	FT Worker	0.232	0	0	0.15	0.298	0.145	0.098	0.035	0.042
Work	Inbound	430	1430	PT Worker	0.037	0	0	0.269	0.282	0.247	0.081	0.062	0.022

Work	Inbound	430	1430	University Student	0	0	0	0.527	0	0	0	0.473	0
Work	Inbound	1500	2400	FT Worker	0.031	0	0	0.356	0.248	0.155	0.074	0.076	0.06
Work	Inbound	1500	2400	PT Worker	0.062	0	0	0.312	0.34	0.101	0.084	0.041	0.06
Work	Inbound	1500	2400	University Student	0	0	0	0.622	0.378	0	0	0	0
Work	Inbound	430	2400	Driving-age Child	0	0	0	0.622	0.378	0	0	0	0
University	Inbound	430	2400	FT Worker	0	0	0	0.096	0.355	0.056	0.288	0.205	0
University	Inbound	430	2400	PT Worker	0	0	0	0.096	0.355	0.056	0.288	0.205	0
University	Inbound	430	2400	University Student	0	0	0	0.096	0.355	0.056	0.288	0.205	0
School	Inbound	430	2400	Driving-age Child	0	0	0	0.047	0.382	0.219	0.158	0.114	0.08
School	Inbound	430	2400	Pre-Driving Child	0	0	0	0.264	0.253	0.198	0.125	0.086	0.074
School	Inbound	430	2400	Preschool	0	0	0	0.391	0.299	0.068	0.112	0.062	0.068
Escort	Inbound	430	2400	FT Worker	0	0	0	0.058	0.355	0.267	0.215	0.105	0
Escort	Inbound	430	2400	PT Worker	0	0	0	0.071	0.359	0.423	0.041	0.035	0.071
Escort	Inbound	430	2400	University Student	0	0	0	0.071	0.359	0.423	0.041	0.035	0.071
Escort	Inbound	430	2400	Homemaker	0	0	0	0.132	0.496	0.096	0.018	0.047	0.211
Escort	Inbound	430	2400	Retired	0	0	0	0.138	0.321	0.316	0.161	0.064	0
Escort	Inbound	430	2400	Driving-age Child	0	0	0	0.132	0.496	0.096	0.018	0.047	0.211
Escort	Inbound	430	2400	Pre-Driving Child	0	0	0	0.132	0.496	0.096	0.018	0.047	0.211
Escort	Inbound	430	2400	Preschool	0	0	0	0	0.52	0.241	0.105	0.134	0
Shop	Inbound	430	2400	FT Worker	0	0	0	0.073	0.609	0.199	0.079	0.04	0
Shop	Inbound	430	2400	PT Worker	0	0	0	0	0.61	0.221	0.169	0	0
Shop	Inbound	430	2400	University Student	0	0	0	0	0	0.491	0.509	0	0
Shop	Inbound	430	2400	Homemaker	0	0	0	0.062	0.41	0.167	0.176	0.058	0.127
Shop	Inbound	430	2400	Retired	0	0	0	0.035	0.448	0.157	0.196	0.148	0.016
Shop	Inbound	430	2400	Driving-age Child	0	0	0	0.062	0.41	0.167	0.176	0.058	0.127
Shop	Inbound	430	2400	Pre-Driving Child	0	0	0	0.062	0.41	0.167	0.176	0.058	0.127
Shop	Inbound	430	2400	Preschool	0	0	0	0.248	0.205	0.265	0.282	0	0
Maintenance	Inbound	430	2400	FT Worker	0	0	0	0.175	0.083	0.354	0.329	0.022	0.037
Maintenance	Inbound	430	2400	PT Worker	0	0	0	0.108	0.441	0.185	0.266	0	0
Maintenance	Inbound	430	2400	University Student	0	0	0	0	0.334	0.666	0	0	0
Maintenance	Inbound	430	2400	Homemaker	0	0	0	0.092	0.342	0.293	0.218	0.055	0
Maintenance	Inbound	430	2400	Retired	0	0	0	0.016	0.259	0.318	0.386	0.021	0
Maintenance	Inbound	430	2400	Driving-age Child	0	0	0	0.092	0.342	0.293	0.218	0.055	0

Maintenance	Inbound	430	2400	Pre-Driving Child	0	0	0	0	0	1	0	0	0
Maintenance	Inbound	430	2400	Preschool	0	0	0	0	0	0	1	0	0
Eating Out	Inbound	430	2400	FT Worker	0	0	0	1	0	0	0	0	0
Eating Out	Inbound	430	2400	PT Worker	0	0	0	1	0	0	0	0	0
Eating Out	Inbound	430	2400	University Student	0	0	0	1	0	0	0	0	0
Eating Out	Inbound	430	2400	Homemaker	0	0	0	0	0	1	0	0	0
Eating Out	Inbound	430	2400	Retired	0	0	0	0	0	1	0	0	0
Eating Out	Inbound	430	2400	Driving-age Child	0	0	0	0	0	0	1	0	0
Eating Out	Inbound	430	2400	Pre-Driving Child	0	0	0	0	0	0	1	0	0
Eating Out	Inbound	430	2400	Preschool	0	0	0	0	1	0	0	0	0
Visiting	Inbound	430	2400	FT Worker	0	0	0	0.252	0.126	0.438	0.184	0	0
Visiting	Inbound	430	2400	PT Worker	0	0	0	0	0.497	0	0.255	0	0.248
Visiting	Inbound	430	2400	University Student	0	0	0	1	0	0	0	0	0
Visiting	Inbound	430	2400	Homemaker	0	0	0	0.312	0.118	0.216	0.354	0	0
Visiting	Inbound	430	2400	Retired	0	0	0	0.312	0.118	0.216	0.354	0	0
Visiting	Inbound	430	2400	Driving-age Child	0	0	0	0.312	0.118	0.216	0.354	0	0
Visiting	Inbound	430	2400	Pre-Driving Child	0	0	0	0.312	0.118	0.216	0.354	0	0
Visiting	Inbound	430	2400	Preschool	0	0	0	0	0	0	0.31	0.69	0
Discretionary	Inbound	430	2400	FT Worker	0	0	0	0.011	0.304	0.012	0.405	0.192	0.076
Discretionary	Inbound	430	2400	PT Worker	0	0	0	0.192	0.351	0.08	0.297	0.08	0
Discretionary	Inbound	430	2400	University Student	0	0	0	0.192	0.351	0.08	0.297	0.08	0
Discretionary	Inbound	430	2400	Homemaker	0	0	0	0.074	0.157	0.376	0.321	0.072	0
Discretionary	Inbound	430	2400	Retired	0	0	0	0.071	0.338	0.163	0.199	0.045	0.184
Discretionary	Inbound	430	2400	Driving-age Child	0	0	0	1	0	0	0	0	0
Discretionary	Inbound	430	2400	Pre-Driving Child	0	0	0	0.81	0	0	0.19	0	0
Discretionary	Inbound	430	2400	Preschool	0	0	0	0	1	0	0	0	0
Work-Based	Inbound	430	2400	All	0.14	0	0	0.118	0.214	0.115	0.366	0.016	0.031

5.3 Intermediate Stop Location Choice Model

The intermediate stop location choice model was estimated using SANDAG's 2006 household interview survey. This model predicts the location (the Master Geographic Reference Area, or MGRA) of each intermediate stop (each location other than the origin and primary destination) on the tour. In this model, a maximum of 3 stops in outbound and 3 stops in inbound direction are modeled for each tour. A number of variables were tested in the stop location choice models, including mode choice logsum, travel distance deviation for stop from the half-tour path, tour specific variables (purpose, mode, origin location, destination location), person and household attributes (gender, age, household income) and land use variables (employment, household, school enrollment and university enrollment). The models were estimated in ALOGIT software as a multinomial logit model.

Estimation Dataset

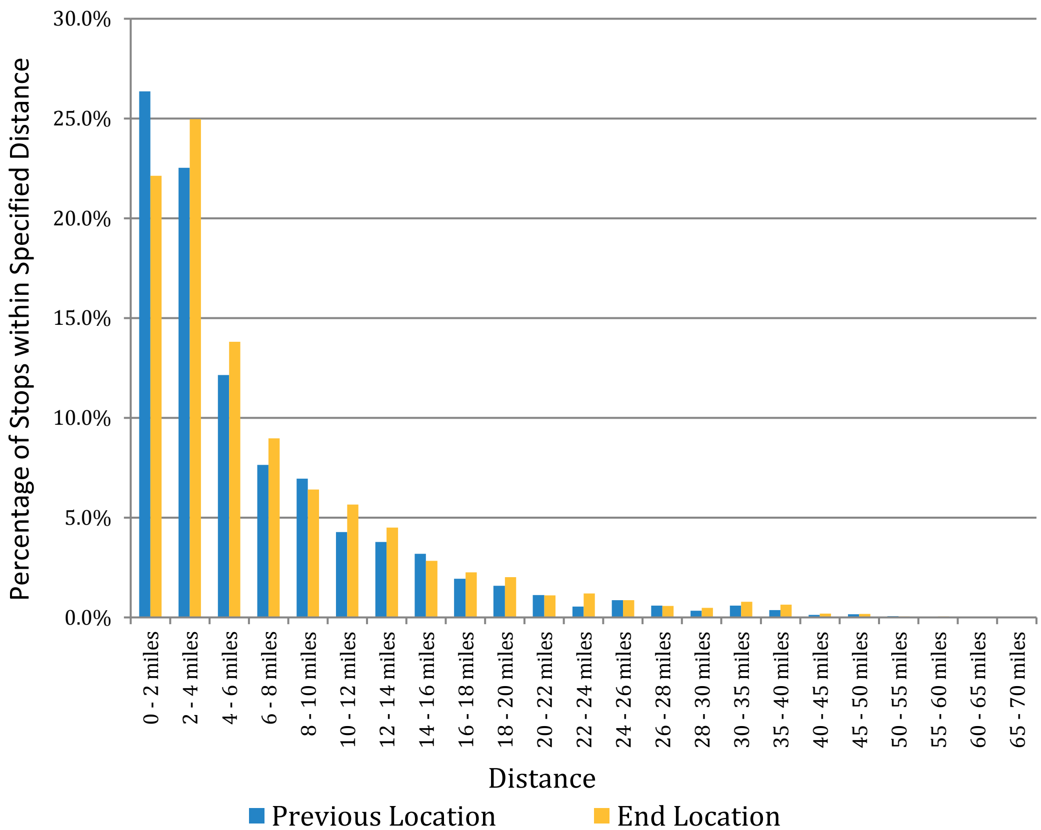
In the SANDAG 2006 household travel behavior survey, there are 5,732 observed stop records including up to 3 stops in each direction. Since there are a large number (over 33,000) of alternative destinations it is not possible to include all alternatives in the estimation dataset. A sampling-by-importance approach was used to choose a set of alternatives. Each record was duplicated 20 times, then different choice sets with 30 alternatives each were selected based on the size term and distance of the alternative destination. This approach is statistically equivalent to selecting 600 alternatives for the choice set. Table 96 below shows the number and percentage of stop records by primary tour purpose and stop purpose. Most of the stops are made for escorting, maintenance and shopping activities comprising for more than 70% of all stops. Nearly 40% of the stops are made on work tours.

Figure 32 shows the proximity of a stop from the previous stop and the end location of the half-tour. A half-tour is the trip beginning from a tour/trip origin and ending at the primary destination of that tour. An outbound half-tour is from the tour origin to the primary destination of that **tour**. An inbound half-tour begins at the primary destination of a tour and ends at the **half-**tour destination (which was also the tour origin). In case of the first stop on the outbound half-tour, the previous location is home (or work for at-work subtours) and end location is the tour primary destination (or subtour destination for at-work subtours). In case of second or later **stops** on the same tour, the previous location is the previous stop on the half-tour and end location is the half-tour destination. Please refer to the section on “Processing of Stops” for more detail.

Table 96: Number of Stop Records by Stop Purpose and Tour Purpose

Purpose	# Stops on Tours by Tour Activity Purpose		# Stops by Stop Activity Purpose	
Work	2,222	39%	333	6%
University	104	2%	34	1%
School	681	12%	0	0%
Escorting	537	9%	1,727	30%
Shopping	857	15%	1,253	22%
Maintenance	628	11%	1,113	19%
Eating Out	63	1%	519	9%
Visiting	151	3%	317	6%
Discretionary	407	7%	435	8%
At Work	81	1%	NA	
Total	**5,731**		**5,731**	

Figure 32: Percentage of Stops within Specified Distance from Previous location and End Location



Model Utility

The utility ($U^{tm}_{isjnkod}$) of choosing a stop MGRA (*s*) for an individual (*n*) for stop purpose (k) between the previous location MGRA (*i*) and half-tour destination MGRA (j) is given by Equation 4.

Equation 4

$$U^{tm}_{isjnkod} = S_{sk} + \alpha \times L^{tm}_{isj} + \sum_g \delta \times Fn[d_{os}, d_{sd}]T^g + \sum_p \beta^p \times d^p_{isj} + \sum_q \phi^q \times d_{isj} N^q_n + \sum_g \delta^g \times d_{isj} T^g + C_s$$

Where:

S_{sk} = the size function for stop mgra (s) and stop purpose (k)

L^{tm}_{isj} = the mode choice logsum for half-tour between zone pair ij via stop s, conditional upon tour purpose (t) and tour mode (m).

$Fn[d_{os}, d_{sd}]$ = function of distance from tour origin to stop (d_{os}) and distance from tour destination to stop (d_{sd}). The final function used is $d_{os}/ (d_{os}+d_{sd})$.This ratio shows if the stop location is closer to tour origin than tour destination.

d^p_{isj} = the various distance deviation terms (*p = linear, log, square root, squared, and cubed*) for stop *(s).*

N^q_n =the qth stop/tour/person /household characteristics (such as stop purpose, tour purpose, stop number, income, age group, person type) for individual n and are used for creating interaction variable with linear distance deviation term(d_{isj}),

T^g =the gth stop/tour characteristics (such as stop purpose, tour purpose, stop number, half-tour direction etc.) and are used for creating interaction variable with linear distance deviation term (d_{isj}),

C_s = a correction term to compensate for the sampling error in the model estimation (i.e. represent the difference between the sampling probability and final estimated probability for each alternative). The appendix explains how this correction factor is calculated.

The size function (S_{sk}) for stop location s, purpose k is a combination of different (*r*) size variables (S_{skr}) such as enrollment, employment by class, households, and their interaction with person/household characteristics. It is included in the utility function as a log term, as shown in Equation 2. The coefficients (γ_{rk}) on the size terms are constrained as positive in the estimation process. Note that the implied value of the coefficient on the first size term variable (r=1) is 1 for each stop purpose. This is to ensure that the size term is not over-specified; all other parameter values are interpreted as ratios of the impact of their corresponding independent variable to the first size term variable. Size term parameters are estimated simultaneously with other stop location choice parameters in ALOGIT. The final estimation results for size variables are shown in Table 3.

Equation 5

$$S_{sk} = \log(S_{sk1} + \sum_{d>1} \gamma_{dk} \times S_{skd})$$

A combination of distance deviation terms is used in the utility such that the composite distance deviation utility function is monotonically decreasing within the maximum chosen distance deviation range.

Sampling Procedure

A probability sampling procedure was used to select MGRAs as alternatives for estimation. The same procedure is also used in model application. The sampling procedure applies a simple multinomial logit model to create a probability distribution of 33,000 MGRAs for every sample record. The sampling model considers the distance deviation for including the stop MGRA in the half- tour, and the size term of the stop MGRA based on stop activity purpose. The size terms for sampling are computed based on the regression parameters estimated for accessibility size calculations. However, in model application, the sampling procedure will use the size terms estimated in this model. Each stop MGRA is assigned a probability computed from this simple model, and a Monte Carlo selection is made according to the probability distribution to obtain the sampled MGRAs. The full stop location choice model is then applied (or estimated) on the sampled MGRAs. The full stop choice model includes a mode choice logsum term, distance deviation terms, and other significant and logical variables. The model also includes a correction factor that accounts for the frequency of selection of the sampled alternative and the selection probability according to the sampling model. The correction factor is described more fully in **Appendix A**.

Main Explanatory Variables

It is not straightforward to segment the model by purpose because size (or attraction) variables are related to purpose of the stop activity while impedance variables are strongly related to the tour characteristics – primary tour purpose, primary mode used for the tour, etc. Therefore, a single model is estimated with size variables based on stop purpose and utility variables based on both stop and tour characteristics.

The following variables have been examined and proved to be significant in the utility functions:

1. Mode choice logsum
2. Distance deviation or "out-of-the-way" distance for stop location when compared to the half-tour distance without detour for any stop
    - Linear distance

Distance squared

Distance logged

3. Distance of stop location from tour origin and destination is used to define closeness to tour origin or destination. This term is interacted with tour purpose, direction of half-tour and stop number.
4. Tour- and stop-specific variables interacted with distance deviation:
    - Stop purpose

Tour purpose

Tour mode

Dummy for 2nd or 3rd stop

Direction of the half-tour

5. Household income group interacted with distance deviation:
    - Low income (less than $60,000)

Medium income ($60,000-100,000)

High income ($100,000 and more)

6. Person characteristics interacted with distance deviation:
    - Gender – female vs. male

Age group

7. Size variables
    - Employment by categories

Number of households

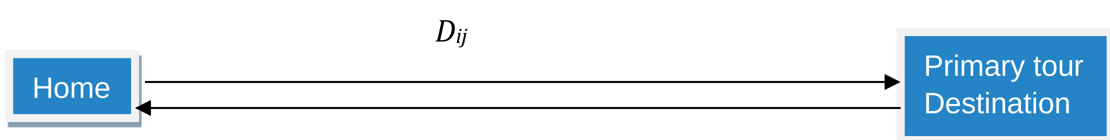
School enrollments – pre-school, K to 6 grade and 7th to 12th grade, based on type of school child in the household

University and other college enrollments

The model operates at a half-tour level using distance and level-of-service to get from half-tour origin to half-tour destination via stop location. In case of multiple stops on a half-tour, the stop locations are processed in a chronological order. The first stop is considered as the origin zone for the second stop, and second is considered the origin zone for the third stop. Detailed processing of stops is explained in the later section.

Processing of Stops

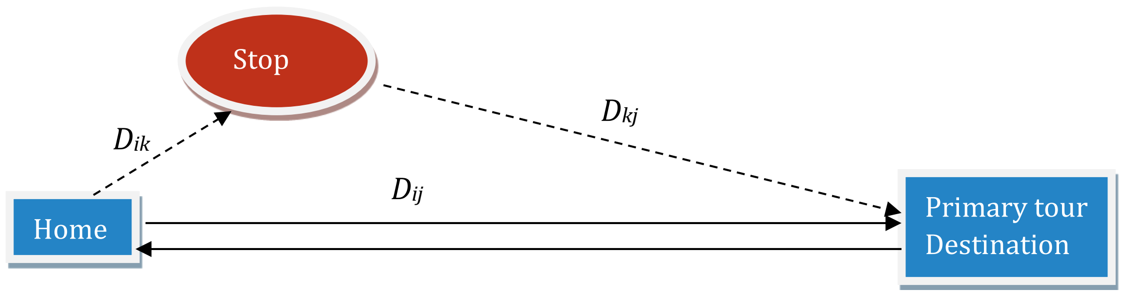
The example below explain show the stops are processed and how the distance deviation is calculated. Consider a tour from home (i) to primary tour destination (j) with distance D_{ij} between the two locations. Assume that this tour has two stops on the outbound half-tour and one stop on the inbound half-tour. The process described below applies to additional stops in any direction.



First, process the first outbound stop (k) for the half-tour. The absolute distance deviation (d_k) for stop k is given by $d_k = D_{ik} + D_{kj} - D_{ij}$ and relative distance deviation (R_k) is given by

$$R_k = \frac{[D_{ik}+D_{kj}-D_{ij}]}{D_{ij}},$$

where D_{ik} is the distance from home (i) to stop k and D_{kj} is the distance from stop k to primary destination (j).



Let's consider the second stop (m) on the half-tour. Since the location of stop (k) is already decided, the deviation for next stop is calculated based on stop (k) as the origin.

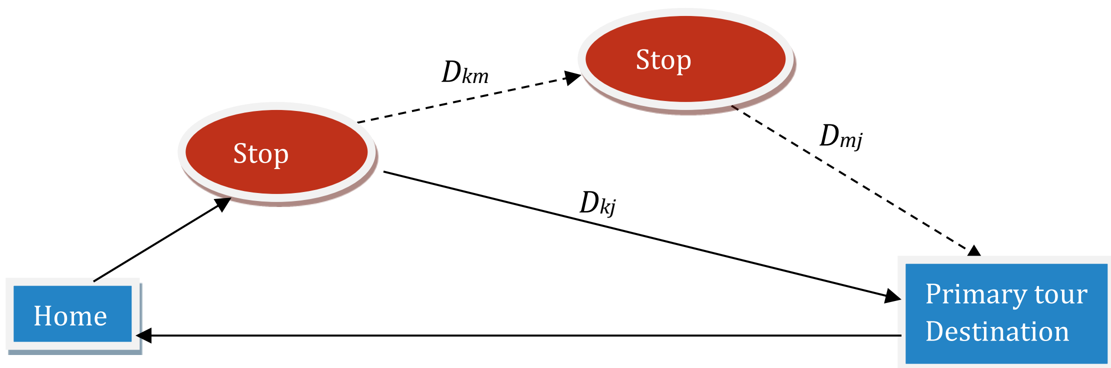
The absolute distance deviation (d_m) for stop m is given by:

$$d_m = D_{km} + D_{mj} - D_{kj}$$

The relative distance deviation (R_m) is given by:

$$R_m = \frac{[D_{km} + D_{mj} - D_{kj}]}{D_{kj}}$$

where D_{km} is the distance from stop k to stop m, and D_{mj} is the distance from stop m to primary destination (j).



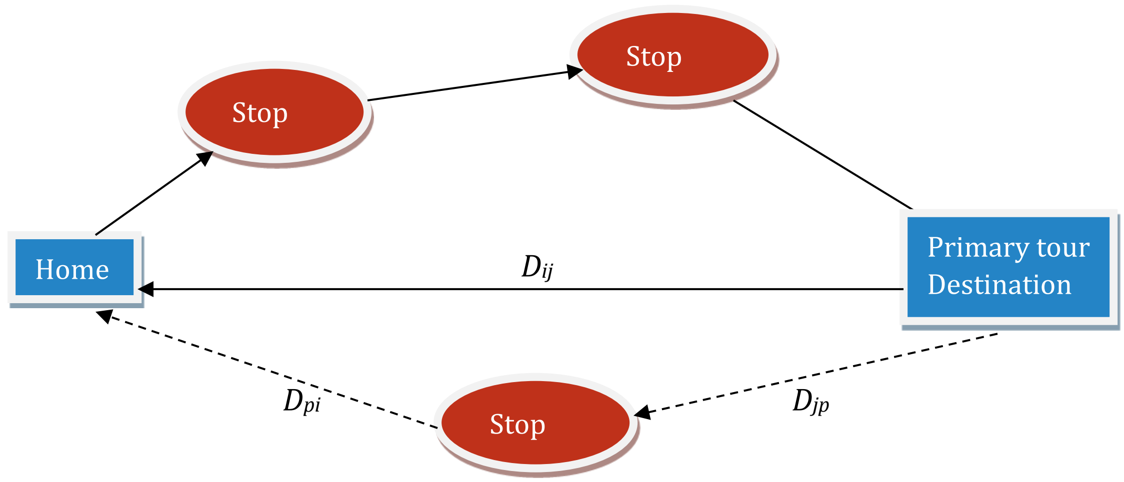
Multiple stops are processed along the half-tour using the same process. For inbound half-tour, the processing is carried out in the same way except that the primary tour destination (or previous stop on inbound half-tour) becomes origin location and home becomes destination location. The absolute distance deviation (d_p) for stop p on the inbound half-tour is given by:

$$d_p = D_{jp} + D_{pi} - D_{ij}$$

And the relative distance deviation (R_p) for stop p on the inbound half-tour is given by:

$$R_p = \frac{[D_{jp} + D_{pi} - D_{ij}]}{D_{ij}}$$

where D_{jp} is the distance from primary destination (j) to stop p and D_{pi} is the distance from stop p to home (i).



Calculation of Mode Choice Logsums

The mode choice logsums are calculated based on the trip mode choice model utilities, which are conditional upon the main mode of the tour. For drive alone tours, walk tours, and bike tours, the logsums are the mode choice utility of taking a half-tour by that single mode since no other trip modes are available for those tour modes. For transit tours, both transit and walk mode utilities are included in the logsum calculation. The logsum term (L_{ikj}) used in the estimation is defined as $L_{ikj} = L_{ik} + L_{jk}$, where L stands for logsum, i is the location before the stop (i.e. tour origin or previous stop), k is the stop location and j is the half-tour destination.

Availability Rules

The availability rules are defined based on accessibility by tour mode. Stop location alternatives with no path by the tour mode are excluded from the location choice set. This only affects the walk, bike, and transit paths because auto paths are available between all origin and destination pairs.

In the sampling procedure, the following availability rules were applied for non-motorized and walk-to-transit tours:

1. Stops on walk tours should be no more than 3 miles from tour origin and tour destination
2. Stops on bike tours should be no more than 6 miles from tour origin and tour destination
3. Stops on walk-to-transit tours should be within walking distance (4000 feet) of a transit stop

In addition to these rules, availability rules were defined during estimation which mostly affected stops on drive-to-transit tours.

Results

Tables 97 and 98 show the estimation results for the intermediate stop destination choice model. The total number of observations is 5731×20 = 114620. However, some records are dropped due to unacceptable choices and errors in size variables during the estimation process. An estimation weight of 1/20 = 0.05 is applied to correct for sample replication. It only affects the significance of the estimated coefficient but not the value of the coefficient itself.

Table 97: Intermediate Stop Location Choice Model (Impedance Variables)

Number of Observations	97,939
Likelihood with Constants only	-16774.6756
Final likelihood	-9092.2656
ρ² w.r.t. zero	0.4469
ρ² w.r.t. constants	0.458

Utility Function Variables	Coeff Mandatory	T-stat	Coeff Maintenance &Discretionary
Mode Choice Logsum	1.3142	24.8	1.0066
Distance Ratio			
Distance Ratio - All Stops	-1.9926	-3.9	-0.4485
Distance Ratio - First Outbound Stop	-0.6487	-4.7	-1.5160
Distance Ratio - First Inbound Stop	1.4972	7.2	1.8051
Distance Ratio - Mandatory Outbound Tour	0.0000	-5.6	-1.3255
Distance Ratio - Mandatory Inbound Tour	0.9173	-3.4	-0.7034
Absolute Distance Deviation			
Linear	0.0000	-1.7	-0.0615
Log	-0.8396	-8.9	-0.9406
Square	0.0000	-3.0	-0.0002
Absolute Distance Deviation - Half-Tour Direction			
Return half tour for Mandatory purpose			0.0029
Absolute Distance Deviation - Stop Purpose			
Work	-0.1066	6.1	0.0637
University	0.0843	5.3	0.0937
Shopping		-1.5	-0.0227
Maintenance	0.0292	2.2	0.0211
Eating Out		1.8	0.0225
Social/Visiting		6.5	0.0686
Discretionary	0.0727	5.8	0.0574
Log Absolute Distance Deviation - Stop Purpose			
Work	1.0298		
Shopping	-0.1994		

Utility Function Variables	Coeff Mandatory	T-stat	Coeff Maintenance &Discretionary
Social/Visiting	0.6522		
Absolute Distance Deviation - Tour Purpose and Mode			
School	0.1122	2.7	0.0187
University	0.0259		
Shopping		3.9	0.0268
Maintenance		4.1	0.0341
Discretionary		-2.2	0.0200
At-Work		3.8	0.0878
Work			0.0500
University			0.0200
Visiting			0.0200
Walk/Bike	0.0000	-1.7	-1.0049
Absolute Distance Deviation - Stop Sequence			
Number of Stops on the half-Tour	0.0000	4.3	0.0205
2nd Stop of half tour	-0.0618	-3.4	-0.0315
3rd+ Stop of half tour	-0.0776	-3.8	-0.0631
Household Variables			
Absolute Distance Deviation - Income - $59,999 or Less	0.0227	5.9	0.0363
Person Variables (Individual Tours Only)			
Absolute Distance Deviation - Female	-0.0707	-3.8	-0.0272
Distance Deviation - Age 35 to 54 yrs	-0.0895	-1.2	-0.0102
Distance Deviation - Age >=55	-0.0987	-2.3	-0.0135

Table 98-a: Intermediate Stop Destination Choice Model (Size Variables)

Stop Purpose	Work		University		Escorting		Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Total Employment	1.0000															
University Enrollments			1.0000													
Number of Households													0.4952	-3.7	0.0273	-12.3
Enrollments for School Children*					5.7072	12.1										
Retail Employment							1.0000		1.0000		0.1378	-5.0			0.0388	-8.6
Professional and Business Services									0.05							
Amusement Services															0.4737	-2.3
Hotel Activity															0.0923	-4.9
Restaurants and Bars							0.2147	-8.5			1.0000		1.0000		0.1229	-6.4
Personal Services and Retail Based									1.7259	3.4						
Religious Activity															1.0000	
Federal non-military activity									1.9857	4.3						
Health Employment									1.9520	4.7						
Number of Households					1.0000						0.0102	-4.1				

* based on presence of school child in the household by grade category type, see Table 98-b for details

Table 99**-b**: Intermediate Stop Destination Choice Model (Size Variables) for Escorting Trip Purpose - specified for each combination of presence of pre-school, grade school, and high school students in the household

Stop Purpose	escort-ps		escort-gs		escort-hs		escort-ps-gs		escort-ps-hs		escort-gs-hs		escort-ps-gs-hs	
	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Total number of households	1.0000		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000	
Total population	5.7072						5.7072		5.7072				5.7072	

Private Education Elementary K-12	5.7072						5.7072		5.7072				5.7072	
Private Education Post-Secondary	5.7072						5.7072		5.7072				5.7072	
Professional and Business Services	5.7072						5.7072		5.7072				5.7072	
Professional and Business Building Maint	5.7072						5.7072		5.7072				5.7072	
Religious Activity	5.7072						5.7072		5.7072				5.7072	
Federal Non-Military Activity	5.7072						5.7072		5.7072				5.7072	
Health Services	5.7072						5.7072		5.7072				5.7072	
Federal Military Activity	5.7072						5.7072		5.7072				5.7072	
State and Local Government Blue Collar	5.7072						5.7072		5.7072				5.7072	
State and Local Government White Collar	5.7072						5.7072		5.7072				5.7072	
Public Education (K-12)	5.7072						5.7072		5.7072				5.7072	
State and Local Government Enterprises Activity	5.7072						5.7072		5.7072				5.7072	
Enrollment K-6			5.7072				5.7072				5.7072		5.7072	
Enrollment 7-12					5.7072				5.7072		5.7072		5.7072	

Findings

The estimated mode choice logsum parameter is **1.31** and is very significant. The distance deviation function measures how far "out-of-way" a stop location is compared to the half-tour path distance. There are two terms used in the utility expression: relative deviation and absolute deviation. Relative distance is more relevant for short distance tours where absolute deviation is small but its proportion to half-tour distance is significant. The composite function (with linear, log and square terms) defined for both terms are strongly negative, as shown in Figures 33 and 34.

Figure 33: Absolute Distance Deviation Function in the Utility Function

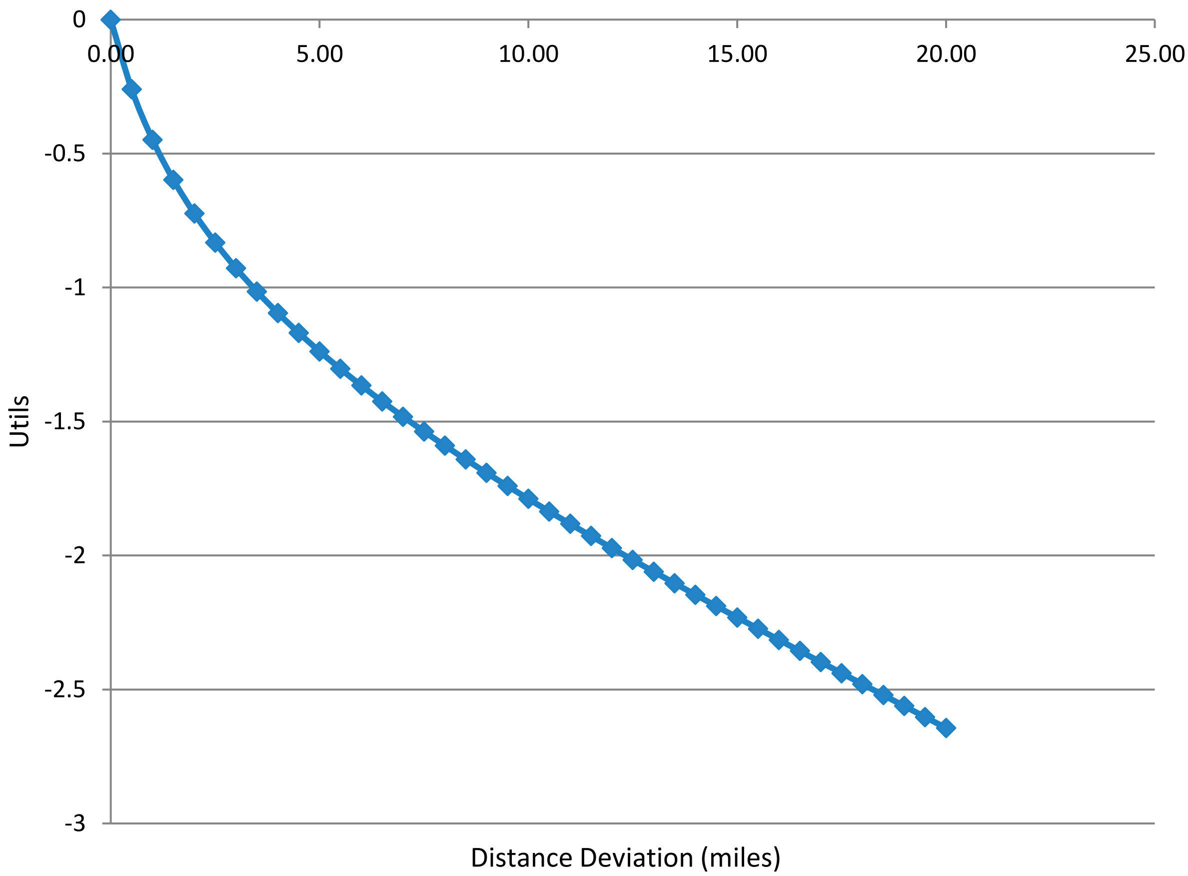
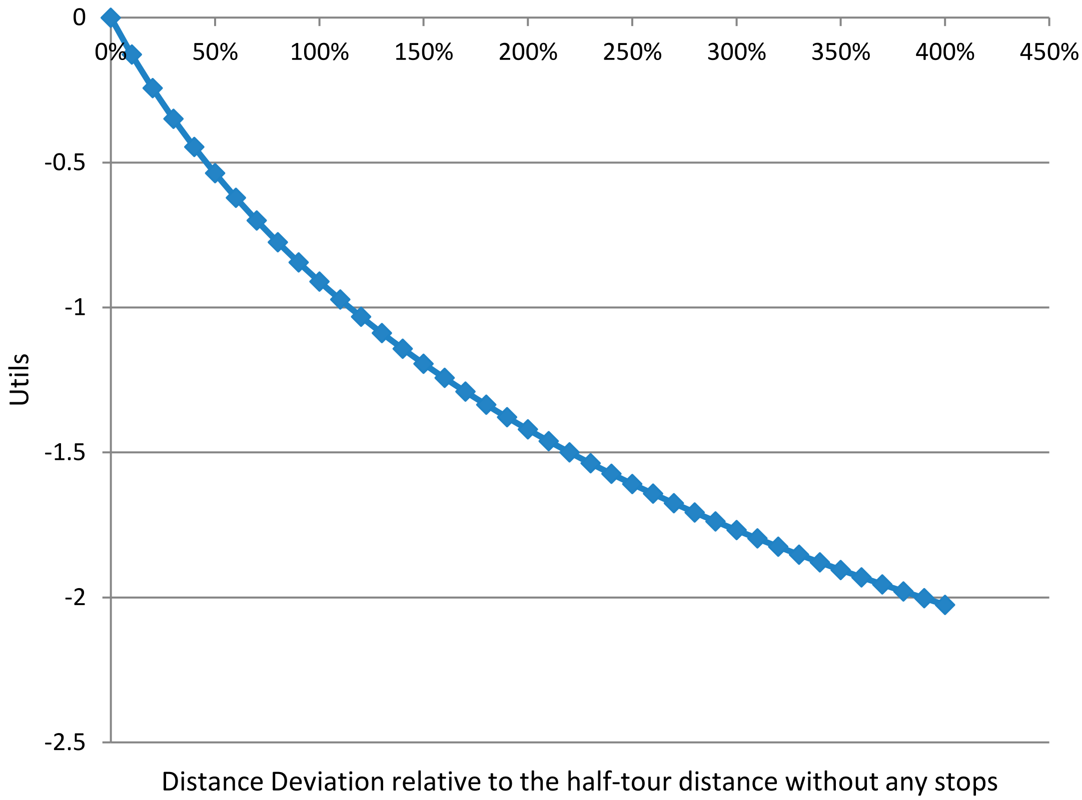


Figure 34: Relative Distance Deviation Function in the Utility Function



Below are interesting findings for the interaction of distance deviation with stop, tour, household and person characteristics:

- *Tour Purpose:* Stops on at-work tours tend to be more out-of-the-way than on any other type of tours. Stops on escorting, visiting and discretionary tours tend to be less out-of-the-way compared to other purposes.
- Stop Purpose: Stops made for purposes other than escorting and shopping tend to be larger deviation from the straight line half tour path with stops for mandatory purposes having the largest deviation.
- Tour Mode: This interaction works in addition to the mode choice logsums. The absolute deviation (in miles) for stops is shorter for non-motorized modes.
- Half-Tour Direction: Stops on the inbound half-tour tend to be more "out-of-the-way" than stops on the outbound half-tour for mandatory tours.
- Number of Stops and Stop Sequence: The deviation tends to be larger for multi-stop half-tours. However, second and the third stop tend to be less "out-of-the-way" compared to first stop.
- Person and Household characteristics: There are strong effects of gender, income and age group on distance deviation. Person characteristics are only applied for individual tours. Females and older individuals (55 years or older) tend to be more sensitive to longer deviations for the stop. Low income household members ($59,999 or less) tend to go more out-of-the-way for stops compared to high income household members.

- Closeness to Tour Origin or Tour Destination: The ratio of distance from tour origin to sum of distance from tour origin and tour destination is used as a measure of closeness of stop to tour origin. Overall, stops tend to be closer to tour origin (usually home).On a multiple stop half-tour, the first stop is closer to origin in the outbound direction and close to destination in the inbound direction. Also, the stops are closer to origin, more on the outbound direction than in the inbound direction, on mandatory tours as compared to non-mandatory tours.

The size variable in Table 3 show similar attraction trends as for the primary non-mandatory tour destinations of the same purpose. Total employment was used for work purpose stops and only university enrollments were found to be significant for university purpose size variable.

5.4 Intermediate Stop Departure Model

The stop departure period choice model is a lookup table of probabilities based upon tour purpose, stop direction, tour departure time, and stop number. Refer to the file *stopdepartarriveproportions.csv* in the UEC folder.

6.0 Trip Mode Choice Model

6.1 Trip Mode Choice Model

The trip mode switching model was estimated using SANDAG's 2006 household interview survey and the 2009 transit on-board survey. It is referred to as a trip mode “switching” model because it predicts the likelihood of each trip mode, conditioned by the chosen tour mode. The main mode is chosen at the tour level but this model predicts the mode for each individual trip on the tour. The model considers a range of network characteristics (travel time, cost, etc.), household and person socio-economic characteristics (household income, auto ownership, number of adults, person age, gender, etc.), and land use/urban form characteristics (population/employment land-use mix density, employment density, and intersection density). The model was estimated in ALOGIT software. Final model estimation results with coefficients and t-statistics for each purpose are shown.

Estimation Dataset

The trip mode choice model was estimated from a combination of 2006 SANDAG household survey data and 2009 transit on-board survey data. The data sets were used with no weighting since non-transit modes were made unavailable for the choice-based transit on-board survey. The home-interview survey is a random sample. Table 100 shows the tabulation of valid records by tour mode and trip mode from the 2006 SANDAG Home Interview Survey and 2009 on-board survey. Note that for the auto tour modes, the transit trip modes are not available, and for the walk and bike tour modes, only walk or bike trips modes are available. Modal availabilities are discussed in the Model Specification section.

Table 100: Valid Records for Trip Mode Choice Model Estimation

Trip Mode	Tour Mode									Total
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Bike	School Bus	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	
Drive-Alone Free	9,971	1,813	904	-	6 *	5	3	32	1	12,735
Drive-Alone Toll	5	2	1	-	-	-	-	-	-	8
Shared 2 Free (GP)	-	5,580	1,485	-	-	13	26	10	25	7,139
Shared 2 Free (HOV)	-	11	2	-	-	-	-	-	-	13
Shared 2 HOV\Toll	-	-	-	-	-	-	-	-	-	-
Shared 3+ Free (GP)	-	-	5,001	-	-	14	18	1	11	5,045
Shared 3+ Free (HOV)	-	-	13	-	-	-	-	-	-	13
Shared 3+ HOV\Toll	-	-	-	-	-	-	-	-	-	-
Walk	53	100	153	1,941	4	6	116	7	12	2,392
Bike	1	4	11	-	192	-	2	-	-	210
School Bus (SB)	-	14	54	-	-	299	2	-	-	369
Walk to Local Bus	-	-	-	-	-	-	13,092	5	25	13,122
Walk to Express Bus							946	-	-	946
Walk to Light Rail	-	-	-	-	-	-	4,281	3	7	4,291
Walk to Commuter Rail	-	-	-	-	-	-	181	1	1	183
PNR to Local Bus	-	-	-	-	-	-	-	285	-	285
PNR to Express Bus							-	270		270
PNR to Light Rail	-	-	-	-	-	-	-	203	-	203
PNR to Commuter Rail	-	-	-	-	-	-	-	252	-	252

Trip Mode	Tour Mode									Total
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Bike	School Bus	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	
KNR to Local Bus	-	-	-	-	-	-	-	-	453	453
KNR to Express Bus							-	-	75	75
KNR to Light Rail	-	-	-	-	-	-	-	1	271	272
KNR to Commuter Rail	-	-	-	-	-	-	-	-	70	70
Total	**10,030**	**7,524**	**7,624**	**1,941**	**202**	**337**	**18,667**	**1,070**	**951**	**48,346**

* There are 6 drive-alone trips on bike tours, due to mode mixing in the survey. Since there were so few cases, this combination was disallowed in estimation and application.

In the estimation data file, some records were dropped from the above table due to the availability rules that relates to trip and tour modes. If the chosen alternative is the only available alternative, then the record is dropped from the estimation (at least one un-chosen alternative must be available). For example, records where the tour mode is drive-alone, and toll is not available, have only one (chosen) trip mode available; drive-alone. In such cases, ALOGIT drops the observation from estimation, since it does not provide any information to the estimation process. The same is true for walk, bike, and school bus tours; no mode switching is allowed for these tours, so walk, bike, and school bus tours are not used to estimate the trip mode choice model. One key limitation of the data used in estimation is that tour mode is unobserved for transit on-board survey records. These records were collected via an OD survey, so attributes of the tour are unknown. For tour mode choice estimation, symmetry of trip mode was assumed; in other words, if the trip was surveyed in the outbound direction, and the mode was walk-local bus, the return tour was also assumed to be walk-local bus. However, the trip mode choice model is trying to measure the propensity to switch modes within a tour. Since non-transit trip modes are never observed in the on-board survey, non-transit alternatives are made unavailable for on-board survey records in estimation. Therefore, if a transit on-board survey record only has one transit mode available (such as walk-local bus) it would have been dropped from the estimation process.

The trip mode choice model alternatives are:

1. Drive-alone Free
2. Drive-Alone Pay
3. Shared-Ride 2 Free (General Purpose Lane)
4. Shared-Ride 2 Free (HOV Lane)
5. Shared-Ride 2 Pay
6. Shared-Ride 3+ Free (General Purpose Lane)
7. Shared-Ride 3+ Free (HOV Lane)
8. Shared-Ride 3+ Pay
9. Walk
10. Bike
11. Walk-Local Bus
12. Walk-Express Bus
13. Walk-Bus Rapid Transit
14. Walk-Light Rail Transit
15. Walk-Commuter Rail
16. PNR-Local Bus
17. PNR-Express Bus
18. PNR-Bus Rapid Transit
19. PNR-Light Rail Transit
20. PNR-Commuter Rail
21. KNR-Local Bus
22. KNR-Express Bus

23. KNR-Bus Rapid Transit
24. KNR-Light Rail Transit
25. KNR-Commuter Rail
26. School Bus

Each trip mode's availability depends upon the chosen tour mode, as shown in Table 101 (available trip modes are denoted by an "A"). These availability rules are directly related to the way in which tour mode is coded based on the combination of trip modes used for a tour. The rules specify that the highest occupancy across all trips is used to code the occupancy of the tour. The rules also dictate that the walk and bike tour modes mean that there is no mode switching for trips on these tours. The rules allow for shared-ride trips on walk-transit tours. Drive-alone is disallowed for walk-transit and KNR-transit tours, since driving on a trip leg in combination with walk-transit would imply PNR-transit as a tour mode. Walk trips are allowed on all tour modes with the exception of driving alone and biking, since these modes imply that the traveler is attached to the mode of transport (the auto or bicycle) for the entire tour. Note that cases in which a traveler parks at a lot and then walks to their destination are treated as a single trip in the context of trip mode choice. A subsequent parking location choice model will break out these trips into the auto leg and the walk leg, for trips to parking-constrained locations. An additional restriction on availability is imposed on work-based sub-tours, where drive-alone is disallowed if the mode to work is not one of the three auto modes (drive-alone, shared 2, or shared 3+). Also the school bus tour mode, which is only available for the School tour purpose, implies symmetry – all trips on school bus tours must be made by school bus.

Table 101: Trip Mode Availability by Tour Mode

	Tour Mode							
Trip Mode	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit
Drive-alone Free	A	A	A				A	
Drive-Alone Pay	A	A	A				A	
Shared-Ride 2 Free (GP Lane)		A	A			A	A	A
Shared-Ride 2 Free (HOV Lane)		A	A			A	A	A
Shared-Ride 2 Pay		A	A			A	A	A
Shared-Ride 3+ Free (GP Lane)			A			A	A	A
Shared-Ride 3+ Free (HOV Lane)			A			A	A	A
Shared-Ride 3+ Pay			A			A	A	A
Walk		A	A	A		A	A	A

Trip Mode	Tour Mode							
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit
Bike					A			
Walk-Local Bus						A	A	A
Walk-Express Bus						A	A	A
Walk-Bus Rapid Transit						A	A	A
Walk-Light Rail Transit						A	A	A
Walk-Commuter Rail						A	A	A
PNR-Local Bus							A	
PNR-Express Bus							A	
PNR-Bus Rapid Transit							A	
PNR-Light Rail Transit							A	
PNR-Commuter Rail							A	
KNR-Local Bus								A
KNR-Express Bus								A
KNR-Bus Rapid Transit								A
KNR-Light Rail Transit								A
KNR-Commuter Rail								A
School Bus	Available for school bus tour mode only, on school tours.							

Utility Structure

The utility expression for each trip mode (i), given a tour mode (j) and the placement of the trip on tour (s) is specified as a linear function of level of service variables (such as time and cost), location specific measures (Location), socio-economic (SE) characteristics, and alternative specific constants (δ, α, and λ), as shown below:

$$U_{i|j,s} = \sum_k(\beta_k * Time_k) + \sum_l(\beta_l * Cost_l) + \sum_m(\beta_m * Location_m) + \sum_n(\beta_n * SE_n) + \delta_{i|j} + \alpha_s + \lambda_i$$

Where:

Time is an array of travel time variables, denoted by the index *k*. Travel time variables are typically disaggregated into in-vehicle and out-of-vehicle time at a minimum, with out-of-vehicle time stratified by walk time, initial wait, and transfer wait time (the latter two categories applicable to the transit mode(s)).

Cost is an array of travel cost variables, denoted by the index i. Travel cost is often disaggregated into the more general out-of-pocket costs (i.e., automobile operating costs and transit fare) and destination parking cost. Costs used in estimation are represented in 2007 dollars. An appropriate auto operating cost for mode choice modeling is currently a subject of debate in California. The auto operating cost used in the tour and trip mode choice model is 19.8 cents/mile. This is based on an average fleet efficiency of 19.5 miles/gallon[4], an average fuel price of $2.63/gallon, and average maintenance costs of 6.3 cents/mile[5].

Location is an array of location-specific variables, denoted by the index *m*. They are used to reflect a set of unique zonal/MGRA-based characteristics such as the land-use mix index.

SE is an array of socio-economic variables, denoted by the index *n*. They include household size and gender. Note that the tour mode choice models contain other variables that influence mode, such as auto ownership; since the trip mode choice model is primarily concerned with mode switching, the level of auto ownership is not a significant factor.

Alternative-specific constants (ASC)

The trip mode choice model has three types of alternative specific constants:

1. Tour mode constants (δ): Trip mode constants that are stratified by tour mode, where the tour mode is the base constant.
2. Mode sequence constants (α): These are constants applied to all trip modes other than the tour mode, stratified by the trip sequence within the tour; first trip, last trip, or only trip (no stops on half-tour). They are referred to as "off-diagonal" constants, because they are applied to all trip modes/tour mode combinations which would be off the main diagonal of a matrix of tour mode versus trip mode combinations. The stratification of the constants by trip sequence captures the effect of the sequence of the trip on the tour on the likelihood of mode switching, as explained more fully below.
3. Transit line-haul mode constants (λ): Trip mode constants specifically for transit line-haul modes.

The trip mode by tour mode constants (δ) affects the distribution of trips by trip mode, according to the chosen tour mode. For example, the drive-alone trip constant for shared-ride 2 tours represents the portion of the drive-alone utility associated with driving alone on a shared-ride 2 tour in which

[4] EMFAC 2007 San Diego County Base Run for Winter 2007

[5] MPO agreed fee for 2009, converted to 2007 dollars using CA Department of Finance (CPI-U San Diego MSA) CPI of 1.038 between 2007 and 2009.

one of the legs of the tour is a shared-2 trip. For example, a drive-alone trip typically occurs after dropping off a child at school.

The mode sequence constants for first trip (at least one outbound stop), last trip (at least one return stop), and no stops on tour help determine how likely a different mode for the trip other than the tour mode is chosen, based on the sequence of the trip within the tour. For example, if a work tour mode was shared ride 2, and there is at least one outbound stop, the likelihood of the first trip mode being some other than shared ride 2 (off-diagonal) is unlikely since the first trip of the tour is often used to drop off a child at daycare; therefore the off-diagonal constant for the first trip of shared-2 tours is typically highly negative.

Figure 35 shows an example of a shared-ride tour with two outbound and one return stops. In addition to relevant time, cost, locational, and socio-economic parameters, the utility equations for trips 1, 2 and 3 will also contain the following constants for the trips:

- $\text{Utility}_{\text{DA|Shared-ride 2 tour, first trip}}$ = … + Trip Mode $\text{Constant}_{\text{DA|Shared 2 tour}}$ + Off-Diagonal $\text{Constant}_{\text{first}}$
  $\text{Utility}_{\text{Shared 2|Shared-ride 2 tour, first trip}}$ = … (no additional constant)

- $\text{Utility}_{\text{DA|Shared-ride 2 tour, second trip}}$ = … + Trip Mode $\text{Constant}_{\text{DA|Shared 2 tour}}$
  $\text{Utility}_{\text{Shared 2|Shared-ride 2 tour, second trip}}$ = … (no additional constant)

- $\text{Utility}_{\text{DA|Shared-ride 2 tour, third trip}}$ = … + Trip Mode $\text{Constant}_{\text{DA|Shared 2 tour}}$ + Off-Diagonal $\text{Constant}_{\text{no-stops}}$
  $\text{Utility}_{\text{Shared 2|Shared-ride 2 tour, third trip}}$ = … (no additional constant)

Figure 35: Work Purpose Shared Ride-2 Tour and One Outbound Stop

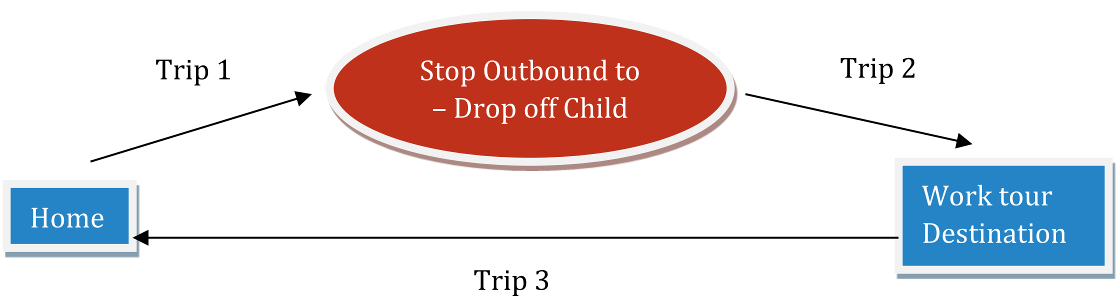
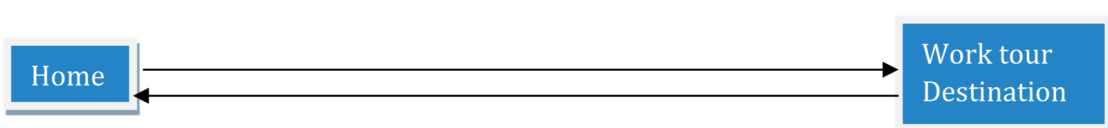


Figure 36 shows a work purpose park and ride to transit tour with no outbound or return stops. The off-diagonal constant for no stops is typically negative as we would assume it is likely that the outbound and return mode would be the same as the tour mode (park and ride to transit).

Figure 36: Work Purpose Park and Ride to Transit Tour No Stops



Finally, there are transit line haul constants that applied to each of the transit trip modes in addition to their trip by tour mode and off-diagonal constants.

Nesting structure

The nested model structure is a 3-level nested structure. For the first level, the primary choice of mode is among auto, non-motorized, transit and school bus (only available for school tours). At the second level, auto has 3 sub-modes (drive-alone, shared-ride 2 and shared-ride 3+), non-motorized has choice between walk and bike, and transit has 3 access options (walk, PNR and KNR). These sub-modes have further choices based as shown in Figure 37.

In application, the model independently addresses modes at the lowest nest level and computes modal utilities. For example, the utility of choosing Drive-Alone-GP (1) and Drive-Alone-Pay (2) would be U_{DA-GP} and U_{DA-Pay}. A composite of the utilities or logsum will represent these drive-alone sub-modes at the next level of nest. The logsum term is the maximum expected utility provided by all sub-modes of a primary mode and it is calculated as

$$LogSum_{DA} = \ln[\, e^{U_{DA-GP}/\theta_1\theta_2} + e^{U_{DA-Pay}/\theta_1\theta_2} \,]$$

where θ_1 is the nesting coefficient for the lower level nest and θ_2 is the nesting coefficient for the upper level nest.

Similarly, logsums are calculated for all the nine modes – drive-alone, shared-ride 2, shared-ride 3+, walk, bike, walk access transit, PNR transit, and KNR transit. Then, the logsums are computed for the upper level nest as shown below for Auto nest.

$$LogSum_{Auto} = \ln[\, e^{\theta_1 LogSum_{DA}} + e^{\theta_1 LogSum_{SR2}} + e^{\theta_1 LogSum_{SR3+}} \,]$$

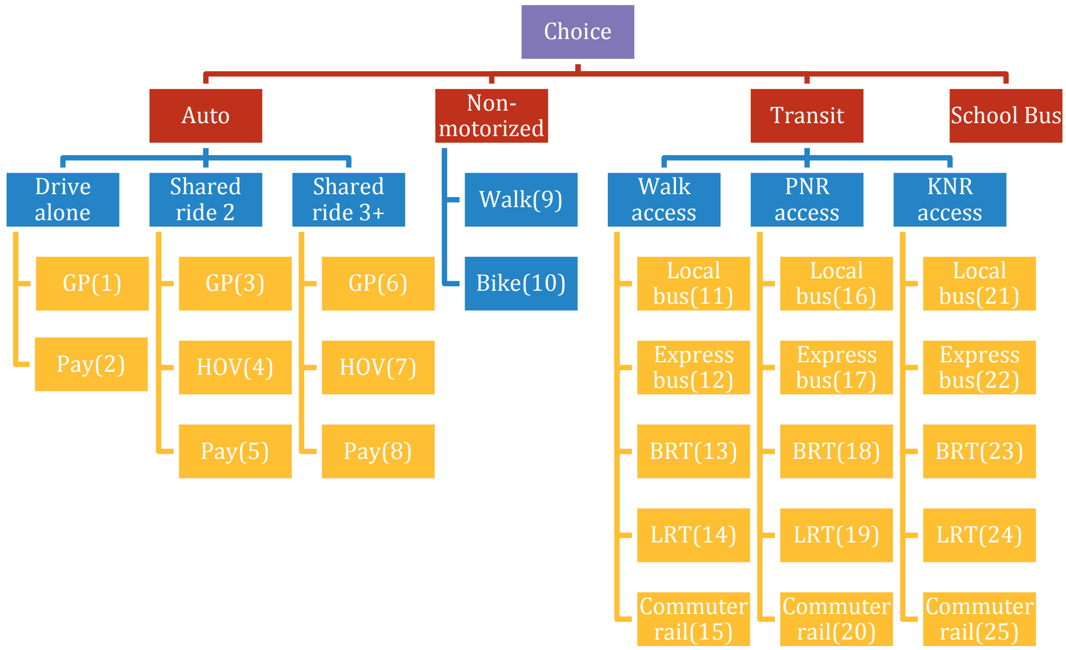
The probability of choosing auto is given by

$$P_{Auto} = \frac{e^{\theta_2 LogSum_{Auto}}}{e^{\theta_2 LogSum_{Auto}} + e^{\theta_2 LogSum_{Non-Motorized}} + e^{\theta_2 LogSum_{Transit}} + e^{\theta_2 LogSum_{SchoolBus}}}$$

The value of nesting coefficients should be between 0 and 1. A value of 1.0 indicates that the lower level modes are not a sub-choice but rather are full options equally competitive with the primary modes. In this instance, these lower level choices can be simplified or included directly in the upper level. A value of 0.0 would indicate that the lower level choices are perfect substitutes for each other.

Similar to tour mode choice estimation, it was not possible to estimate the nesting structure using the available data; this may be due to the lack of available alternatives across different nests. The nesting structure was therefore imposed upon the estimation process. The nesting coefficients asserted in the model are 0.6 at the top level and 0.4 at the bottom level.

Figure 37: Mode Choice Nesting Structure



Home Based Work Model Estimation

The first model estimated was for the home based work purpose. This was the most extensive estimation, and the results of this estimation informed the specification of models for the other purposes. The following table shows the work purpose records used in estimation by tour mode and trip mode from the home interview survey and on-board survey. Note that records with tour modes of drive-alone, walk, and bike were not used in estimations since only their chosen mode was available (there were insufficient drive-alone pay observations in the data to represent this alternative explicitly).

Table 102. Home Based Work Tour Mode by Trip Mode Available Records

Trip Mode	Tour Mode							
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	Total
Drive-Alone Free	-	791	484	-	-	12	-	**1,287**
Shared 2 Non HOV, Non Toll	-	798	234	-	7	4	12	**1,055**
Shared 2 HOV	-	6	-	-	-	-	-	**6**
Shared 3+ Non HOV, Non toll	-	-	445	-	9	-	1	**455**
Shared 3+ HOV	-	-	2	-	-	-	-	**2**
Walk	-	15	5	-	24	3	2	**49**
Walk to Local Bus	-	-	-	-	1,892	-	5	**1,897**
Walk to Express Bus	-	-	-	-	352	-	-	**352**
Walk to Light Rail	-	-	-	-	1,244	-	4	**1,248**
Walk to Commuter Rail	-	-	-	-	57	1	-	**58**
PNR to Local Bus	-	-	-	-	-	74	-	**74**
PNR to Express Bus	-	-	-	-	-	152	-	**152**
PNR to Light Rail	-	-	-	-	-	99	-	**99**
PNR to Commuter Rail	-	-	-	-	-	196	-	**196**
KNR to Local Bus	-	-	-	-	-	-	90	**90**
KNR to Express Bus	-	-	-	-	-	-	30	**30**
KNR to Light Rail	-	-	-	-	-	-	79	**79**
KNR to Commuter Rail	-	-	-	-	-	-	49	**49**
Total	**-**	**1,610**	**1,170**	**-**	**3,585**	**541**	**272**	**7,179**

There were 7,179 observations used for estimation of this model after elimination of non-available alternatives. A number of coefficients and constant terms were estimated, as described below.

Model Estimation Findings

The final model is a mix of estimated and asserted coefficients. In cases where the estimated values were not reasonable, but the coefficient was important for the model, the coefficients were asserted.

- The ASC for the transit line haul modes were asserted since the estimated ones were illogical, possibly due to sampling bias. They were asserted using the work tour mode choice transit line haul constants and rescaling them to trip mode choice model using the work trip mode choice in-vehicle coefficient (tour mode constant = trip model constant/trip model in-vehicle time coefficient * tour model in-vehicle time coefficient). The park and ride and kiss and ride constants were estimated, and will be re-assessed during calibration.
- The ASC off-diagonal constant for the first trip of a shared ride two-person tour with at least one outbound stop is negative since the likelihood of the first trip mode being something other than a shared ride-two person is less likely. The ASC off-diagonal constant for the last trip is also negative for shared ride two-persons tour since the likelihood of the last trip mode being something other than a shared ride two person (off-diagonal) is less likely. Similar patterns were found for the off-diagonal constants for trips within a shared ride three-person tour. However for drive transit tour modes, the likelihood of the trip mode being something other than the drive transit mode is more likely; the first trip could be shared ride 2 or 3+ trip (dropping off a child to school) before driving to transit station. Also if there are no stops on the half-tour, the likelihood of the trip mode being something other than the tour mode is highly unlikely.
- The estimated in-vehicle time coefficient was highly significant at -0.0320, reflecting the influence of in-vehicle time on trip mode choice.
- The estimated walk mode time coefficient was highly significant at -0.0849. The high relative value of walk mode time (at approximately 3 miles per hour) compared to in-vehicle time reflects the strong disutility of increasing distance on walk probability.
- The cost coefficient was stratified by income classes. For the two low income groups, the cost coefficients were negative and statistically significant; while for the two high income groups they were statistically insignificant. The resulting values of time (VOT) for the lower income groups were lower than expected and the VOT for the higher income groups were larger than expected. In the final run, these coefficients were constrained such that VOT for work trips were the same as those in the work tour model. VOT were calculated as half of the average hourly wage rate for each household income group, as follows:
    - $0-$30,000: $15,000 (average yearly income) / 2080 (hours/year) * ½ * 1 (workers/household) = $3.61/hour
    - $30,001 - $60,000: $45,000 (average yearly income) / 2080 (hours/year) * ½ * 1.33 (workers/household) = $8.13/hour
    - $60,001 - $100,000: $80,000 (average yearly income) / 2080 (hours/year) * ½ * 1.44 (workers/household) = $13.33/hour
    - $100,001 and greater: $186,472 (average yearly income) / 2080 (hours/year) * ½ * 1.18 (workers/household) = $38.14/hour (capped at $30.00/hour)

- Transit total walk access time coefficient was more negative than expected, so the value was asserted at 1.5666 times the in-vehicle time coefficient.
- Transit drive access time was not significant, and the sign varied across estimation runs, so this coefficient was asserted at 1.88 times the in-vehicle time coefficient. Transit initial wait was also asserted at 1.5 times the in-vehicle time coefficient.
- Transit total wait time was estimated as more negative than expected, so it was asserted at 1.5 the in-vehicle time coefficient.
- The transfer wait time and the number of transfer variable were both significant, but the value of number of transfers was too negative, so the number of Non-PNR transfers coefficient was asserted to be equivalent to 5 times of in-vehicle time.
- In addition to testing the land-use mix index, variables for the intersection and employment density were tested. Ideally, intersection density would be measured across the entire route for walk and bike trips. However, this is not possible. Instead, the intersection density at the origin end of the trip was tested but dropped eventually. Employment density at the destination end of the trip was tested, under the assumption that the proximity of services to the workplace has a higher effect on trip mode choice. Only employment density was positive and significant for drive to transit trips at the destination end of the trip, although the magnitude was small (0.0251).
- When the ASCs were stratified by auto sufficiency, none of the coefficients were significant. This is likely due to the fact that auto sufficiency was already included in the tour mode choice model, and therefore is accounted for in the constants by tour mode within the trip mode choice model.
- The shared ride 2 and shared ride 3+ modes were also stratified by household size. However, the coefficients were insignificant, and so the variables were not kept,
- The gender stratification showed that women are more likely than men to choose transit, but less likely than men to choose non-motorized modes (walking, biking).

Table 103: Implemented Work Mode Choice Coefficients

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
In-Vehicle Time (c_ivt)	-0.0320	-14.8076	1.0000
Express Bus IVT Factor	0.9000		-28.13
BRT IVT Factor	0.9000		-28.13
LRT IVT Factor	0.8500		-26.56
Commuter Rail IVT Factor	0.7500		-23.44
Cost			
Low (<30k)	-0.0054		0.17
Medium-Low (30-60k)	-0.0022		0.07
Medium-High (60-100k)	-0.0016		0.05

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Very High (100k+)	-0.0006		0.02
Transit Access Time			
Walk Time (access, egress, auxiliary time)	-0.0501		1.57
Drive Access Time	-0.0602		1.88
First Wait	-0.0480		1.50
Transfer Wait	-0.0480	-15.0661	1.50
Non-PNR Number of Transfers Penalty	c_ivt*5		5.00
PNR Transfer Penalty	c_ivt*15		15.00
Land-Use Mix Variables (* 0.01)			
Origin MGRA Du/Emp Mix Coefficient ,applied to walk, bike	0.2252	4.6631	-7.04
Employment Density			
Destination MGRA Emp Density Coefficient ,applied to drive-transit	0.0251	8.3928	-0.78
Walk Mode Time	-0.0849	-4.8934	2.65
Bike Mode Time Coefficient	-0.0986		3.08
Bike Logsum Coefficient	0.0672		-2.10
Tour Mode Constants			
Tour Mode: Drive-alone			
Trip Mode: Walk	0.0000		0.0000
Tour Mode: Shared-2			
Trip Mode: Drive-alone-free	1.5263	5.7183	-47.70
Trip Mode: Drive-alone-pay	0.4344		-13.58
Trip Mode: Walk	0.3608	0.7869	-11.28
Tour Mode: Shared-3+			
Trip Mode: Drive-alone	0.9640	5.6067	-30.13
Trip Mode: Shared-2	-0.0587	-0.1625	1.83
Trip Mode: Walk	-1.3507	-1.9126	42.21
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-2.4724	-7.5051	77.26

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Trip Mode: Shared-3+	-4.5791	-7.6662	143.10
Trip Mode: Walk	0.3522	1.3521	-11.01
Tour Mode: PNR-Transit			
Trip Mode: Drive-Alone	-0.2126	0.1185	6.64
Trip Mode: Shared-2	-0.7898	-1.9437	24.68
Trip Mode: Walk	1.9881	2.4136	-62.13
Trip Mode: Walk-Transit	-0.5261	-0.7597	16.44
Tour Mode: KNR-Transit			
Trip Mode: Shared-Ride (2 or 3)	-0.3024	-0.1715	9.45
Trip Mode: Walk	2.3071	2.1970	-72.10
Mode Sequence Constants			
Tour Mode: Shared-2 (applied to Drive-alone, Walk trip modes)			
First Trip: Off Diagonal	-3.0147	-15.0941	94.21
Last Trip: Off Diagonal	-2.0599	-12.4512	64.37
No Stops: Off Diagonal	-3.2030	-16.1330	100.09
Tour Mode: Shared-3+ (applied to Drive-alone, Shared-2, and Walk Trip Modes)			
First Trip: Off Diagonal	-1.8752	-10.1590	58.60
Last Trip: Off Diagonal	-1.6110	-9.0951	50.34
No Stops: Off Diagonal	-2.2614	-8.9742	70.67
Tour Mode: Walk-Transit (applied to Shared-2 and Shared-3 Trip Modes)			
No Stops: Off Diagonal	-1.6562	-2.9629	51.76
Tour Mode: PNR-Transit (applied to all Drive, Walk, and Walk-Transit Trip Modes)			
First Trip: Off Diagonal	1.1830	1.1376	-36.97
Last Trip: Off Diagonal	4.0169	2.9582	-125.53
Tour Mode: KNR-Transit (applied to all Shared-Drive, Walk, and Walk-Transit Trip			

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Modes)			
First Trip: Off Diagonal	1.1830		-36.97
Last Trip: Off Diagonal	4.0169		-125.53
ASC - Line-Haul Mode			
Walk - Express Bus	0.5600		-17.50
WALK - Bus Rapid Transit	0.3200		-10.00
WALK - Light-Rail	0.5600		-17.50
WALK - Commuter Rail	0.8000		-25.00
PNR - Express Bus	0.1600	4.9834	-5.00
PNR - Bus Rapid Transit	0.3200		-10.00
PNR - Light-Rail	0.5600	3.7227	-17.50
PNR - Commuter Rail	0.8000	13.2699	-25.00
KNR - Express Bus	0.1600	0.4601	-5.00
KNR - Bus Rapid Transit	0.3200		-10.00
KNR - Light-Rail	0.5600	1.1127	-17.50
KNR - Commuter Rail	0.8000	4.2416	-25.00
ASC Adjustments			
Tour Mode:Shared-2			
Trip Mode: Drive-alone	1.2472		-38.98
Trip Mode: Walk	0.5760		-18.00
Tour Mode:Shared-3			
Trip Mode: Drive-alone	1.0548		-32.96
Trip Mode: Shared-2	1.3530		-42.28
Trip Mode: Walk	1.2835		-40.11
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-1.3892		43.41
Trip Mode: Shared-3	0.6019		-18.81

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Trip Mode: Walk	-1.6379		51.18
Tour Mode: PNR-Transit			
Trip Mode: Drive-alone	-0.4533		14.17
Trip Mode: Shared-2	-0.6543		20.45
Trip Mode: Walk	-3.1971		99.91
Trip Mode: Walk-Transit	0.8470		-26.47
Tour Mode: KNR-Transit			
Trip Mode: Shared-2	-2.2269		69.59
Trip Mode: Shared-3	-3.9393		123.10
Trip Mode: Walk	0.1161		-3.63
Trip Mode: Walk-Transit	10.1242		-316.38
Household Variable Constants			
Female: Non-motorized	-1.1033	-2.6801	34.48
Female: Transit	1.0624	2.6231	-33.20
Female, Shared-ride 2	0.2743	1.1470	-8.57
Female, Shared-ride 3+	0.0718	0.7002	-2.24
PNR - Premium			
Trip Mode: PNR_EXP	'-12.5*c_ivt		**-12.5**
Trip Mode: PNR_CR	-25*c_ivt		**-25**

Observations			7179
Initial Likelihood			-6750.2388
Final Likelihood			-4874.9638

Home Based University Model Estimation

The university purpose model was estimated based initially on the home based work results. The additional estimation runs refined the estimation specific for this purpose. The following table shows the university purpose records used in estimation by tour mode and trip mode from the home interview survey and on-board survey. There were 2,351 observations used for estimation of this model.

Table 104: Home Based University Tour Mode by Trip Mode Available Records

Trip Mode	Tour Mode							
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	Total
Drive-Alone Free	50	27	10	-	-	1	-	**88**
Shared 2 Non HOV, Non Toll	-	69	6	-	4	1	1	**81**
Shared 2 HOV	-	-	-	-	-	-	-	**-**
Shared 3+ Non HOV, Non toll	-	-	25	-	1	1	2	**29**
Shared 3+ HOV	-	-	-	-	-	-	-	**-**
Walk	2	4	1	-	7	-	-	**14**
Walk to Local Bus	-	-	-	-	1,033	-	2	**1,035**
Walk to Express Bus	-	-	-	-	75	-	-	**75**
Walk to Light Rail	-	-	-	-	673	-	2	**675**
Walk to Commuter Rail	-	-	-	-	2	-	1	**3**
PNR to Local Bus	-	-	-	-	-	106	-	**106**
PNR to Express Bus	-	-	-	-	-	7	-	**7**
PNR to Light Rail	-	-	-	-	-	35	-	**35**
PNR to Commuter Rail	-	-	-	-	-	2	-	**2**
KNR to Local Bus	-	-	-	-	-	-	116	**116**
KNR to Express Bus	-	-	-	-	-	-	7	**7**
KNR to Light Rail	-	-	-	-	-	-	69	**69**
KNR to Commuter Rail	-	-	-	-	-	-	7	**7**
Total	**52**	**100**	**42**	**-**	**1,795**	**153**	**207**	**2,351**

Model Estimation Findings

- The ASC for the transit line haul modes were asserted since the estimated ones were illogical, possibly due to sampling bias. They were asserted using the university tour mode choice transit line haul constants and rescaling them to trip mode choice model using the university trip mode choice in-vehicle coefficient. The park and ride and kiss and ride constants were estimated and will be re-assessed during calibration.
- The mode sequence constants are all negative, reflecting the relative disutility of using a mode other than the chosen tour mode for the first or last trip of the tour, except for the first trip on a walk-transit tour. This may reflect the likelihood of mode switching from walk to walk-transit for stops on transit tours.
- The estimated in-vehicle time coefficient was highly significant at -0.033.
- The estimated bike mode time coefficient was highly significant at -0.178; The estimated walk mode time coefficient was significant at -0.08868.
- The cost coefficient stratified by income classes did not work in this purpose, most likely due to low observations in the higher income groups. Therefore, the cost coefficient was asserted as 0.08 times the in-vehicle time for all income groups, consistent with the university tour mode choice model.
- The transit total walk access (egress, and auxiliary) time coefficient was estimated at -0.0518; The transit initial and transfer wait time coefficient was estimated at -0.0622 for this model.
- The drive access transit time coefficient was asserted as -0.0502. .
- The land-use mix variable coefficients were not significant and so was dropped for the university trip mode choice model.
- ASCs were estimated for each mode, but the HOV lane mode constant could not be estimated due to lack of observations.
- The gender stratification showed that women are less likely than men to carpool for university tours. This may reflect the need for more independence in university-related travel, in order to make other, non-escort related stops on the university tour.

Table 105: Implemented University Mode Choice Coefficients

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
In-Vehicle Time	-0.03344	-12.9395	1.0000
Express bus IVT factor	0.9000		-26.92
BRT IVT factor	0.9000		-26.92
LRT IVT factor	0.8500		-25.42
Commuter rail IVT factor	0.7500		-22.43
Cost	-0.0027		0.08
Transit Access Time			
Drive Access Time	-0.0502		1.50
Out-of-vehicle time (first wait or transfer wait time)	-0.0622	-13.4943	1.86
Transfer penalty	-0.1672		5.00
Walk (access, egress, auxiliary) time	-0.0518		1.55
Bike mode time	-0.1783		5.33
Walk Mode Time	-0.0887	-4.8957	2.65
Bike logsum coefficient	0.0672		-2.01
Tour Mode Constants			
Tour Mode: Shared-2			
Trip Mode: Drive-alone	-0.4565	-1.2744	13.65
Trip Mode: Walk	1.5144	1.7491	-45.29
Tour Mode: Shared-3+			
Trip Mode: Drive-alone	-0.9291	-1.5751	27.79
Trip Mode: Shared-2	-0.9941	-1.6339	29.73
Trip Mode: Walk	1.5067	1.1335	-45.06
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-4.0608	-6.8138	121.45
Trip Mode: Shared-3+	-5.2742	-4.9604	157.74
Trip Mode: Walk	0.7361	0.8617	-22.01
Tour Mode: PNR-Transit			
Trip Mode: Drive Alone	-2.2672	-1.9034	67.81
Trip Mode: Shared-2	-1.9560	-1.5547	58.50

Trip Mode: Shared-3+	-1.7391	-1.3615	52.01
Mode Sequence Constants			
Tour Mode: Shared-2 (applied to Drive-alone and Walk Trip Modes)			
First Trip: Off Diagonal	-1.2971	-1.7476	38.79
Last Trip: Off Diagonal	-0.7345	-1.0747	21.97
No Stops: Off Diagonal	-3.2105	-3.0031	96.02
Tour Mode: Shared-3+ (applied to Drive-alone,Shared-2, and Walk Trip Modes)			
First Trip: Off Diagonal	-1.7826	-1.9089	53.31
Last Trip: Off Diagonal	-1.1489	-0.8599	34.36
No Stops: Off Diagonal	-1.8930	-1.5899	56.61
Tour Mode: Walk-Transit (applied to Shared Drive and Walk Trip Modes)			
First Trip: Off Diagonal	0.4204	0.3697	-12.57
Tour Mode: PNR-Transit (applied to all Drive, Walk, and Walk-Transit Trip Modes)			
No Stops: Off Diagonal	-1.0002	-1.2834	29.91
Tour Mode: KNR-Transit (applied to all Shared Drive, Walk, and Walk-Transit Trip Modes)			
No Stops: Off Diagonal	-1.0002	-1.2834	29.91
ASC Line-Haul Mode			
Walk - Express Bus	0.6400		-19.14
Walk - Bus Rapid Transit	0.3200		-9.57
Walk - Light-Rail	0.6400		-19.14
Walk - Commuter Rail	0.6400		-19.14
PNR - Express Bus	0.1600	-0.2164	-4.79
PNR - Bus Rapid Transit	0.3200		-9.57
PNR - Light-Rail	0.6400	1.8705	-19.14
PNR - Commuter Rail	0.6400		-19.14
KNR - Express Bus	0.1600	-0.9641	-4.79
KNR - Bus Rapid Transit	0.3200		-9.57

KNR - Light-Rail	0.6400	2.7083	-19.14
KNR - Commuter Rail	0.6400	1.8753	-19.14
Household Variable Constants			
female: Shared-2	-0.7308	-1.9499	21.86
female: Shared-3+	-1.1176	-2.0081	33.42
ASC Adjustments			
Tour Mode:Shared-2			
Trip Mode: Drive-alone	1.1094		-33.18
Trip Mode: Walk	1.5714		-47.00
Tour Mode:Shared-3			
Trip Mode: Drive-alone	1.2801		-38.28
Trip Mode: Shared-2	1.4818		-44.32
Trip Mode: Walk	1.6100		-48.15
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-0.9000		26.92
Trip Mode: Shared-3	0.0421		-1.26
Trip Mode: Walk	-1.7720		53.00
Tour Mode: PNR-Transit			
Trip Mode: Shared-3	-0.1734		5.19
Trip Mode: Walk	-3.2434		97.00
Tour Mode: KNR-Transit			
Trip Mode: Shared-3	-1.3398		40.07
Trip Mode: Walk	15.2330		-455.58
ASC Adjustments HOV Constant			
Trip Mode: Shared-2-HOV	1.0000		-29.91
Trip Mode: Shared-3-HOV	1.0000		-29.91
ASC Adjustments Toll Constant			
Trip Mode: Drive-alone-pay	1.0000		-29.91
Trip Mode: Shared-2-pay	1.0000		-29.91
Trip Mode: Shared-3-pay	1.0000		-29.91
PNR - Premium			
Trip Mode: PNR_EXP	-15*c_ivt		-15
Trip Mode: PNR_CR	-		-30

30*c_ivt

Observations			2351
Initial Likelihood			-2129.9909
Final Likelihood			-1612.7507

Home Based School Model Estimation

The following table shows the school purpose records used in estimation by tour mode and trip mode from the home interview survey and on-board survey. There were 3,537 observations used for estimation of this model.

This model also includes estimation for the school bus mode, which is not considered by the other purposes because it only applies to this purpose.

Table 106: Home Based School Tour Mode by Trip Mode Available Records

Trip Mode	Tour Mode: Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	School Bus	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	Total
Drive-Alone Free	62	-	-	-	-	-	-	-	**62**
Shared 2 Non HOV, Non Toll	-	373	433	-	-	5	-	2	**813**
Shared 2 HOV	-	-	-	-	-	-	-	-	**-**
Shared 3+ Non HOV, Non toll	-	-	1,603	-	-	6	-	2	**1,611**
Shared 3+ HOV	-	-	4	-	-	-	-	-	**4**
Walk	-	42	118	-	-	6	-	-	**166**
School Bus	-	-	2	-	-	-	-	-	**2**
Walk to Local Bus	-	-	-	-	-	413	-	2	**415**
Walk to Express Bus	-	-	-	-	-	31	-	-	**31**
Walk to Light Rail	-	-	-	-	-	239	-	-	**239**
Walk to Commuter Rail	-	-	-	-	-	4	-	-	**4**
PNR to Local Bus	-	-	-	-	-	-	15	-	**15**
PNR to Express Bus	-	-	-	-	-	-	-	-	**-**
PNR to Light Rail	-	-	-	-	-	-	16	-	**16**
PNR to Commuter Rail	-	-	-	-	-	-	3	-	**3**
KNR to Local Bus	-	-	-	-	-	-	-	98	**98**
KNR to Express Bus	-	-	-	-	-	-	-	9	**9**
KNR to Light Rail	-	-	-	-	-	-	-	48	**48**
KNR to Commuter Rail	-	-	-	-	-	-	-	1	**1**
Total	**62**	**415**	**2,160**	**-**	**-**	**704**	**34**	**162**	**3,537**

Model Estimation Findings

- The ASC for the transit line haul modes were asserted since the estimated ones were illogical, possibly due to sampling bias. They were asserted using the school tour mode choice transit line-haul constants and rescaling them to the trip mode choice model using the school trip mode choice in-vehicle coefficient. The park and ride and kiss and ride constants were estimated, and will be re-assessed during calibration.
- All off-diagonal constants are negative, with the exception of the following:
    - The first and last trip of a walk-transit tour, perhaps reflecting an increased probability of stopping on the way to/from school when using transit, coupled with walking trips.
- In-vehicle time was estimated and reasonable at -0.020. The smaller value of in-vehicle time compared to work reflects a lower value-of-time for children.
- The cost coefficients were negative and were stratified by household income.
- Transit total walk access time, first wait time, transfer wait time, and drive access time coefficients were estimated and all had negative and significant values.
- The land-use mix density and intersection density variables were not significant in the school trip mode choice model, and so were dropped.
- Walk mode time was significant and negative at -0.13619; Bike mode time coefficient was estimated at -0.1248.
- Age-specific constants for age groups under 6, 6 to 12 and 13 to 15 were interacted withnon-motorized, and transit modes. The interaction of the under 6 age group with the non-motorized modes resulted in a significant negative coefficient, indicating that children under 6 are more likely to be driven to school by an adult rather than walk or bike to school. The interaction of the 13 to 15 age group with walk to transit modes also resulted in a significant negative coefficient. This may reflect that older students are more independent and can walk or bike to school by themselves.

Table 107: Implemented School Mode Choice Coefficients

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
In-Vehicle Time(c_ivt)	-0.0200	-2.5918	1.00
Express bus IVT factor	0.9000		-45.00
BRT IVT factor	0.9000		-45.00
LRT IVT factor	0.8500		-42.50
Commuter rail IVT factor	0.7500		-37.50
Cost			
Low (<30k)	-0.0220		1.10
Medium-Low (30-60k)	-0.0090		0.45
Medium-High (60-100k)	-0.0060		0.30
Very High (100k+)	-0.0060		0.30
Transit Access Time			
Walk Time (access, egress, auxiliary)	-0.0750	-5.6045	3.75
Drive Time	-0.0152		0.76
First Wait	-0.0300		1.50
Transfer Wait	-0.0403	-3.6806	2.02
Walk Mode Time	-0.1362	-11.0503	6.81
Bike Mode Time	-0.1248		6.24
Bike Logsum	0.0672		-3.36
Number of Transfers Penalty	c_ivt*5	-2.3739	5.00
Tour Mode Constants			
Tour Mode: Shared-2			
Trip Mode: Walk	4.5212	1.2525	-226.06
Tour Mode: Shared-3+			
Trip Mode: Shared-2	1.0997	-8.5520	-54.99
Trip Mode: Walk	3.5035	3.4589	-175.18
Trip Mode: School bus	-0.8046	-0.8168	40.23
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-2.532	-5.6527	126.60
Trip Mode: Shared-3+	-3.9212	-5.5696	196.06
Trip Mode: Walk	0.1589	-1.1165	-7.95

Mode Sequence Constants

Tour Mode: Shared-2 (applied to drive alone, walk and school bus)			
First Trip: Off Diagonal	-2.532	0.4924	126.60
Last Trip: Off Diagonal	-4.052	-0.5222	202.60
No Stops: Off Diagonal	-14.554	-0.4129	727.70
Tour Mode: Shared-3+ (applied to walk)			
First Trip: Off Diagonal	-1.0797	-4.9882	53.99
Last Trip: Off Diagonal	-1.0034	-5.6191	50.17
No Stops: Off Diagonal	-1.1307	-10.0288	56.54
Tour Mode: Shared-3+ (applied to drive alone, shared -2 and school bus)			
First Trip: Off Diagonal	-3.919		195.95
Last Trip: Off Diagonal	-3.667		183.35
No Stops: Off Diagonal	-3.866		193.30
Tour Mode: Walk-Transit (applied to shared drive, walk)			
First Trip: Off Diagonal	0.921	0.7454	-46.05
Last Trip: Off Diagonal	1.580	1.7804	-79.00
No Stops: Off Diagonal	-1.706	-2.1700	85.30
Line-Haul Mode Constants			
Walk - Express Bus	0.0998	-5.1538	-4.99
Walk - Bus Rapid Transit	0.1996		-9.98
Walk - Light-Rail	0.3991	-6.0533	-19.96
Walk - Commuter Rail	0.3991	0.9835	-19.96
PNR - Express Bus	0.0998		-4.99
PNR - Bus Rapid Transit	0.1996		-9.98
PNR - Light-Rail	0.3991	5.9007	-19.96
PNR - Commuter Rail	0.3991	2.0052	-19.96
KNR - Express Bus	0.0998	1.5615	-4.99
KNR - Bus Rapid Transit	0.1996		-9.98
KNR - Light-Rail	0.3991	4.1916	-19.96
KNR - Commuter Rail	0.3991	-1.5498	-19.96
ASC Adjustments			
Tour Mode:Shared-2			
Trip Mode: Drive-alone	0.3761		-18.81

Trip Mode: Walk	1.1217	-56.09
Tour Mode:Shared-3		
Trip Mode: Drive-alone	0.2204	-11.02
Trip Mode: Shared-2	0.8849	-44.245
Trip Mode: Walk	0.4251	-21.255
Tour Mode: Walk-Transit		
Trip Mode: Shared-2	-4.1440	207.2
Trip Mode: Shared-3	-2.6330	131.65
Trip Mode: Walk	-3.3483	167.415
Tour Mode: PNR-Transit		
Trip Mode: Walk	-3.1382	156.91
Trip Mode: Walk-Transit	-3.7232	186.16
Tour Mode: KNR-Transit		
Trip Mode: Shared 2	2.7152	-135.76
Trip Mode: Shared 3	2.1207	-106.035
Trip Mode: Walk - Transit	7.8663	-393.315
ASC Adjustments Toll Constant (applied to drive pay)	10*c_ivt	*10*
PNR - Premium		
PNR_ Express Bus	-15*c_ivt	*-15*
PNR_ Commuter Rail	-30*c_ivt	*-30*
Household Variable Constants		

Age 1 to 5: Non-motorized	-1.7110	-4.2673	85.55
Age 6 to 12: Non-motorized	-0.7620	-2.8765	38.1
Age 13 to 15: Non-motorized	-0.3120	-1.3853	15.6
Age 13 to 15: Walk to Transit	-1.7430	-3.8471	87.15

Observations			3537
Initial Likelihood			-3520.9502
Final Likelihood			-2299.4844

Home Based Maintenance Model Estimation

The following table shows the maintenance purpose records used in estimation by tour mode and trip mode from the home interview survey and on-board survey. There were 6,749 observations used for estimation of this model.

Table 108: Home Based Maintenance Tour Mode by Trip Mode Available Records

Trip Mode	Tour Mode							
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	Total
Drive-Alone Free	-	836	328	-	-	7	-	**1,171**
Shared 2 Non HOV, Non Toll	-	1,826	546	-	6	1	7	**2,386**
Shared 2 HOV	-	5	3	-	-	-	-	**8**
Shared 3+ Non HOV, Non toll	-	-	1,536	-	2	-	-	**1,538**
Shared 3+ HOV	-	-	0	-	-	-	-	**0**
Walk	-	24	16	-	70	-	3	**113**
Walk to Local Bus	-	-	-	-	991	2	9	**1,002**
Walk to Express Bus	-	-	-	-	50	-	-	**50**
Walk to Light Rail	-	-	-	-	403	1	1	**405**
Walk to Commuter Rail	-	-	-	-	5	-	-	**5**
PNR to Local Bus	-	-	-	-	-	7	-	**7**
PNR to Express Bus	-	-	-	-	-	-	-	**-**
PNR to Light Rail	-	-	-	-	-	6	-	**6**
PNR to Commuter Rail	-	-	-	-	-	4	-	**4**
KNR to Local Bus	-	-	-	-	-	-	38	**38**
KNR to Express Bus	-	-	-	-	-	-	1	**1**
KNR to Light Rail	-	-	-	-	-	-	15	**15**
KNR to Commuter Rail	-	-	-	-	-	-	-	**-**
Total	**-**	**2,691**	**2,429**	**-**	**1,527**	**28**	**74**	**6,749**

Estimation results in this section apply to shopping, escorting, and all other maintenance purposes. Both individual and joint tours are considered in the estimation, including escort tours.

Model Estimation Findings

- The ASC for the transit line haul modes were asserted since the estimated ones were illogical, likely due to sampling bias. They were asserted using the maintenance tour mode choice transit line haul constants, rescaled to the trip mode choice model using the maintenance trip mode choice in-vehicle coefficient. The park and ride and kiss and ride constants were estimated, and will be re-assessed during calibration.
- The mode sequence constants are all negative, with the exceptions of Walk-Transit.
- The in-vehicle time was estimated at-0.0340.
- The cost coefficients were asserted to what was in the maintenance tour model mode choice. Value of time calculations show that the very highest income group has a much higher value of time for this purpose than the other income categories:
    - $2.49 Low Income
    - $5.67 Medium-Low
    - $9.27 Medium-High
    - $20.41 Very High
- Transit total walk access time coefficients were asserted at the 1.25 times of the in-vehicle time coefficient.
- First wait time and drive access time was asserted at 1.5 times the in-vehicle time since the estimated value was positive and insignificant.
- The emp density variable for the walk/bike mode at the destination MGRA was the only density measure that was significant and positive, at 0.09300.
- The walk mode time was negative and significant at -0.07994
- The bike mode time coefficient was negative and significant at -0.1540.
- 0 Auto Households had positive coefficient on the walk trip modes on a walk to transit tour. 0 Auto households had a negative coefficient on the shared-ride 2 trip mode on a shared-ride 3+ tour mode. This is a reasonable result for households without easy access to an auto.
- Alternative-specific constants for household size categories 2, 3, and 4+ were interacted with shared-ride modes in order to reflect the effect of household size on ride-sharing. While all interaction terms with shared ride 2 are negative, the constants for interactions with shared ride 3 were positive.
- Constants for joint tours were interacted with trip modes. A joint tour includes at least two household members, plus 0 or more non-household members. The negative constant for shared-3+ where there are two household members on the joint tour reflects the disutility of including a non-household member on a joint tour. The negative constants for the non-shared-ride modes reflect the disutility of using a non-carpool mode for a joint tour. A set of mode-specific constants were estimated for escort tour purpose. They reflect the increased probability of using auto modes rather than transit or walking for escort tours (though walk mode has a higher utility than transit for escort tours, all else being equal).

Table 109: Implemented Maintenance Mode Choice Coefficients

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
In-Vehicle Time(c_ivt)	-0.0340	-8.1863	1.00
Transfer penalty	c_ivt*5		5.00
Express bus IVT factor	0.9000		-26.47
BRT IVT factor	0.9000		-26.47
LRT IVT factor	0.8500		-25.00
Commuter rail IVT factor	0.7500		-22.06
Cost			
Low (<30k)	-0.0080		0.24
Medium-Low (30-60k)	-0.0040		0.12
Medium-High (60-100k)	-0.0020		0.06
Very High (100k+)	-0.0010		0.03
Transit Access Time			
Walk Time (access, egress, auxiliary time)	-0.0425		1.25
Drive Access Time	-0.0510		1.50
First Wait	-0.0510		1.50
Transfer Wait	-0.0590	-7.6304	1.74
Land-use mix Variables (* 0.01)			
Destination MGRA emp density coefficient ,applied to walk, bike	0.09300	2.4605	-2.74
Bike Logsum	0.0672		-1.98
Walk Mode Time	-0.0799	-8.2047	2.35
Tour Mode Constants			
Tour Mode: Shared-2			
Trip Mode: Drive-alone	-0.656	-9.5008	19.29
Trip Mode: Walk	-2.2366	-4.9715	65.78
Tour Mode: Shared-3+			13.29
Trip Mode: Drive-alone	-0.452	-9.0659	19.29
Trip Mode: Walk	-1.5731	-2.8642	46.27
Tour Mode: Walk-Transit			
Trip Mode: Shared-2	-3.437	-9.0445	101.09
Trip Mode: Shared-3+	-4.71	-8.1324	138.53
Trip Mode: Walk	2.848	0.0364	-83.76
Tour Mode: PNR-Transit			

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
Trip Mode: Walk-Transit	1.584	7.5411	-46.59
Tour Mode: KNR-Transit			
Trip Mode: Walk-Transit	2.159	6.6730	-63.50
Mode Sequence Constants			
Tour Mode: Shared-2			
Tour Mode: Walk-Transit (applied to shared-2 and shared-3 trips)			
First Trip: Off Diagonal	-1.4770	-1.8500	43.44
No Stops: Off Diagonal	-1.5218	-3.2698	44.76
Line-Haul Mode Constants			
Walk - Express Bus	0.1700	-10.2027	-5.00
Walk - Bus Rapid Transit	0.3400		-10.00
Walk - Light-Rail	0.6800	-9.3826	-20.00
Walk - Commuter Rail	0.6800	-3.2050	-20.00
PNR - Express Bus	0.1700		-5.00
PNR - Bus Rapid Transit	0.3400		-10.00
PNR - Light-Rail	0.6800	0.8905	-20.00
PNR - Commuter Rail	0.6800	2.2819	-20.00
KNR - Express Bus	0.1700	-0.5045	-5.00
KNR - Bus Rapid Transit	0.3400		-10.00
KNR - Light-Rail	0.6800	-0.0663	-20.00
KNR - Commuter Rail	0.6800		-20.00
Household Variable Constants			
Tour Mode: Shared-3+ AUTO SUFFICIENCY			
Trip Mode: Shared-2 AUTO 0	-1.4690	-0.9358	43.21
Trip Mode: Shared-2 AUTOS < ADULTS	-0.3240	-1.3881	9.53
Tour Mode: Walk-Transit AUTO SUFFICIENCY			
Trip Mode: Walk AUTO 0	1.4240	1.0328	-41.88

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
Household size2: Shared-2	0.00000	-5.4927	0.00
Household size2: Shared-3+	0.00000	-3.9642	0.00
Household size3: Shared-2	-0.4160	-6.6122	12.24
Household size3: Shared-3+	0.7920	-2.4535	-23.29
Household size4: Shared-2	-0.4440	-6.5242	13.06
Household size4: Shared-3+	0.4240	-4.1929	-12.47

Joint Variables

Trip Mode: Shared-3+ for Persons on Joint tour <=2	-0.1100	-2.0057	3.24
Trip Mode: Walkon Joint Tour	-1.6690	-6.1583	49.09
Trip Mode: Walk Transit on Joint Tour	-0.8240	-3.7325	24.24
Trip Mode: Drive Transit on Joint Tour	-1.6290	-1.3122	47.91
Escort Tour Dummy for walk	-1.2700	2.4033	37.35
ASC Adjustments			
Tour Mode:Shared-2 Individual Tour :			
Trip Mode: Drive-alone	0.3739		-11.00
Trip Mode: Walk	-0.3371		9.91
Tour Mode:Shared-3 Individual Tour:			
Trip Mode: Drive-alone	0.3622		-10.65
Trip Mode: Shared-2	0.3740		-11.00
Trip Mode: Walk	-1.1800		34.71
Tour Mode: Walk-Transit Individual Tour:			
Trip Mode: Shared-2	-2.3757		69.87
Trip Mode: Walk	-6.4046		188.37
Tour Mode: KNR-Transit Individual Tour:			
Trip Mode: Shared 2	2.6293		-77.33
Trip Mode: Walk	7.6684		-225.54
Trip Mode: Walk - Transit	16.3730		-481.56
ASC Adjustments			
Tour Mode:Shared-2:			
Trip Mode: Drive-alone	0.1254		-3.69
Trip Mode: Walk	-2.3522		69.18

Parameter	Coeff	T-Stat	Ratio(Coeff/IVT)
Tour Mode:Shared-3 Joint Tour:			
Trip Mode: Drive-alone	0.0337		-0.99
Trip Mode: Shared-2	-0.2176		6.40
Trip Mode: Walk	-0.3031		8.91
Tour Mode: Walk-Transit Joint Tour:			
Trip Mode: Shared-3	0.6928		-20.38
Trip Mode: Walk	-1.2356		36.34
ASC Adjustments Toll Constant (applied to all drive pay)	10*c_ivt		10.00
PNR - Premium			
PNR_ Express Bus	-15*c_ivt		-15
PNR_ Commuter Rail	-30*c_ivt		-30
Observations			6749
Initial Likelihood			-24467.245
Final Likelihood			-22059.114

Home Based Discretionary Model Estimation

The following table shows the discretionary purpose records used in estimation by tour mode and trip mode from the home interview survey and on-board survey. There were 4,851 observations used for estimation of this model.

Model estimation results in this section apply to eating out, visiting, and all other discretionary purposes. Similar to the maintenance purpose, this model also estimated joint tours for the non-motorized and transit modes, and for the female gender.

Table 110. Home Based Discretionary Tour Mode by Trip Mode Available Records

Trip Mode	Tour Mode							
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Walk to Transit	Park Ride to Transit	Kiss Ride to Transit	Total
Drive-Alone Free	-	113	66	-	-	-	-	**179**
Shared 2 Non HOV, Non Toll	-	764	178	-	4	-	-	**946**
Shared 2 HOV	-	-	2	-	-	-	-	**2**
Shared 3+ Non HOV, Non toll	-	-	905	-	-	-	-	**905**
Shared 3+ HOV	-	-	6	-	-	-	-	**6**
Walk	-	15	13	-	9	-	-	**37**
Walk to Local Bus	-	-	-	-	1,493	-	-	**1,493**
Walk to Express Bus	-	-	-	-	129	-	-	**129**
Walk to Light Rail	-	-	-	-	919	-	-	**919**
Walk to Commuter Rail	-	-	-	-	17	-	-	**17**
PNR to Local Bus	-	-	-	-	-	37	-	**37**
PNR to Express Bus	-	-	-	-	-	1	-	**1**
PNR to Light Rail	-	-	-	-	-	28	-	**28**
PNR to Commuter Rail	-	-	-	-	-	16	-	**16**
KNR to Local Bus	-	-	-	-	-	-	71	**71**
KNR to Express Bus	-	-	-	-	-	-	6	**6**
KNR to Light Rail	-	-	-	-	-	-	48	**48**
KNR to Commuter Rail	-	-	-	-	-	-	7	**7**
Total	**-**	**892**	**1,170**	**-**	**2,571**	**82**	**132**	**4,851**

Model Estimation Findings

- The ASC for the transit line haul modes were asserted since the estimated ones were illogical probably due to sampling bias. They were asserted using the discretionary tour mode choice transit line haul constants and rescaling them to trip mode choice model using the discretionary trip mode choice in-vehicle coefficient. The park and ride and kiss and ride constants are the estimated ones and will be re-assessed during calibration.
- The mode sequence constants reflect an increased probability of the first trip and last trip of a multi-stop shared-ride tour being a lower occupancy than the shared-ride mode. Given that lower occupancy levels are only available for individual shared-ride tours, these coefficients make sense. The first trip of the tour would typically be to a friend's house, to pick up the person on the way to the maintenance activity, and the last trip would be after the friend is dropped off.
- The in-vehicle time coefficient was estimated at -0.0300 for the discretionary purpose.
- In the estimation runs, the cost coefficients were similar to the discretionary tour mode choice model except for the very high income (which came out positive), so the values were asserted using the discretionary tour mode choice values and resulted in value of time calculations as shown below:
  - $2.43 Low Income
  - $5.30 Medium-Low
  - $9.00 Medium-High
  - $22.47 Very High
- Transit total walk access time coefficient was both negative and significant at -0.0433.. Initial wait time was asserted at 1.5 times the in-vehicle time. Transfer wait time coefficient was asserted at -0.0550. Drive access time was also asserted at 1.5 times the in-vehicle time because the estimated value came out positive and insignificant. The estimated coefficient for number of transfers was too negative across all model estimations so it was asserted to be equal to 5 minutes of in-vehicle time.
- The walk mode time was negative at -0.06413.
- The bike mode time coefficient was negative and significant at -0.2190.
- The land-use mix variable for the walk/bike mode at the origin MGRA was significant and positive at 0.2750. This shows that if there are more households and employment at a trip origin makes it more likely that a person will choose to walk for their discretionary tour.
- Women are less likely to use transit compared to men for discretionary tours.
- Shared-ride 2 and 3+ was positive and significant for household size 3+. Shared-ride 3+ was less positive than shared-ride 2. This makes sense because in the 3 person households not all household members are traveling together on these tours.
- Joint tour coefficients were tested for the discretionary purpose but did not result in any significance.

Table 111: Implemented Discretionary Mode Choice Coefficients

Parameter	Coeff	T-Stat	Ratio
In-Vehicle Time	-0.0300	-9.7626	1.0000
Express Bus IVT factor	0.9000		-30.00
BRT IVT factor	0.9000		-30.00
LRT IVT factor	0.8500		-28.33
Commuter Rail IVT factor	0.7500		-25.00
Cost			
Low (<30k)	-0.0070		0.23
Medium-Low (30-60k)	-0.0030		0.10
Medium-High (60-100k)	-0.0020		0.07
Very High (100k+)	-0.0008		0.03
Transit Access Time			
Walk Time (access, egress, auxiliary)	-0.0433	-3.7030	1.44
Drive Access Time	-0.0450		1.50
First Wait	-0.0450		1.50
Transfer Wait	-0.0550	-11.8196	1.83
Number of Transfers Penalty	c_ivt*5		5.00
Land-use mix Variables (* 0.01)			
Origin MGRA Du/Emp mix Coefficient, applied to walk, bike	0.2750	3.4854	-9.17
Walk Mode Time	-0.0641	-5.5828	2.14
Bike Mode Time	-0.2190		7.30
Bike Logsum	0.0672		-2.24
Tour Mode Constants			
Tour Mode: Shared-2			
Trip Mode: Drive-alone	-0.688	-3.7181	22.93
Trip Mode: Walk	1.854	3.3142	-61.80
Tour Mode: Shared-3+			
Trip Mode: Drive-alone	-1.73	-6.6398	57.67
Trip Mode: Shared-2	-1.247	-6.7219	41.57
Trip Mode: Walk	0.878	1.8486	-29.27
Tour Mode: Walk-Transit			

Parameter	Coeff	T-Stat	Ratio
Trip Mode: Shared-2	-7.223	-4.6647	240.77
Trip Mode: Walk	2.418	1.9022	-80.60
Mode Sequence Constants			
Tour Mode: Shared-2 (applied to drive alone trip and walk trip)			
First Trip: Off Diagonal	0.807	2.3898	-26.90
No Stops: Off Diagonal	-3.241	-6.6408	108.03
Tour Mode: Shared-3+ (applied to drive alone,shared-2, and walk trip mode)			
First Trip: Off Diagonal	0.397	1.7500	-13.23
No Stops: Off Diagonal	-1.773	-8.1863	59.10
Tour Mode: Walk-Transit (applied to shared drive, and walk trip modes)			
First Trip: Off Diagonal	-3.045	-1.7259	101.50
No Stops: Off Diagonal	-3.06	-2.0873	102.00
Line-Haul Mode Constants			
Walk - Express Bus	0.15	-10.6611	-5.00
Walk - Bus Rapid Transit	0.6		-20.00
Walk - Light-Rail	1.35	-18.9597	-45.00
Walk - Commuter Rail	0.6	-4.1418	-20.00
PNR - Express Bus	0.15	-2.0599	-5.00
PNR - Bus Rapid Transit	0.6		-20.00
PNR - Light-Rail	1.35	3.0328	-45.00
PNR - Commuter Rail	0.6	2.3021	-20.00
KNR - Express Bus	0.15	-0.6639	-5.00
KNR - Bus Rapid Transit	0.6		-20.00
KNR - Light-Rail	1.35	3.2072	-45.00
KNR - Commuter Rail	0.6	0.1545	-20.00
Household Variable Constants			
female: Transit	-2.7360	-2.3555	91.20
Household size3+: Shared-2	0.9580	1.8961	-31.93
Household size3+: Shared-3+	0.6950	0.9787	-23.17

Parameter	Coeff	T-Stat	Ratio
ASC Adjustments			
Tour Mode:Shared-2 Individual Tour :			
Trip Mode: Drive-alone	2.0321		-67.74
Trip Mode: Walk	-1.3659		45.53
Tour Mode:Shared-3 Individual Tour:			
Trip Mode: Drive-alone	2.6732		-89.11
Trip Mode: Shared-2	0.8272		-27.57
Trip Mode: Walk	0.1387		-4.62
Tour Mode: Walk-Transit Individual Tour:			
Trip Mode: Shared-2	1.6369		-54.56
Trip Mode: Shared-3	-0.3602		12.01
Trip Mode: Walk	-6.1107		203.69
Tour Mode: PNR-Transit Individual Tour:			
Trip Mode: Drive alone	-2.0410		68.03
Trip Mode: Walk	1.5780		-52.60
Trip Mode: Walk - Transit	5.2242		-174.14
Tour Mode: KNR-Transit Individual Tour:			
Trip Mode: Shared 2	2.6657		-88.86
Trip Mode: Shared 3	3.9246		-130.82
Trip Mode: Walk	9.6071		-320.24
Trip Mode: Walk - Transit	12.4501		-415.00
ASC Adjustments			
Tour Mode:Shared-2 Tour :			
Trip Mode: Drive-alone	0.0421		-1.40
Trip Mode: Walk	-1.2905		43.02
Tour Mode:Shared-3 Joint Tour:			
Trip Mode: Drive-alone	0.0671		-2.24
Trip Mode: Shared-2	0.4450		-14.83
Trip Mode: Walk	-0.5505		18.35
Tour Mode: Walk-Transit Joint Tour:			

Parameter	Coeff	T-Stat	Ratio
Trip Mode: Shared-3	-0.2306		7.69
Trip Mode: Walk	-4.5371		151.24
ASC Adjustments Toll Constant	10*c_ivt		10.00
(applied to drive pay)			
PNR - Premium			
PNR_ Express Bus	-15*c_ivt		-15.00
PNR_ Commuter Rail	-30*c_ivt		-30.00
Observations			4851
Initial Likelihood			-8402.1438
Final Likelihood			-6700.9354

At-Work Subtour Model Estimation

The At-Work Sub-tour mode choice model was largely asserted because the estimated coefficients did not make sense, due to lack of observations across alternatives.

Model Estimation Findings

- The in-vehicle time coefficient was asserted at -0.060.
- The value of time for at-work subtours was asserted at $9.47.
- The cost coefficient was asserted at -0.0038 and assumed the same for all income groups.
- Transit access walk time was asserted at -0.1000; Drive access time was asserted at 2 times (-0.1200) the in-vehicle time.
- The total wait time constrained to 1.5 times (-0.0900) the in-vehicle time.
- Number of Transfers penalty was constrained to equal to 5 times of in-vehicle time.
- Mode time for walk was asserted at -0.15926.
- If there were no stops on the particular tour, the likelihood of the trip mode being something other than the tour mode is highly unlikely (negative coefficient).

Table 112: Implemented At-Work Subtour Mode Choice Coefficients

Parameter	Coeff	Ratio
In-Vehicle Time (c_ivt)	-0.0600	1.00
Express Bus IVT factor	0.9000	-15.00
BRT IVT factor	0.9000	-15.00
LRT IVT factor	0.8500	-14.17

Commuter Rail IVT factor	0.7500	-12.50
Cost	-0.0038	0.06
Transit Access Time		
Walk Time (access, egress, auxiliary time)	-0.1000	1.67
Drive Access Time	-0.1200	2.00
First Wait	-0.0900	1.50
Transfer Wait	-0.0900	1.50
Number of Transfers	c_ivt*5	5.00
Walk Mode Time	-0.1593	2.66
Bike mode time coefficient	-0.1200	2.00
Bike logsum coefficient	0.0672	-1.12
ASC - Tour Mode Constants		
Tour Mode: Shared-2		
Trip Mode: Drive-alone	-1.2965	21.61
Tour Mode: Shared-3+		
Trip Mode: Drive-alone	-1.3733	22.89
Trip Mode: Shared-2	-2.9959	49.93
Tour Mode: Walk - Transit		
Trip Mode: Walk	-5.0	83.33
Mode Sequence Constants		
Tour Mode: Shared-2 (applied to Drive-alone and Walk Trip Mode)		
No Stops: Off Diagonal	-1.4142	23.57
Tour Mode: Shared-3+ (applied to Drive-alone, Shared-2, and Walk Trip Mode)		
No Stops: Off Diagonal	-1.7313	28.86
Line-Haul Mode Constants		
Walk - Express Bus	0.3200	-5.33
Walk - Bus Rapid Transit	0.6400	-10.67
Walk - Light-Rail	0.9600	-16.00
Walk - Commuter Rail	1.2800	-21.33

ASC Adjustments Toll Constant (applied to all drive-pay)	10*c_ivt	10
ASC Adjustments		
Tour Mode:Shared-2:		
Trip Mode: Drive-alone	0.9865	-16.44
Trip Mode: Walk	-0.9499	15.83
Tour Mode:Shared-3 Tour:		
Trip Mode: Drive-alone	1.0684	-17.81
Trip Mode: Shared-2	1.2569	-20.95
Trip Mode: Walk	-0.7247	12.08
Tour Mode: Walk-Transit:		
Trip Mode: Shared-2	9.9350	-165.58
Trip Mode: Shared-3	9.9350	-165.58

The estimated trip mode choice models (also known as trip mode switching models) reflect the propensity to choose a trip mode for each trip on a tour, reflecting the availability of trip modes given the chosen tour mode, the levels-of-service of those available alternatives, the influence of household and person-specific variables, zonal mixed land use and employment densities and the sequence of the trip within the overall tour. Many of the parameters in the model were estimated using the SANDAG household and transit on-board surveys, including alternative-specific constants relating tour mode to trip mode, sequence of trip within tour, socioeconomic influence, and certain level-of-service parameters. However, there were some parameters that could not be estimated and had to be asserted in the implemented model. These include the cost coefficients by income classes, wait time, drive access time, and the number of transfers. Most of these are related to transit use, and are consistent with some of the issues encountered during tour mode choice estimation as well.

6.2 Parking Location Choice

The parking location choice model determines where vehicles are parked at the terminal end of each trip with a destination in *parkarea 1* (downtown San Diego area). For work trips, the model will subtract the output from the employer parking reimbursement model from the daily price of parking at each alternative destination to determine the effective price borne by the individual. The output of the model will be used to obtain traffic assignments that are more accurate at small scales in the downtown area during the morning and afternoon peaks. The coefficients from the parking location choice model estimation are also used in defining the logsum-weighted average parking cost used in mode choice.

Estimation Dataset

The primary data sources that were used for the development of the parking location choice model were the *2010-2011 Parking Behavior Survey* and the *2009-2010 Parking Inventory*. The parking behavior survey captured not only people's location decisions, but also the amount they were reimbursed by their employers. These behavioral data were supplemented with the supply data from the parking inventory to weight the behavior survey records and provide measures of attraction sizes during application of the parking location choice model.

In the parking behavior survey, over the period from May 2010 to February 2011, a sample of 1,563 persons parking at forty-eight selected garages and lots throughout the city were given a paper-and-pencil survey asking questions about their demographics, trip origin and destination, purpose, payment amount and schedule, activity duration, and reimbursement from their employers. The survey instrument is shown below in Figure 38. The surveyors also collected data from the operators of the parking lots regarding the number of stalls, prices, and pay schedules offered. That data source comprised the 2009/2010 Parking Inventory.

Figure 38. Parking Behavior Survey

SANDAG

2010 PARKING BEHAVIOR SURVEY

The San Diego Association of Governments needs your help to better plan for transportation and parking needs. All responses are confidential. Thank you!

PLEASE RETURN COMPLETED SURVEY TO SURVEYOR TODAY (FROM 6 A.M. TO 7 P.M.) AND ENTER DRAWING TO WIN $100 GAS CARD

1. **What time did you LEAVE HOME before ARRIVING at this parking lot today?**
   ___ ___:___ ___ a.m. or p.m. (circle one)

2. **What time did you ARRIVE at this lot today?**
   ___ ___:___ ___ a.m. or p.m. (circle one)

3. **What time did you (or will you) LEAVE this lot today? (actual or expected)**
   ___ ___:___ ___ a.m. or p.m. (circle one)

4. **What time did you (or will you) ARRIVE HOME after parking at this lot today? (actual or expected)**
   ___ ___:___ ___ a.m. or p.m. (circle one)

5. **Did you (will you) pay to park in this lot today?**
   - ☐ Yes (paid for all of it)
   - ☐ Yes (paid for part of it)
   - ☐ No (skip to Question 7)

6. **If yes to Q5: I pay $___ ___ ___. ___ ___ per (check one)**
   - ☐ Hour
   - ☐ Day
   - ☐ Week
   - ☐ Month
   - ☐ Other

7. **Will all or part of your parking be reimbursed?**
   - ☐ Yes Paid or Reimbursed by employer
     How much $________
   - ☐ Yes Paid or Reimbursed by someone else
     How much $________
   - ☐ No

8. **How long did you search for a parking space before parking at this lot today?**
   ________ minutes

9. **Where did you COME FROM before arriving at this lot today? (check one)**
   - ☐ My Home
   - ☐ Work
   - ☐ Business meeting
   - ☐ School/College Classes
   - ☐ Shopping
   - ☐ Food/Drink/Entertainment
   - ☐ Medical Services
   - ☐ Other ________

10. **What is the address or nearest cross streets of that place?**
    ________ Street No. ________ Street Name
    OR
    ________ Street 1 AND ________ Street 2
    ________ City ________ ZIP Code

11. **Where will you (did you) WALK TO AFTER LEAVING YOUR CAR at this lot ?**
    - ☐ My Home
    - ☐ Work
    - ☐ Business meeting
    - ☐ School/College Classes
    - ☐ Shopping
    - ☐ Food/Drink/Entertainment
    - ☐ Medical Services
    - ☐ Other

12. **How many minutes will it (did it) take to walk there?**
    ________ minutes

13. **What is the address or nearest cross streets of that place?**
    ________ Street No. ________ Street Name
    OR
    ________ Street 1 AND ________ Street 2
    ________ City ________ ZIP Code

14. **How many people traveled with you in your vehicle to this parking lot today? (please write in number)**
    ______ Members of your household that are 18 years or over
    ______ Members of your household that are under 18 years old
    ______ Non-members of your household (any age)

15. **Are you currently employed?**
    - ☐ Yes (full time, 35 hours or more a week)
    - ☐ Yes (part time, less than 35 hours a week)
    - ☐ No

16. **If yes, what is your occupation? Please write occupation and small description of the work. For example – "City Planner, I plan for transit needs of the city." or "Retail manager, I manage the 7-11 store."**

17. **Are you currently a student?**
    - ☐ Yes (full time)
    - ☐ Yes (part time – less than a full class load)
    - ☐ No

18. **What is the address or nearest cross streets of your home? (If previously listed in Q10 or Q13, you do not need to write again)**
    ________ Street No. ________ Street Name
    OR
    ________ Street 1 AND ________ Street 2
    ________ City ________ ZIP Code

19. **In what year were you born? 19 ___ ___**

20. **Are you . . .**
    - ☐ Male
    - ☐ Female

21. **What is the total annual income of all the people living in your household?**
    - ☐ $0 to $29,999
    - ☐ $30,000 to $59,999
    - ☐ $60,000 to $99,999
    - ☐ $100,000 to $149,999
    - ☐ $150,000 or more

PLEASE COMPLETE IF WOULD LIKE TO ENTER DRAWING TO WIN 1 OF 5 $100 GAS CARDS

NAME________________

PHONE NUMBER________________

Utility Structure

The choice of parking location is modeled with a multinomial logit model with size variables. In this random utility model, the attractiveness to decision-maker *n* of each alternative *i* is defined in terms of a utility function

$$u_{ni} = \beta_i X_{ni} + \gamma \log(S_{ni}) + \varepsilon_{ni}$$

where β_i is a vector of parameters; X_{ni} is a vector of attributes of the alternative, decision-maker, and/or interactions between them; γ is a scale parameter indicating the degree to which the errors of elemental alternatives within each MGRA are correlated (McFadden 1978); S_{ni} is a size variable corresponding to the number of elemental alternatives in MGRA *i;* and ε_{ni} are independent and identically-distributed extreme value type I errors. The probability of choosing alternative *i* from the set of alternatives C_n is

$$P_{ni} = \frac{\exp(u_{ni})}{\sum_{j \in C_n} \exp(u_{nj})}.$$

When the model is applied, the set of alternatives for each choice will be every MGRA within one mile of the destination MGRA. For estimation, the set of alternatives was limited to the MGRAs that were included in the choice-based sample in the parking behavior survey. Other alternatives cannot be included in the estimation because they were not preferred by survey respondents in model application, the likelihood of observing an agent parking at a non-sampled location was zero.

Main Explanatory Variables

The variables tested in model estimation are shown below. Interaction terms are indented in italics.

Walk distance from parking MGRA to destination MGRA

- *Age*
- *Income*
- *Vehicle occupancy*
- *Trip is made jointly by multiple members of the household*
- *Occupation type*

Difference between origin-destination drive time and origin to parking location drive time

- *Income*

Average cost of parking in MGRA for duration of activity minus amount reimbursed by employer, if any

- *Household income*
- *Vehicle occupancy*

Alternative is in same MGRA as destination

- *Parking is reimbursed*
- *Vehicle Occupancy*
- *Density of employment at destination*
- *Density of parking at destination*

Results

The model was estimated from the parking behavior survey using the Weighted Exogenous Sample Maximum Likelihood Estimator (WESMLE) with weights equal to the number of spaces in the chosen lot divided by the number of samples from that lot in the observed data. The choice-based sample in the parking behavior survey was a large barrier to the reliable estimation of a location choice model. Since locations that were not sampled could not be included in the set of alternatives, little information was revealed about individual's preferences. The only alternative sampled lots were often very far away from the destination. Furthermore, the imputation of destination from cross streets and use of an aggregate parking cost variable could have potentially caused biased coefficients.

Because of difficulty estimating the model from the problematic parking behavior survey sample, we estimated a very simple model, and constrained the value of time (ratio of cost and walk distance coefficients) to $15 (where a walk speed of 3 miles per hour was assumed). The coefficients of this simple model are shown below.

Table 113: Estimated Parking Location Choice Utility Function Parameters

Variable	Segment	Coeff.
Walking distance to destination, miles	Work	-11.8000
Cost of parking, cents	Work	-0.0072
Walking distance to destination, miles	Other	-11.8000
Cost of parking, cents	Other	-0.0041

In application, the number of stalls in each MGRA was introduced as a size variable to bring the aggregate demand for each MGRA in line with the number of parking spaces available. The size variable representing the number of elemental alternatives in each MGRA was simply the number of stalls available to the decision-maker. Private stalls are only available in the destination MGRA, and on-street stalls are only available for activities with durations of three hours or less. Nonlinear-in-parameters size variable coefficients within the logarithm could not be estimated, because we were not aware of a method for defining it in the model estimation process—such as that in Daly (1980)—that applies to choice-based samples of elemental alternatives. The choice-based sample also required that the scale parameter γ be assumed to equal one.

II. Special Market Models

This section describes the estimation of special market models in the San Diego CT-RAMP modeling system, including the following markets:

- Cross-Border Model: A tour-based simulation model addressing travel into, out of, and within San Diego County made by Mexican residents
- Airport Ground Access Model: A trip-based simulation model addressing trips to and from San Diego International Airport.
- Visitor Model: A tour-based simulation model addressing travel made by overnight visitors within San Diego County.
- External Model: A model addressing travel between San Diego County and the rest of the United States, or travel through San Diego County.

7.0 Cross Border Model

7.1 Estimation Dataset

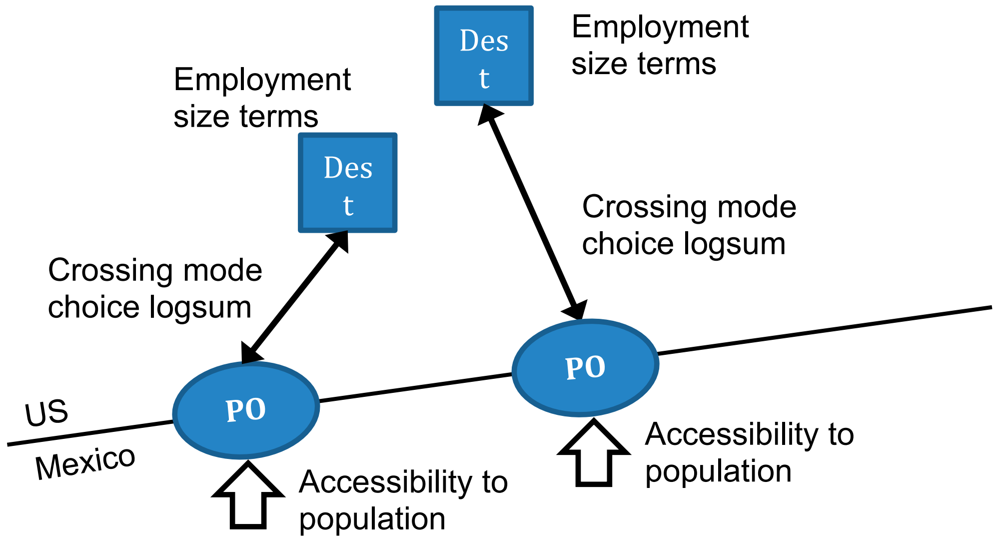
In 2010, SANDAG collected data on Mexican resident border crossings into the United States and their travel patterns within the US. Data was collected at the three border crossing stations – San Ysidro, Otay Mesa, and Tecate. Based upon this data, PB developed a travel demand model for Mexican residents. The purpose of this model is two-fold. The primary purpose of the model is to measure the impact of Mexican resident travel on the San Diego transport network. The model accounts for Mexican resident demand (such as auto volume, transit boarding, and toll revenue) for transportation infrastructure in San Diego County. The other purpose of the model is to forecast border crossings at each current and potential future border crossing station.

7.2 Border Crossing Primary Destination and Station Crossing Choice

The primary destination and border crossing choice model is a joint choice of tour primary destination in the US and border crossing station. Due to the number of alternatives in the model, sampling will be used to select a sub-set of primary destination MGRAs and border crossing pairs. The sampling procedure will be based upon a simplified destination choice model that takes into account:

- The distance from the TAZ where the MGRA is located in to the border crossing station
- A size variable indicating the number of elemental alternatives in the MGRA
- The accessibility of the border crossing station to persons in Mexico

Figure 39: Diagram of Primary Destination and Crossing Station (POE) Choice Model



Utility Structure

The utility of a combination of destination and crossing station for the sample of alternatives model is:

$$U_{d,s} = \ln\left[\sum_{o=1}^{O} Pop_o * \exp(\alpha * Dist_{o,s})\right] + \ln[Size_d] + \beta * Dist_{s,d} + \gamma_s$$

Where:

o = Tour origin in Mexico

O = Total number of tour origins

d = Tour primary destination in the US

D = Total number of tour primary destinations

s = Border crossing station

Pop_o = Population of origin zone

$Size_d$ = Size of primary destination zone d (*f*(population, employment))

$Dist_{o,s}$ = Distance from tour origin zone o to station s in miles

$Dist_{s,d}$ = Distance from station s to tour primary destination zone d in miles

α = -0.190

β = -0.125

γ_s = -0.762 for Otay Mesa, mandatory tours

= -1.642 for Otay Mesa, non-mandatory tours

= -0.201 for Tecate, mandatory tours

= -2.016 for Tecate, non-mandatory tours

Note that the first term in the utility function representing the accessibility to population in Mexico does not depend on the destination, and can be pre-calculated and stored in memory.

The simplified destination and station choice model will be used to select a subset of 100 destination/station pairs. To speed calculations, the TAZ will be sampled first since distance is the only measure of impedance used to represent accessibility of primary destination to station, and distance is represented at the TAZ level. Zone size in this case will be equal to the sum of the sizes of the MGRAs within the TAZ. Once the TAZ is sampled, an MGRA within the TAZ can be chosen based on the pre-calculated probability of the MGRA within the TAZ, which is based on the MGRA proportion of the TAZ size. Note that the total number of alternatives in the model is TAZs * stations (currently 13,800).

Once the sample of destination\station-pairs is chosen, a border crossing mode choice logsum from Model 2.3 will be computed for each sampled destination\station-pair. This composite utility and a piecewise linear function of distance will replace the simple distance term in the station\destination utility ($U_{d,s}$) and a choice will be made of actual destination and station from the sampled alternatives. The times and costs in the trip mode choice logsums will be based upon the specific departure and arrival periods for each tour.

The model was estimated together with the border crossing mode choice in a full-information maximum likelihood nested logit structure with the border crossing mode nested below destinations. This estimation is described in the mode choice section.

Table XX: Cross Border Primary Destination and Crossing Station Model Estimation - Utility Function Parameters, for Mandatory Tours

Parameter	Coeff	T-Stat
Logsum for tour mode choice	1.0000	
Station accessibility	1.0000	
POE Constants		
POE is Otay Mesa, Mandatory	**-0.8960**	
POE is Tecate, Mandatory	**1.5180**	
POE Calibration Adjustment Constants		
POE is Otay Mesa, Calibration Adjustment for year 2010	2.5069	
POE is Tecate, Calibration Adjustment for year 2010	3.6201	
POE is Otay Mesa, Calibration Adjustment, for year 2015, 2040	2.7191	
POE is Tecate, Calibration Adjustment, for year 2015,2040	3.5372	
POE is OME, Calibration Adjustment, for year 2015,2040	-5.7131	
POE is Jucumba, Calibration Adjustment, for year 2040	5.0000	
POE is Otay Mesa, Calibration Adjustment for year 2010	2.5069	
Piecewise Linear Distance Constants		
Piecewise Linear Distance - 0 to 2 miles, Mandatory	-2.6000	-2.81
Piecewise Linear Distance - 2 to 5 miles, , Mandatory	-0.1000	-2.14
Piecewise Linear Distance - 5 to 10 miles, Mandatory	-0.7000	
Piecewise Linear Distance - 10 to 20 miles, Mandatory	-1.5000	-5.78
Piecewise Linear Distance - 20 miles +, Mandatory	-0.5000	-2.04

Destination size term	1.0000	
Size Variables		
Work Size - blue collar employment	0.184	
Work Size - retail employment	1.000	
Work Size - entertainment employment	0.562	
Work Size - service employment	0.986	
Work Size - other employment	0.363	
School Size - education employment	0.087	
School Size - college enrollment	1.000	

Table XX: Cross Border Primary Destination and Crossing Station Model Estimation - Utility Function Parameters, for Non-Mandatory Tours

Parameter	Coeff	T-Stat
Logsum for tour mode choice	**1.0000**	
Station accessibility	**1.0000**	
POE Constants		
POE is Otay Mesa, Non-Mandatory	-1.4960	
POE is Tecate, Non-Mandatory	-0.1340	
POE Calibration Adjustment Constants		
POE is Otay Mesa, Calibration Adjustment, for year 2010	**2.5069**	
POE is Tecate, Calibration Adjustment, for year 2010	**3.6201**	
POE is Otay Mesa, Calibration Adjustment, for year 2015,2040	2.7191	
POE is Tecate, Calibration Adjustment, for year 2015,2040	3.5372	
POE is OME, Calibration Adjustment, for year 2015,2040	-5.7131	
POE is Jucumba, Calibration Adjustment, for year 2040	5.0000	
Piecewise Linear Distance Constants		
Piecewise Linear Distance - 0 to 2 miles, Non-Mandatory	-4.6635	-2.81
Piecewise Linear Distance - 2 to 5 miles, Non-Mandatory	-0.7028	-2.14
Piecewise Linear Distance - 5 to 10 miles, Non-Mandatory	-0.5959	-5.78
Piecewise Linear Distance - 10 to 20 miles, Non-Mandatory	-1.2549	-5.78
Piecewise Linear Distance - 20 miles +, Non-Mandatory	-0.5421	-2.04
Destination size term	1.0000	
Size Variables		
Cargo Size - blue collar employment	0.612	
Cargo Size - retail employment	1.000	
Cargo Size - other employment	1.154	

Shop Size - retail employment	1.000	
Shop Size - entertainment employment	2.306	
Visit Size - households	1.000	
Visit Size - health employment	1.576	
Visit Size - other employment	1.038	
Other Size - retail employment	1.000	
Other Size - entertainment employment	0.710	
Other Size - education employment	0.167	
Other Size - health employment	0.028	
Other Size - other employment	4.707	

7.3 Border Crossing Tour Time-of-Day Choice

The time of entry into the US and return to the Mexican border was simulated for each tour from a distribution specific to each tour purpose. The distribution of entry and return times was taken from the expanded border crossing survey, but may be adjusted for analysis of forecast scenarios. This simple structure of the time-of-day choice model was selected because the variability in the level-of-service at each border crossing was not sufficient to estimate a random utility model from the border crossing survey. Unlike with the San Diego resident models, the time-of-day choice model was simulated prior to the spatial choice model in order to provide more specific inputs regarding the level-of-service between each potential border crossing and destination for the specific entry and return times for the tour. An example of the tour entry and return times for the Work tour purpose appears in Table 114.

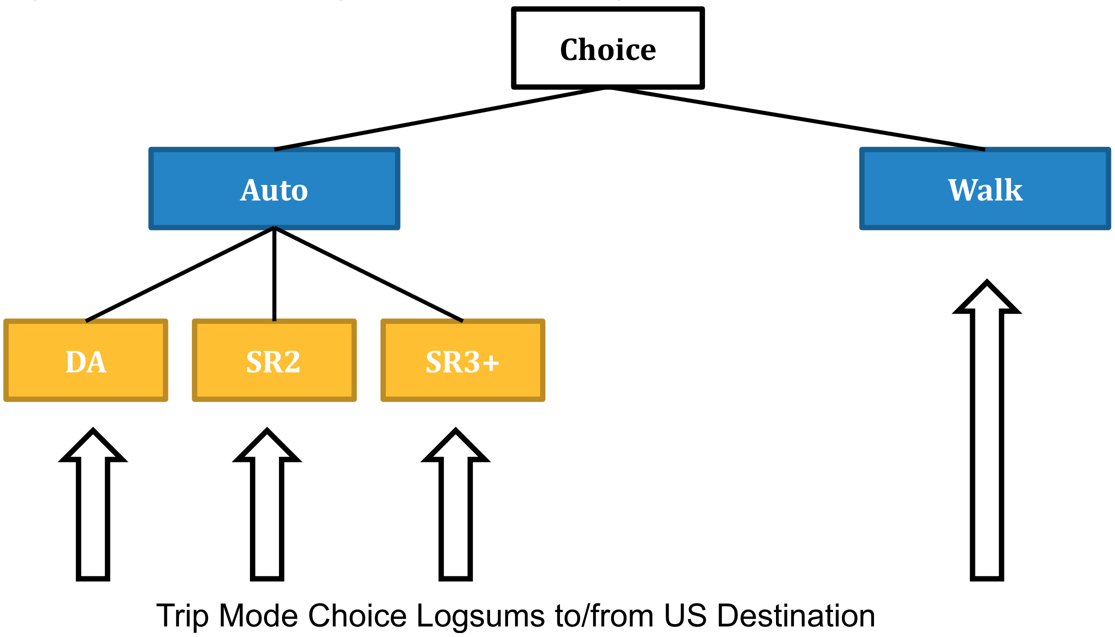
Table 114: Joint Distribution of Entry and Return Time for Work Tours

Entry Period	From	To	Return Period 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total
4	0600	0628	-	-	-	-	-	-	-	-	-	-	-	-	-	.003	-	-	-	-	-	-	-	-	-	-	.003
5	0630	0699	-	-	-	-	-	-	.002	-	-	.003	-	-	-	-	.002	.002	.002	.002	-	-	-	-	-	-	.014
6	0700	0728	-	-	-	.002	-	.006	-	.017	.003	-	.003	.013	.005	.004	.002	.002	.002	-	-	-	-	.003	-	-	.060
7	0730	0799	-	-	.002	-	-	-	.005	.002	.007	.013	.013	.002	.007	.006	-	-	-	-	.009	-	-	-	-	-	.068
8	0800	0828	-	.004	-	-	.010	.004	-	.011	.002	.010	.004	.002	.007	.009	.005	.002	.003	.002	-	-	-	-	-	-	.076
9	0830	0899	.004	-	-	-	-	.002	-	.004	.004	.007	.010	.013	-	.007	.002	-	-	.007	-	-	.004	-	-	.003	.068
10	0900	0928	-	-	-	-	.002	-	-	.007	.007	.007	.004	.007	-	.004	-	.007	.005	-	-	-	-	-	-	-	.050
11	0930	0999	-	-	-	-	-	-	-	-	.005	-	.003	.006	-	.002	.002	.003	-	.007	-	-	-	-	.003	.002	.032
12	1000	1028	-	-	-	-	-	-	.004	-	-	.004	-	.005	.005	.023	-	-	.003	-	-	-	.005	.007	-	-	.056
13	1030	1099	-	-	-	-	.003	-	-	.020	.007	-	-	.007	.004	.033	.005	.038	.003	-	.007	.003	-	.005	.003	.003	.143
14	1100	1128	-	-	.007	-	-	-	-	-	-	-	.007	-	.016	.019	-	.003	.003	.010	.007	.003	.013	-	-	.010	.099
15	1130	1199	-	-	-	-	.007	-	-	.011	-	.010	-	.004	-	-	.003	-	-	-	-	-	-	.005	.012	.003	.055
16	1200	1228	-	-	-	-	-	.005	-	-	-	-	-	-	-	-	.007	-	-	-	-	-	-	.011	-	.003	.026
17	1230	1299	-	-	-	-	-	-	-	.007	-	-	-	-	-	-	.005	-	.003	.011	-	-	-	-	-	.013	.039
18	1300	1328	-	-	-	-	-	-	.003	.007	-	-	.003	-	.005	-	-	.003	-	-	-	-	-	.004	-	.008	.034
19	1330	1399	-	-	.004	-	-	-	-	-	-	-	.004	.004	-	.005	-	.010	-	-	-	-	.004	.007	-	.011	.049
20	1400	1428	-	-	-	-	-	-	-	-	-	.003	-	-	.004	.004	-	.005	-	-	-	-	-	-	-	-	.017
21	1430	1499	-	-	-	-	-	-	-	-	-	.004	-	.010	-	-	-	.016	-	-	-	-	.007	-	-	-	.036
22	1500	1528	-	-	-	-	-	-	-	-	.003	-	-	-	-	-	-	-	.017	-	-	.003	-	-	.007	.017	.048
23	1530	1599	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.003	-	.003	-	.007
24	1600	1628	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.007	-	-	-	-	-	-	-	-	.007
25	1630	1699	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.010	.010
26	1700	1728	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.003	-	-	-	.003
	Total		**.004**	**.004**	**.013**	**.002**	**.022**	**.017**	**.015**	**.085**	**.037**	**.062**	**.051**	**.072**	**.053**	**.119**	**.034**	**.100**	**.043**	**.040**	**.023**	**.010**	**.040**	**.041**	**.029**	**.084**	**1.000**

7.4 Border Crossing Tour Mode Choice

This model chooses tour mode based on a known tour destination, border crossing station, and entry/return time-of-day. Figure 40 shows the nesting structure of the model, where auto modes of different occupancies are combined together into an auto nest. In addition to differences between the auto and walk wait times at the border, the choice of border crossing mode is influenced primarily by the trip-mode choice logsum corresponding to the border crossing mode. Because the utilities of the trip modes are conditioned by the tour mode, the logsums for the walk alternative are weighted toward walk and transit accessibility, while the auto logsums are weighted toward auto accessibility.

Figure 40: Border Crossing Mode Choice Nesting Structure



The model was estimated jointly with the primary destination and station crossing choice model with full information maximum likelihood and modes nested below destinations. One hundred combinations of destination and crossing locations were selected according to the sampling of alternatives model, and each of these alternatives had the full set of border crossing modes available as sub-alternatives below the destination/crossing nest. Only the upper level nests were sampled, and so only the utilities needed to be corrected for sampling, not the border crossing mode choice logsums. The upper level nesting parameter was not significantly different from one, and was therefore constrained to one. This finding indicates that the sensitivity of spatial choices to wait time at the border is not different from the sensitivity of mode choices. The estimated utility function parameters appear in Table 115 and Table 116.

Results

Table 115: Cross Border Mode Choice Utility Function Parameters, Non-Mandatory Tours

Parameter	Coeff	T-Stat
Impedance		
Border wait time coefficient	-0.012	-1.79
Trip mode choice logsum to/from dest coefficient	0.214	7.45
Constants		
SR2 - ASC	-1.080	-8.74
SR2 – Crossing Used SENTRI (additional to ASC)	0.421	3.32
SR2 – School Tour (additional to ASC)	0.494	2.78
SR2 – Cargo (additional to ASC)	0.332	3.26
SR3 - ASC	-1.352	-8.07
SR3 – Crossing Used SENTRI (additional to ASC)	-0.155	-0.69
SR3 – School Tour (additional to ASC)	-0.064	-0.26
SR3 – Cargo Tour (additional to ASC)	0.024	0.23
WALK - ASC	-1.934	-6.34
Walk – School Tour (additional to ASC)	0.411	0.95
Walk – Cargo Tour (additional to ASC)	-0.994	-3.17
Calibration adjustment constant for SR2	0.8914	
Calibration adjustment constant for SR3	0.9573	
Calibration adjustment for Walk	-0.6261	
Nesting Coefficients		(from 1.0)
Nesting coef0. - nesting coefficient for 1st level above lowest level	1.000	Constrained
Nesting coef1. - nesting coefficient for 1st level above lowest level	0.284	-32.63

Table 116: Cross Border Mode Choice Utility Function Parameters, Mandatory Tours

Parameter	Coeff	T-Stat
Impedance		
Border wait time coefficient	-0.030	-4.84
Trip mode choice logsum coefficient to/from dest.	0.200	11.83
Constants		
SR2 - ASC	-0.546	-9.58

Parameter	Coeff	T-Stat
SR2 – Crossing used SENTRI (additional to ASC)	0.170	3.38
SR3 - ASC	-0.982	-10.77
SR3 – Crossing used SENTRI (additional to ASC)	0.123	2.21
WALK - ASC	-3.400	-10.64
SR2 – Visit Tour (additional to ASC)	0.042	0.73
SR3 – Visit Tour (additional to ASC)	0.052	0.88
Walk – Visit Tour (additional to ASC)	0.180	0.60
SR2 – Other Tour (additional to ASC)	0.079	1.74
SR3 – Other Tour (additional to ASC)	0.023	0.46
Walk – Other Tour (additional to ASC)	0.340	1.49
Nesting Coefficients		(from 1.0)
Nesting coef0. - nesting coefficient for lowest level - concrete alternatives	1.000	
Nesting coef1. - nesting coefficient for 1st level above lowest level	0.173	-69.50
Calibration adjustment constants		
Calibration adjustment constant for SR2	0.1608	
Calibration adjustment constant for SR3	0.2728	
Calibration adjustment for Walk	0.5962	

7.5 Border Crossing Stop Frequency Choice

The border crossing stop frequency choice model will be a lookup table of probabilities based upon tour purpose and duration from the border crossing survey data. An example for work tours appears in Table 117. See model input folder file *crossBorder_stopFrequency.csv* for full list of stop frequency probabilities for all tour purposes.

Table 117: Stop Frequency Probabilities for Work Tours

Outbound Stops	Return Stops	Tour Duration (Hours)		
		0 to 3.5	4 to 7.5	8 to 24
0	0	0.511	0.690	0.489
0	1	0.127	0.098	0.137
0	2	0.000	0.032	0.034
0	3	0.000	0.031	0.004
1	0	0.103	0.067	0.127
1	1	0.103	0.027	0.015
1	2	0.052	0.000	0.016

1	3	0.000	0.000	0.000
2	0	0.000	0.023	0.105
2	1	0.000	0.012	0.011
2	2	0.104	0.000	0.011
2	3	0.000	0.000	0.000
3	0	0.000	0.021	0.028
3	1	0.000	0.000	0.021
3	2	0.000	0.000	0.000
3	3	0.000	0.000	0.000
Total		**1.000**	**1.000**	**1.000**

7.6 Border Crossing Stop Purpose Choice

The stop purpose choice model will be a lookup table of probabilities based upon tour purpose and number of stops on tour. An example for the work tour purpose appears in Table 118. See model input folder file *crossBorder_stopPurpose.csv* for full list of stop purpose probabilities for all tour purposes.

Table 118: Stop Purpose Probabilities for Work Tours

Direction	Stop Sequence	Multiple Stops	Stop Purpose						Total
			Work	School	Cargo	Shop	Visit	Other	
Outbound	1	No	0.050	0.000	0.081	0.387	0.207	0.276	1.000
Outbound	1	Yes	0.150	0.048	0.089	0.405	0.064	0.244	1.000
Outbound	2	Yes	0.034	0.000	0.101	0.591	0.029	0.246	1.000
Outbound	3	Yes	0.029	0.000	0.170	0.376	0.000	0.425	1.000
Inbound	1	No	0.025	0.000	0.112	0.530	0.052	0.281	1.000
Inbound	1	Yes	0.000	0.038	0.184	0.380	0.038	0.360	1.000
Inbound	2	Yes	0.000	0.000	0.028	0.521	0.033	0.419	1.000
Inbound	3	Yes	0.190	0.000	0.000	0.648	0.000	0.162	1.000

7.7 Border Crossing Stop Location Choice

The stop location choice model predicts the location of stops along the tour other than the primary destination. The stop location model is structured as a multinomial logit model using MGRA attraction size variable and route deviation measure as impedance. The alternatives are sampled from the full set of MGRAs, based upon the out-of-direction distance to the stop and the size of the MGRA. The sampling mechanism is also subject to certain rules based on tour mode. All destinations are available for auto tour modes, as long as there is a positive size term for the MGRA. Intermediate stops on walk tours must be within 3 miles of both the tour origin and primary destination MGRAs. The sampling for intermediate stops on walk-transit tours is based upon the MGRAs that are within walking distance of the boarding or alighting stops at the tour origin and primary destination.

The intermediate stop location choice model works by cycling through stops on tours. The level-of-service variables (including mode choice logsums) are calculated as the additional utility between the last location and the next known location on the tour. For example, the LOS variable for the first stop on the outbound direction of the tour is based on additional impedance between the tour origin and the tour primary destination. The LOS variable for the next outbound stop is based on the additional impedance between the previous stop and the tour primary destination. Stops on return tour legs work similarly, except that the location of the first stop is a function of the additional impedance between the tour primary destination and the tour origin. The next stop location is based on the additional impedance between the first stop on the return leg and the tour origin, and so on. The utility function parameters for the intermediate stop location choice model appear in Table 119.

Results

Table 119: Stop Location Choice Utility Function Parameters

Parameter	Coeff	T-Stat
Sample of alternatives correction factor	1.000	
Impedance		
Additional trip mode choice logsum incurred for stop	2.123	40.95
First/Last Stop Distance Effects		
Distance to orig. > 1 mi. (binary), out stop first	-0.700	-5.28
Distance to dest. > 1 mi. (binary), out. stop last	-0.841	-5.78
Distance to dest. over 1 (max 3), out. stop last	-0.194	-3.49
Distance to dest. > 1 mi. (binary), ret. stop first	-0.860	-6.06
Distance to dest. over 1 (max 3), ret. stop firt		
Distance from POE. > 1 mi. (binary), return stop last	-0.366	-1.66
Distance to POE over 1 (max 3), return stop last	-0.269	-4.21
Tour Duration Effects		
Mode choice Logsum, tour duration < 2 hours	0.796	2.92
Mode choice Logsum, tour duration > 8 hours	-0.317	-3.53
Size Variables		
Work Size - See Primary Destination Choice	1.000	
School Size - See Primary Destination Choice	1.000	
Cargo Size - See Primary Destination Choice	1.000	

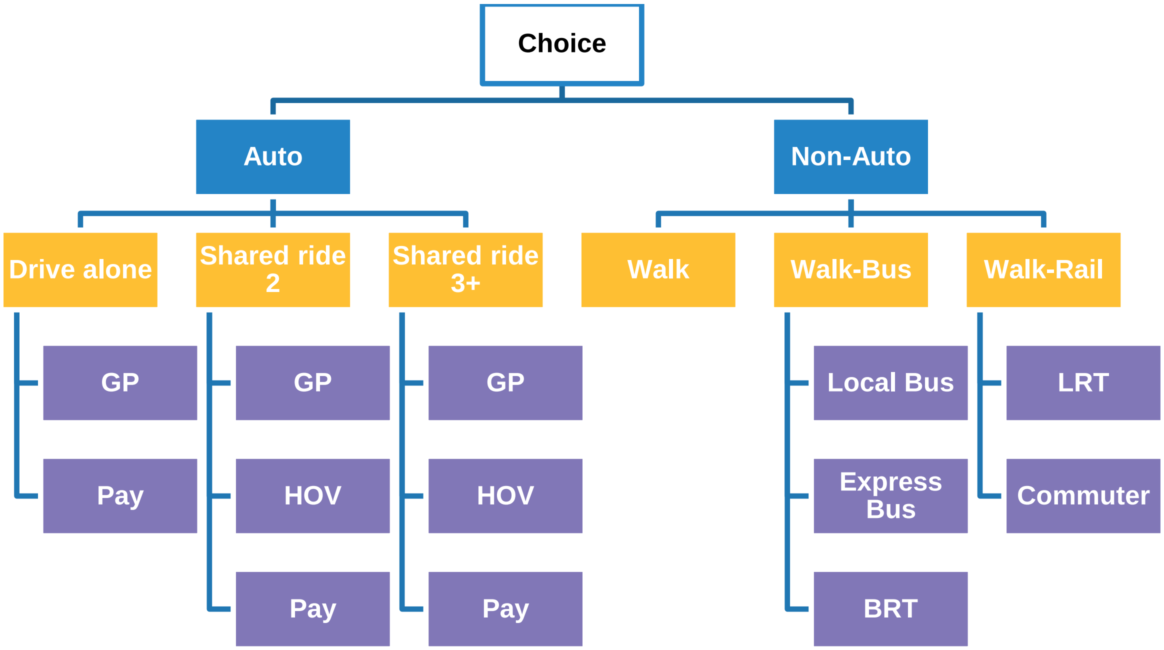
7.8 Border Crossing Trip Departure Choice

Each border crossing trip will be assigned to a trip departure time period. The first and last trips of the tour are set to the entry/return time periods from primary destination and station cross choice model (Model 2.2), respectively. Each intermediate trip departure time is calculated from a lookup table of probabilities that consider the number of remaining half-hour periods in the tour from the last scheduled trip and whether the stop is made on the outbound or return direction. See model input folder file *crossBorder_outboundStopDuration.csv and crossBorder_inboundStopDuration.csv* for the lookup probabilities.

7.9 Border Crossing Trip Mode Choice

A trip mode is chosen for each trip on the tour. The utility of each mode is a function of the time and cost of the mode for the period that the trip occurs in, and is influenced by the mode used to cross the border. Trip modes are consistent with the resident travel model, as shown in Figure 41, though certain modes (bike, drive-transit, and school bus) are unavailable for Mexican residents.

Figure 41: Mexican Resident Trip Mode Choice Model for Travel in US



Additionally, the nesting structure includes walk and transit alternatives together in a non-auto nest because of the similarity between the modes induced by border crossing. The full set of General Purpose (GP), High-Occupancy Vehicle lane (HOV), Pay, Local, Express, Bus Rapid Transit (BRT), Light Rail Transit (LRT), and Commuter Rail will be predicted during simulation of the model, but only the upper two levels were included in model estimation because the specific sub-modes were not reported in the cross-border travel survey. The scale parameters and alternative-specific constants for the lowest-level alternatives will be borrowed from the San Diego resident models.

Table 120: Trip Mode Choice Utility Function Parameters

Parameter	Coeff	T-Stat	Equiv. IVT
Impedance			
In-vehicle time	-0.021	-6.63	1.00
Express bus IVT factor	0.9000		
BRT IVT factor	0.9000		
LRT IVT factor	0.8500		
Commuter rail IVT factor	0.7500		
Walk time (walk mode)	-0.037	-12.31	1.76
Cost (cents)	-0.005	-4.78	0.22
Transit out-of-vehicle time	-0.032	Constrained	1.50
Number of transfers above one	-0.504	-1.86	25.46
Transfer penalty - PNR	c_ivt*15		
Calibration Adjustment Constants			
SR2 –cross mode is DA (ASC)	0.1280		
SR3 –cross mode is DA (ASC)	0.3012		
Walk – cross mode DA (ASC)	0.2003		
Transit – cross mode DA (ASC)	-0.7947		
Transit (WALK_LR, WALK_CR) – cross mode DA (ASC)	-0.6915		
SR2 –cross mode is SR2 (ASC)	0.5901		
SR3 –cross mode is SR2 (ASC)	-1.1094		
Walk – cross mode S2 (ASC)	-0.0579		
Transit (Walk_LOC, Walk_EXP, Walk_BRT)– cross mode S2 (ASC)	-2.0305		
Transit (WALK_LR, WALK_CR) – cross mode S2 (ASC)	-1.9985		
SR2 – cross mode S3 (ASC)	-0.8562		
SR3 – cross mode S3 (ASC)	-1.3324		
Walk – cross mode S3 (ASC)	-0.4514		
Transit (Walk_LOC, Walk_EXP, Walk_BRT)– cross mode S3 (ASC)	-2.4453		
Transit (WALK_LR, WALK_CR) – cross mode S3 (ASC)	-2.3297		
SR2 – cross mode Walk (ASC)	-0.6874		

SR3 – cross mode Walk (ASC)	-1.0476		
Walk – cross mode Walk (ASC)	-0.0762		
Transit (Walk_LOC, Walk_EXP, Walk_BRT)– cross mode Walk (ASC)	-2.6149		
Transit (WALK_LR, WALK_CR) – cross mode Walk (ASC)	-2.1859		
ASC - Crossing Mode Interactions (Trip Mode – Tour Mode)			
SR2 - cross mode is DA	-0.8160		
SR2 - cross mode is SR2	1.5075	23.58	-71.08
SR2 - cross mode is SR3	1.4795	17.24	-69.74
SR2 - cross mode is walk	0.7495	8.73	-35.34
SR3 - cross mode is DA	-1.2825		
SR3 - cross mode is SR2	1.3030	14.87	-61.44
SR3 - cross mode is SR3	2.7155	27.57	-128.01
SR3 - cross mode is walk	0.9660	8.91	-45.54
Walk - cross mode is DA	-0.6565		
Walk - cross mode is SR2	0.1270	0.67	-5.98
Walk - cross mode is SR3	1.0335	5.77	-48.71
Walk - cross mode is walk	3.0745	9.87	-144.94
Transit - cross mode is DA	-2.0185		
Transit - cross mode is SR2	-0.3370	-1.19	15.90
Transit - cross mode is SR3	1.1935	4.91	-56.26
Transit - cross mode is walk	3.1525	8.91	-148.62
SENTRI Interactions			
SR2 - crossed with SENTRI	-0.5310	-9.50	25.05
SR3 - crossed with SENTRI	-0.8825	-12.51	41.61
Walk - crossed with SENTRI	-0.3875	-2.34	18.26
Transit - crossed with SENTRI	0.6285	2.73	-29.63
Tour Purpose Interactions			
SR2 - tour purpose work	-0.7970	-8.65	37.58
SR3 - tour purpose work	-0.7525	-6.59	35.47
ASC - Line-haul mode			
Walk-Transit (Walk_EXP,Walk_BRT,Walk_LR,Walk_CR)	0.3400		

Nesting coefficient 0.493

Rho-squared w.r.t zero	0.400
Rho-squared w.r.t constants	0.310

8.0 Airport Ground Access Model

In 2008, San Diego International Airport (SDIA) conducted a survey of airport passengers in which data was collected on their travel to the airport prior to their departure. Based upon this data, PB developed a model of travel to and from the airport for arriving and departing passengers. The purpose of this model was to capture the demand of airport travel on transport facilities in San Diego County. Additionally, the model allows SANDAG to test the impacts of various parking price and supply scenarios at the airport.

8.1 Airport Destination Choice Model

The airport destination choice model chooses the origin or destination MGRA, depending on whether the travel party is arriving or departing. The model is based upon the airport survey data, which collected the zip code of the origin location for trips made to the airport by departing passengers.

Residents on Personal Trip Origin Choice Model

The resident-personal choice model was estimated with 2485 records from the airport survey set.

Model Findings:

- For the final model estimation, office, military, and other employment size terms were included while coefficient for households was constrained to 1.
- Distance terms for distance, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.

The final implemented coefficients for the selected variables are shown in Table 121.

Table 121: Airport Resident-PersonalOrigin Choice Estimation

Parameter	Coeff	T-Stat
Distance	-0.004	-1.01
log(distance)	-0.238	-4.39
Size Terms (exponentiated params)		
Households	1.000	Base
Employment		
Office	0.001	-2.67
Other	0.018	-23.40
Military	0.032	-23.27
Observations		2485
Initial Likelihood		-11332
Final Likelihood		-10862

Residents on BusinessTrip Origin Choice Model

The resident-business choice model was estimated with 1292 records from the airport survey set.

Model Findings:

- • For the final model estimation, office, military and other employment size terms were included while coefficient for households was constrained to 1.
- • Distance terms for distance, distance-squared, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.

The final implemented coefficients for the selected variables are shown in Table 122.

Table 122. Airport Resident-Business Origin Choice Estimation

Parameter	Coeff	T-Stat
Distance	0.032	1.70
log(distance)	-0.492	-4.31
squared	0.0005	-1.72
Size Terms (exponentiated params)		
Households	1.000	Base
Employment		
Office	0.013	-9.17
Other	0.015	-17.90
Military	0.007	-13.67
Observations		1292
Initial Likelihood		-5680
Final Likelihood		-5551

Visitors on Personal Trip Origin Choice Model

The visitor personal choice model was estimated with 2573 records from the airport survey set.

Model Findings:

- For the final model estimation, amusement, other employment, and household size terms were included while coefficient for hotel employment was constrained to 1.
- Distance terms for distance, distance-squared, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.
- A La Jolla constant was included and had a positive term which indicated that visitors to the airport for personal reasons were more likely to be from La Jolla.

The final implemented coefficients for the selected variables are shown in Table 123.

Table 123. Airport Visitor-Personal Origin Choice Estimation

Parameter	Coeff	T-Stat
Distance	0.014	1.27
log(distance)	-0.364	-5.94
Squared distance	-0.000320	-1.96
La Jolla Constant	0.337	3.62
Size Terms (exponentiated params)		
Hotel Employment	1.000	Base
Amusement Employment	0.263	-6.37
Other Employment	0.003	-29.93
Households	0.020	-41.06
Observations		2573
Initial Likelihood		-9919
Final Likelihood		-9454

Visitors on Business Trip Origin Choice Model

The visitor business choice model was estimated with 1292 records from the airport survey set.

Model Findings:

- For the final model estimation, office, government, military, amusement, other employment, and household size terms were included while coefficient for hotel employment was constrained to 1.
- Distance terms for distance, distance-squared, and the log of distance were included in the final estimation. The inclusion of the log of the distance makes this a non-linear distance expression.
- A La Jolla constant was included and had a positive term which indicated that visitors to the airport for personal reasons were more likely to be from La Jolla.

The final implemented coefficients for the selected variables are shown in Table 124.

Table 124: Airport Visitor-Business Origin Choice Estimation

Parameter	Coeff	T-Stat
Distance	0.070	4.30
log(distance)	-0.897	-11.99
Distance_squared	-0.000894	-3.47
La Jolla Constant	0.712	6.82
Size Terms (exponentiated params)		
Hotel employment	1.000	Base
Other Employment		
Office	0.010	-10.43
Other	0.007	-16.79
Government (Federal Non-Military+ w.col st\loc)	0.040	-4.21
Military	0.007	-16.55
Amusement Employment	0.098	-4.67
Households	0.007	-26.10
Observations		1292
Initial Likelihood		-5680
Final Likelihood		-5591

8.2 Airport Trip Mode Choice

Since the data in the ground access survey is too aggregate to estimate a mode choice model, trip mode was asserted based upon estimation work from applications of the similar models in other regions (i.e. Port of Portland).

The model explicitly represented the options of parking versus pick-up/drop-off for private vehicle trips. All trips were assigned either curbside (for pick-up/drop-off, taxi, shuttle/van/courtesy vehicle, and transit) or parking lot (terminal, off-site SAN lot, or off-site private lot). The choice of transit access and line-haul mode were not shown but was modeled explicitly, as was the path choice for HOV or pay options for auto trips.

Table XX: Airport Mode Choice Model Estimate Results - Utility Function Parameters

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Time Coefficients for DA, SR2,SR3			
In-Vehicle time coefficient(c_ivt)	-0.0300		1.00
Walk Time coefficient (access, egress, auxiliary time)	-0.0520		1.73
Cost Coefficients for DA and SR2			
Cost coefficient for income less than 25k	-0.0030		0.10
Cost coefficient for income 25-50k	-0.0010		0.03
Cost coefficient for income 50-75k	-0.0006		0.02
Cost coefficient for income 75-100k	-0.0004		0.01
Cost coefficient for income 100-125k	-0.0003		0.01
Cost coefficient for income 125-150k	-0.0003		0.01
Cost coefficient for income 150-200k	-0.0002		0.01
Cost coefficient for income 200k+	-0.0001		0.003
Cost coefficient for personal is 50% of business	c_cost*0.5		
Cost Coefficients for SR3			
Cost coefficient for income lt 25k	-0.0052		0.17
Cost coefficient for income 25-50k	-0.0017		0.06
Cost coefficient for income 50-75k	-0.0010		0.03
Cost coefficient for income 75-100k	-0.0007		0.02
Cost coefficient for income 100-125k	-0.0006		0.02
Cost coefficient for income 125-150k	-0.0005		0.02
Cost coefficient for income 150-200k	-0.0004		0.01
Cost coefficient for income 200k+	-0.0003		0.01
Cost coefficient for personal is 50% of business	c_cost*0.5		
Time Coefficients for Transit			
In-vehicle time coefficient	-0.0300		1.00
Walk Time coefficient (access, egress, auxiliary time)	-0.0520		1.73
First wait time coefficient	-0.0450		1.50
Transfer wait time coefficient	-0.0550		1.83

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Drive access time coefficient	-0.0450		1.50
Transfer penalty	-0.1500		5.00
Express bus IVT factor	0.9000		-30.00
BRT IVT factor	0.9000		-30.00
LRT IVT factor	0.8500		-28.33
Commuter rail IVT factor	0.7500		-25.00
Cost Coefficients for Transit			
Cost coefficient for income less than 25k	-0.0030		0.10
Cost coefficient for income 25-50k	-0.0010		0.03
Cost coefficient for income 50-75k	-0.0006		0.02
Cost coefficient for income 75-100k	-0.0004		0.01
Cost coefficient for income 100-125k	-0.0003		0.01
Cost coefficient for income 125-150k	-0.0003		0.01
Cost coefficient for income 150-200k	-0.0002		0.01
Cost coefficient for income 200k+	-0.0001		0.003
Cost coefficient for personal is 50% of business	c_cost*0.5		
ASC – for Transit by Line-haul modes:			
WALK_EXP or KNR_EXP	0.30		-10.00
WALK_BRT or KNR_BRT	0.30		-10.00
WALK_LR or KNR_LR	0.45		-15.00
WALK_CR or KNR_CR	0.60		-20.00

Table XX: Airport Mode Choice Model Estimate Results - for Arrival Mode - Utility Function Parameters

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
Time Coefficients			
In-Vehicle time coefficient(c_ivt)	-0.0250		1.00
First wait time coefficient	-0.0500		2.00
Walk auxiliary Time coefficient	-0.0500		2.00
Cost Coefficients			
Cost coefficient for income less than 25k	-0.0025		0.100
Cost coefficient for income 25-50k	-0.0008		0.032
Cost coefficient for income 50-75k	-0.0005		0.020
Cost coefficient for income 75-100k	-0.0004		0.016
Cost coefficient for income 100-125k	-0.0003		0.012
Cost coefficient for income 125-150k	-0.0002		0.008
Cost coefficient for income 150-200k	-0.0002		0.008
Cost coefficient for income 200k+	-0.0001		0.004
Cost coefficient for personal is 50% of business	c_cost*0.5		
Constants - Resident Business by arrival mode			
PARK_TERMINAL	2.2006		-88.02
PARK_SANOFF	1.5487		-61.95
PARK_PVTOFF	1.9428		-77.71
PUDO_ESC	-0.3453		13.81
TAXI	0.1157		-4.63
SHUTTLE \ VAN	-1.6783		67.13
TRANSIT	-0.7443		29.77
Constants - Resident Personal by arrival mode			
PARK_TERMINAL	0.9799		-39.20
PARK_SANOFF	0.6235		-24.94
PARK_PVTOFF	0.9975		-39.90
PUDO_ESC	-0.3932		15.73
TAXI	-0.7975		31.90

Parameter	Coeff	T-Stat	Ratio (Coeff/IVT)
SHUTTLE \ VAN	-1.8452		73.81
TRANSIT	-1.2820		51.28
Constants – Visitor Business by arrival mode			
PUDO_ESC	-1.3572		54.29
RENTAL	2.1427		-85.71
TAXI	1.2698		-50.79
SHUTTLE \ VAN	1.1564		-46.26
TRANSIT	-1.7326		69.30
Constants – Visitor Business by arrival mode			
PUDO_ESC	-0.5989		23.96
RENTAL	0.7136		-28.54
TAXI	-0.3895		15.58
SHUTTLE \ VAN	-0.4353		17.41
TRANSIT	-0.4870		19.48

9.0 Visitor Model

In 2011, the San Diego Association of Governments (SANDAG) conducted a survey of airport passengers and hotel guests in which data was collected on their travel while visiting San Diego. Based upon this data, a model of visitor travel was developed. The purpose of this model is to capture the demand of visitor travel on transport facilities in San Diego County.

9.1 Visitor Travel Parties and Tour Generation

This section describes the generation of visitor travel parties, the generation of tours, and the attribution of each.

Visitor Travel Party Generation

The number of visitors to San Diego in 2009, according to the San Diego Convention and Visitor Bureau, are summarized by visitor segment in Table 125.

Table 125: Number of Visitors

	Count	Frequency
Business	2.5M	17%
Personal	11.8M	83%
Total	**14.3M**	**100%**

Visitors are generated for two visitor segment types:

- **Business:** Self-identified as business traveler, or self-identified as 'Both Business and Personal' but took at least one 'business' purpose trip on travel day
- **Personal:** Self-identified as personal traveler, or self-identified as 'Both Business and Personal' but took no business purpose trips on travel day. A few self-identified Personal travelers have reported Work tours.

The distributions of visitors by segment in the visitor survey are shown in Table 126. We assume that the share of business travelers in the San Diego Convention and Visitor Bureau data (17%) is more accurate than the visitor survey (25%) since the visitor survey was a place-based survey and likely did not capture a proportional share of visitors staying in households. Therefore the visitor data was re-weighted to the split of business versus personal travelers from the Convention and Visitor Bureau data.

Table 126: Survey Respondents by Visitor Segment

Segment	Visitor Respondent Count	% of Total
Business	259	25%
Personal	769	75%
Total	**1,028**	**100%**

The model generates visitor parties by segment by applying separate occupancy rates to hotels and households, which were obtained from the San Diego Convention and Visitor Bureau. The occupancy rate for hotels is 70%; while the occupancy rate for households is 1.8% (a bit less than 2 out of every 100 households in San Diego County have visitors, on average). The model then applies separate distributions of visitor parties by segment to hotel visitor parties and household visitor parties separately. The frequencies used are shown in Table 127.

According to the visitor survey, only 2% of overnight visitors stayed in a location that was not identified as a hotel or private residence. Of those, 54% stayed at a military base and 38% stayed at a vacation rental. For the purposes of this model, vacation rentals are included in the estimate of households. A small number of visitors could be allocated to the military base in the future, but this is not done currently in the model.

Table 127: Share of Visitor Parties by Segment and Overnight Accommodation

Segment	Hotel	Household
Business	30%	4%
Personal	70%	96%
Total	**100%**	**100%**

Visitor parties are attributed with household income based upon the distribution of parties by visitor segment and income, as shown in Table 128. Note that party size and auto availability are attributed on a tour-by-tour basis, since these attributes can change depending on which tour is undertaken and which day it is taken on.

Table 128: Visitor Parties by Visitor Segment and Household Income

Income	Business	Personal
< $30k	7%	34%
$30-$60k	29%	34%
$60-$100k	34%	20%
$100-$150k	16%	7%
$150k+	14%	5%
Total	**100%**	**100%**

Tour Generation

Next, tours are generated by visitor parties and attributed with party size, auto availability, and income attributes. There are three tour purposes, which were coded based on the reported trip purpose in the survey, as follows:

- **Work:** Business travel made by Business travelers
- **Recreational:** All other recreational purposes besides dining
- **Dining:** Travel to eating establishments

Tour purpose was coded according to a hierarchy of trip purposes, with work at the top and dining last. Tours by visitor segment are shown in Table 129.

Table 129: Tour Purpose by Visitor Segment

Person Type	Business	% of Total	Personal	% of Total
Work	154	59%	27	4%
Recreational	78	30%	691	90%
Dining	27	10%	51	7%
Total	**259**	**100%**	**769**	**100%**

Each travel party can generate one or more tours of each purpose on any given day. The tour generation rates are shown in Table 130 (for the business segment) and Table 131 (for the personal segment).

Table 130: Tour Distribution, Business Parties

Work	Recreational	Dining	Total Tours	Frequency
1	0	0	1	40%
2	0	0	2	1%
0	1	0	1	29%
1	1	0	2	5%
0	2	0	2	1%
0	0	1	1	11%
1	0	1	2	10%
0	1	1	2	3%

Table 131: Tour Distribution, Personal Parties

Work	Recreational	Dining	Total Tours	Frequency
1	0	0	1	3%
0	1	0	1	82%
1	1	0	2	0%
0	2	0	2	5%
0	0	1	1	6%
0	1	1	2	4%
0	2	1	3	0%
0	1	2	3	0%

The average size of the travel parties was obtained from both the San Diego Convention and Visitor Bureau numbers and the visitor survey. The visitor survey averages are slightly smaller.

Table 132: Average Party Size

	Business	Personal
Convention and Visitor Bureau	1.3	2.4
Visitor Survey	1.04	2.2

Ultimately, the average party size observed in the survey is used in the model. The distribution of visitor tours by party size and tour purpose is shown in Table 133.

Table 133: Tours by Party Size and Tour Purpose

Party Size	Work	Recreate	Dining
1	31%	4%	10%
2	12%	12%	13%
3	18%	29%	33%
4	15%	23%	17%
5	3%	17%	6%
6	0%	5%	6%
7	20%	9%	14%
8	0%	0%	0%
9	0%	0%	0%
10	1%	0%	0%
Total	**100%**	**100%**	**100%**

Most visitors in the visitor survey did not have access to an automobile.

Table 134 shows the number and percentage of visitors who made complete tours by auto accessibility. If a person drove into San Diego, either in a personal or rental vehicle, they were assumed to have access to a car during their stay. If a person flew into San Diego and rented a car, they were also assumed to have access to a car. Persons who do not fit into either of those categories were assumed to have no vehicle. The model uses the distribution of tours by auto availability to attribute each tour with whether an auto is available, as shown in Table 135.

Table 134: Auto Availability by Segment

	Business	% of Total	Personal	% of Total
Drove into San Diego	18	8%	82	12%
Flew into SD, rented car	67	31%	173	25%
No Vehicle	197	60%	617	64%
Total	**215**	**100%**	**699**	**100%**

Table 135: Auto Availability by Tour Purpose

Auto Available	Work	Recreate	Dining
Yes	38%	58%	53%
No	62%	42%	47%
Total	100%	100%	100%

9.2 Visitor Tour Time of Day

The visitor time of day choice model selects an outbound and return half-hour period, based on a probability distribution created using the visitor survey observed tour arrival and departure data, by tour purpose. Model input is the observed percent of tours by purpose with each combination of departure and arrival time period. See model input folder file *visitor_TourTOD.csv* for full list of visitor time of day probabilities for all tour purposes.

9.3 Visitor Destination Choice

The tour destination choice model predicts the 'preferred' destination for the tour at the level of the Master Geographic Reference Area (MGRA). There are two stages involved in the estimation and application of the model. In the first phase, a list of sampled MGRAs is created. In the second phase, a multinomial logit form is applied to each sampled alternative and a destination MGRA is selected. The two-stage procedure is necessary in order to minimize the computational burden associated with computing mode choice logsums for each tour to 21633 MGRAs. In both estimation and application, 30 destination MGRAs were sampled.

Mode choice logsums used in this model were based upon an asserted mode choice model that was derived from the resident discretionary tour mode choice model.

In order to create the initial sample file, the number of tours attracted to each zone in the survey data was aggregated, and then the number of households and employment categories in each zone were appended. Using maximum likelihood, a multinomial logit destination choice size term was estimated for each of the zonal attributes. Based on the standard error for each result, the most statistically robust size terms were selected for use in creating the sample. Each tour record then had 30 possible samples selected, using the estimated size terms and mgra data to pick the sample set. The sampled file was passed into alogit to estimate the full model which chooses the destination MGRA for each tour based on a utility expression.

Size Terms for Sampling

The size terms used for sampling are shown in Table 136.

Table 136: Size Terms for Sampling

Visitor Size Terms	Work	Recreation	Dining
Total employment	1.0000		
Retail employment		1.0000	
Amusement employment		1.1700	
Hotel employment		1.5800	0.1240
Restaurant & bar employment		1.1300	1.0000
Households			0.0760
Acres of active park		5.0700	
Acres of active beach		7.8400	
Cabrillo National monument		7041.34	
Sea World		7147.03	
Legoland		6004.60	0.3104
San Diego Safari Park		15935.00	1.0000
Midway		12968.70	
San Diego Zoo		10419.12	

Visitor Work Model Estimation

The first model estimated was the home based work purpose. This purpose had 181 observations in the survey set.

Model Estimation Findings:

- The initial model runs tested the mode choice logsum and the employment group size terms. The mode choice logsum initially estimated with a value of just less than one, which is within the reasonable range. The logsum value should always be between 0 and 1. If the value is greater than 1, then it means that the mode choice has a greater impact on destination selection than any other variable (ie distance, employees at that location, etc.).
- Introduction of size term for total employment produced a reasonable model result.
- Distance terms were not significant for this model.
- Splitting employment into categories had mixed results, with many insignificant groups and some unreasonably large coefficients on the groups that were significant.
- The convention center MGRA attracts so many visitors that it was heavily impacting the employment categories, particularly for hotel employees. Splitting it out as a separate size term, or an alternative-specific constant was not successful.
- Income of the visitor interacted with distance did not produce a significant result.
- Availability of a vehicle (either personal or rental) did not produce a reasonable coefficient.

Final Model:

- For the final model estimation, only the total employment size term was maintained. Splitting out the employment categories did not yield reasonable results. This is most likely due to the low number of observations, and the high number of work tours attracted to a handful of zones.

The final estimated coefficients for the selected variables are contained in Table 137.

Table 137: Estimated Destination Choice Model for Work Tours

Variable	Coefficient
Mode choice logsum	0.946
Distance	-0.625
Size variable - Total Employment	1.000

Visitor Recreation Model Estimation

The visitor recreation purpose had 769 observations in the dataset. This purpose includes all tours that have a primary stop other than work or dining.

Model Estimation Findings:

- The initial model run of logsum and distance resulted in a reasonable logsum of .848. The distance term was very small and negative, and barely significant.
- The addition of size terms caused the logsum to change very little, but made the distance term positive. A positive distance term indicates that traveling a longer distance is more desirable, which is not reasonable.
- Auto availability and income interaction with distance did not yield significant results.
- Size terms for various recreation-related employment were used. These include retail, amusement, hotel, restaurant/bar employment, as well as the acreage of open park, active park, and active beach.

Final Model:

- For the final model estimation, only the logsum and size terms were included.
- Although the size terms for acreage estimated, their magnitude is quite large and may be replaced with the value from the sampling procedure used in the first stage of the process in model implementation.

The final estimated coefficients for the selected variables are contained in Table 138.

Table 138: Estimated Destination Choice Model for Visitor Recreation Tours

Variable	Coefficient
Mode choice logsum	0.867
Size variable - Retail	1.000
Size variable - Amusement Employment	9.455
Size variable - Hotel Employment	0.478
Size variable - Restaurant/Bar Employment	1.649
Size variable - Active Park Acreage	62.080
Size variable - Open Park Acreage	36.204
Size variable - Active Beach Acreage	311.745

Visitor Dining Model Estimation

The visitor dining purpose had 78 observations in the data set.

Model Estimation Findings:

- The initial model run estimated the mode choice logsum at 1.467. A mode choice logsum larger than 1 is not considered reasonable, because it means that the choice of mode has the most influence on the choice of destination.
- The size terms used for this model were employment at restaurants, as well as employment at hotels.
- The size term for restaurant was used as the base. The size term for hotel employment was small but significant.
- Auto availability and income interacted with distance were not significant.
- Distance terms were not significant.

Final Model:

- For the final model estimation, the logsum was constrained to 1.
- The size terms for both restaurant and hotel employment were kept in the model.

The final estimated coefficients for the selected variables are contained in Table 139.

Table 139: Estimated Destination Choice Model for Visitor Dining Tours

Variable	Coefficient
Mode choice logsum	1.000
Distance	-0.5
Size variable- Restaurant/bar employment	1.000
Size variable - Hotel employment	0.156

Implemented Destination Choice Coefficients

Most of the estimated coefficients were included as is into the model code, however, the acreage size terms for the recreation purpose were determined to be too high compared to the employment terms. Instead, the first stage size term estimation (which generated size terms for the sampling procedure) was used to estimate more reasonable values. The implemented destination choice coefficients are contained in Table 140.

Table 140: Implemented Destination Choice Coefficients

Variable	Work	Recreation	Dining
Mode choice logsum	0.94564	0.8674	1
Distance	-0.625		-0.5
Visitor Size Terms			
Total employment	1.0000		
Retail employment		1.0000	
Amusement employment		1.1700	
Hotel employment		1.5800	0.1240
Restaurant & bar employment		1.1300	1.0000
Households			0.0760
Acres of active park		5.0700	
Acres of active beach		7.8400	
Cabrillo National monument		7041.34	
Sea World		7147.03	
Legoland		6004.60	0.3104
San Diego Safari Park		15935.00	1.0000
Midway		12968.70	
San Diego Zoo		10419.12	

9.4 Visitor Tour Mode Choice

This model chooses a tour mode based on a known trip origin and destination MGRAs, and travel party characteristics including purpose, party size, and income. Since the data in the visitor survey is too aggregate to estimate a mode choice model, the model was asserted based on the resident tour mode choice model, with some modifications. Figure 42 shows a nesting structure of the mode choice model. Note that the modes are the same as are used in the resident model, with the addition of the taxi mode, which utilizes the same coefficients as auto modes (in-vehicle time and cost), though cost is based on an initial fare (meter-drop) and a cost-per-mile.

The implemented visitor tour mode choice coefficients are listed in TableXX.

Table 141: Survey Respondents by Purpose and Trip Mode

Mode	Tours				Trips on Tours			
	Business	% of Total	Personal	% of Total	Business	% of Total	Personal	% of Total
Personal Vehicle	49	19%	279	36%	75	11%	633	34%
Rental Car	75	29%	233	30%	160	24%	528	29%
Taxi	29	11%	184	24%	93	14%	458	25%
Walk/Bike	104	40%	68	9%	330	49%	201	11%
Bus	1	0%	4	1%	5	1%	18	1%
Trolley	1	0%	0	0%	5	1%	2	0%
Coaster	0	0%	0	0%	1	0%	4	0%
Other Mode	0	0%	1	0%	1	0%	5	0%
Total	**259**	**100%**	**769**	**100%**	**670**	**100%**	**1849**	**100%**

Figure 42: SANDAG Nested Tour Mode Choice model structure

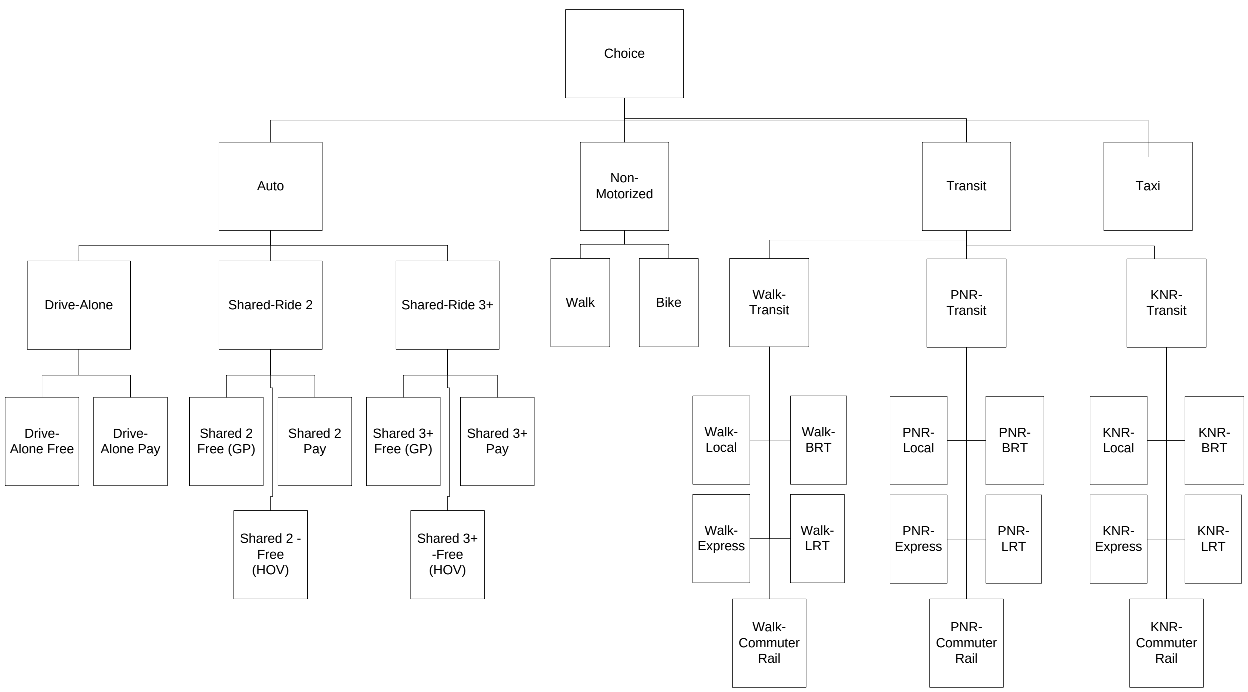


Table XX: Implemented Visitor Tour Mode Choice Coefficients

Coefficient Name	Value	Ratio (Coeff/IVT)
In-vehicle time coefficient	-0.0150	1.00
First wait time coefficient	-0.0230	1.53
Transfer wait time coefficient	-0.0230	1.53
Walk access time coefficient	-0.0380	2.53
Walk egress time coefficient	-0.0380	2.53
Walk auxiliary time coefficient	-0.0380	2.53
Drive access time coefficient	-0.0166	1.11
Transfer penalty	0	
Transfer penalty - PNR	c_ivt*15	15
Express bus IVT factor	0.9000	-60.00
BRT IVT factor	0.9000	-60.00
LRT IVT factor	0.8500	-56.67
Commuter rail IVT factor	0.7500	-50.00
Walk mode time coefficient	-0.0528	3.52
Bike mode time coefficient	-0.0988	6.59
Cost coefficient for income < $30k	-0.0037	0.25
Cost coefficient for income $30k-$60k	-0.0017	0.11
Cost coefficient for income $60k - $100k	-0.0010	0.07
Cost coefficient for income > $100k	-0.0004	0.03
Origin MGRA du/emp mix coefficient, applied to walk, bike	0.17243	-11.50
Origin MGRA intersection density coefficient, applied to walk, bike	0.00571	-0.38
ASC - Express Bus	0.3000	-20.00
ASC – BRT	0.3000	-20.00
ASC – LRT	0.45	-30.00
ASC - Commuter Rail	0.6000	-40.00
ASC - TransitDrive	-5.1561	343.74
ASC - Transit KNR	0.8448	-56.32
Calibration Constants Adjustment		

Coefficient Name	Value	Ratio (Coeff/IVT)
Drive Alone, Work Tour	0.4021	-26.81
Drive Alone, Recreation Tour	0.6607	-44.05
Drive Alone, Dining Tour	-0.8974	59.83
Shared3, Work Tour	1.3899	-92.66
Shared3, Recreation Tour	-0.2676	17.84
Shared3, Dining Tour	0.7100	-47.33
Walk, Work Tour	1.2605	-84.03
Walk, Recreation Tour	-0.3291	21.94
Walk, Dining Tour	3.7940	-252.93
Transit, Work Tour	-0.9709	64.73
Transit, Recreation Tour	-2.0553	137.02
Transit, Dining Tour	-0.7676	51.17
Taxi, Work Tour	0.4017	-26.78
Taxi, Recreation Tour	-0.3591	23.94
Taxi, Dining Tour	-0.8690	57.93
Calibration Constants Adjustment		
Drive Alone, Work Tour	-1.4165	94.43
Drive Alone, Recreation Tour	2.3580	-157.20
Drive Alone, Dining Tour	3.4488	-229.92
Shared3, Work Tour	-0.5988	39.92
Shared3, Recreation Tour	0.8992	-59.95
Shared3, Dining Tour	1.9586	-130.57
Walk, Work Tour	5.3497	-356.65
Walk, Recreation Tour	2.2304	-148.69
Walk, Dining Tour	9.7803	-652.02
Transit, Work Tour	-2.3944	159.63
Transit, Recreation Tour	-1.3499	89.99
Transit, Dining Tour	2.2797	-151.98
Taxi, Work Tour	-0.7194	47.96
Taxi, Recreation Tour	3.0562	-203.75
Taxi, Dining Tour	4.7503	-316.69

9.5 Visitor Stop Frequency

The number of stops per tour is determined by sampling from the observed distribution of number of stops per tour. The model input is the percentage of observed number of stops (both inbound and outbound) by purpose and tour duration. The input frequency table is too large for documentation, but the frequency of stops by tour purpose and segment is shown in Table 142. For simplicity's sake, intermediate stops are not allowed on non-motorized or transit tours (which speeds up and simplifies the intermediate stop sampling procedure). See model input folder file *visitor_stopFrequency.csv* for full list of visitor stop frequency probabilities.

Table 142: Frequency of Stops on Tour

Number of Stops	Business Respondents			Personal Respondents	
	Work	Shop\Recreate	Eat Out	Shop\Recreate	Eat Out
0	31%	47%	100%	52%	94%
1	41%	44%	0%	42%	6%
2	28%	9%	0%	6%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

9.6 Visitor Stop Purpose

Purpose of stops is determined by the observed purpose of stops in the visitor survey. The model input is the percentage of observed stops by purpose, stop number, number of stops on tour, and stop direction (inbound or outbound). The frequency of stops by tour purpose and segment is shown in Table 143, and the probabilities are shown in Table 144.

Table 143: Stops by Purpose

	Business Respondent			Personal Respondent	
Stop Purpose	Work	Shop\Recreate	Eat Out	Shop\Recreate	Eat Out
Work	100%	63%	76%	5%	5%
Shop\Recreate	0%	37%	24%	95%	93%
Eat Out	0%	0%	0%	0%	2%

Table 144: Visitor Stop Purpose Probabilities

Tour Purpose	Direction	Stop Number	Multiple Stops	Stop Purpose Work	Stop Purpose Recreation	Stop Purpose Dining
Work	Outbound	1	No	0	0	1
Work	Outbound	1	Yes	0	0.5	0.5
Work	Outbound	2	Yes	0	0.5	0.5
Work	Outbound	3	Yes	0	0.5	0.5
Work	Inbound	1	No	0.142857	0.214286	0.642857
Work	Inbound	1	Yes	0.109589	0.232877	0.657534
Work	Inbound	2	Yes	0.055556	0.777778	0.166667
Work	Inbound	3	Yes	0	0.666667	0.333333
Recreation	Outbound	1	No	0	0	1
Recreation	Outbound	1	Yes	0	0.5	0.5
Recreation	Outbound	2	Yes	0	0.5	0.5
Recreation	Outbound	3	Yes	0	0.5	0.5
Recreation	Inbound	1	No	0	0.483051	0.516949
Recreation	Inbound	1	Yes	0	0.520599	0.479401
Recreation	Inbound	2	Yes	0	0.419355	0.580645
Recreation	Inbound	3	Yes	0	1	0
Dining	Outbound	1	No	0	0	1
Dining	Outbound	1	Yes	0	0.5	0.5
Dining	Outbound	2	Yes	0	0.5	0.5

Tour Purpose	Direction	Stop Number	Multiple Stops	Stop Purpose Work	Stop Purpose Recreation	Stop Purpose Dining
Dining	Outbound	3	Yes	0	0.5	0.5
Dining	Inbound	1	No	0	0.5	0.5
Dining	Inbound	1	Yes	0	0.5	0.5
Dining	Inbound	2	Yes	0	0.5	0.5
Dining	Inbound	3	Yes	0	0.5	0.5

9.7 Visitor Stop Location

The visitor stop location model was asserted, based on the discretionary purpose of the resident stop location choice model. See section 5.3 from the residential models. .

Table XX: Visitor Stop Location Choice Model

Utility Function Variables	Coefficients	T-stat
Size term	**1.0000**	
Mode Choice Logsum	2.1230	
Mode choice logsum, tour duration < 2 hours interaction	0.7960	
Mode choice logsum, tour duration> 8 hours interaction	-0.3170	
Distance Ratio		
Distance from origin > 1 mi. (binary), first on outbound leg	-0.7000	
Distance to primary destination > 1 mi. (binary), last on outbound leg	-0.8410	
Distance to primary destination over 1 (max. 3), last on outbound leg	-0.1940	
Distance to primary destination > 1 mi. (binary), first on return leg	-0.8600	
Distance from origin > 1 mi. (binary), last on return leg	-0.3660	
Distance to origin over 1 (max 3), last on return leg	-0.2690	

9.8 Visitor Trip Time of Day

The visitor stop time of day is chosen based on a distribution of observed stop durations from the survey. Distributions were prepared for stop duration for outbound and inbound stops, by purpose, and overall tour duration. See model input folder file *visitor_outboundStopDuration.csv* and *visitor_inboundStopDuration.csv* for full list of visitor stop time of day probabilities.

9.9 Visitor Trip Mode Choice

As with tour mode choice, the visitor trip mode choice model was asserted. It is based on the resident trip mode choice model, with the addition of a taxi mode.

The implemented visitor trip mode choice coefficients are listed in Table XX.

Table XX: Implemented Visitor Trip Mode Choice Coefficients

Coefficient Name	Value	Ratio (Coeff/IVT)
In-vehicle time coefficient	-0.0300	1.00
First wait time coefficient	-0.0457	1.52
Transfer wait time coefficient	-0.0457	1.52
Walk access time coefficient	-0.0457	1.52
Walk egress time coefficient	-0.0457	1.52
Walk auxiliary time coefficient	-0.0457	1.52
Walk mode time coefficient	-0.0536	1.79
Transfer penalty	-0.7200	24.00
Transfer penalty - PNR	c_ivt*15	15.00
Express bus IVT factor	0.9000	-30.00
BRT IVT factor	0.9000	-30.00
LRT IVT factor	0.8500	-28.33
Commuter rail IVT factor	0.7500	-25.00
Bike mode time coefficient	-0.0988	3.29
Cost coefficient for income < $30k	-0.0075	0.25
Cost coefficient for income $30k-$60k	-0.0033	0.11
Cost coefficient for income $60k - $100k	-0.0021	0.07
Cost coefficient for income > $100k	-0.0009	0.03
ASC - Line-haul mode		
WALK_EXP	0.3400	-11.33
WALK_BRT	0.3400	-11.33
WALK_LR	0.8100	-27.00
WALK_CR	0.9400	-31.33

10.0 External Model

The external travel models predict characteristics of all vehicle trips and selected transit trips crossing the San Diego County border.

10.1 External Model Definition of Trip Type

The external-external, external-internal, and internal-external trips in San Diego County were segmented into the following trip types:

- **US-US:** external-external trips whose production and attraction are both in the United States, but not in San Diego County
- **US-MX:** external-external trips with one trip end in the United States and the other in Mexico
- **US-SD:** external-internal trips with a production elsewhere in the United States and an attraction in San Diego County
- **MX-SD:** external-internal trips with a production in Mexico and an attraction in San Diego County (covered by the Mexican resident microsimulation model)
- **SD-US:** internal-external trips with a production in San Diego and an attraction elsewhere in the United States
- **SD-MX:** internal-external trips with a production in San Diego County and an attraction in Mexico

10.2 External Model Estimation of Trip Counts by Type

The total count of trips by production and attraction location was estimated in a series of steps:

1. The number of trips made by Mexican residents to attractions in San Diego was previously determined during development of the Mexican resident travel microsimulation model.
2. The trips in the resident travel survey were expanded to estimate the total number of trips made by San Diego residents to attractions in Mexico.
3. The number of MX-SD (1) and SD-MX (2) trips was subtracted from the total number of border-crossings to derive an estimate of the number of US-MX trips. The distribution of US-MX trips among external stations on the US-side of San Diego County will be assumed to be proportional to the total volume at each external station, regardless of the point of entry at the Mexican border.
4. The number of US-MX trips was then subtracted from the total number of trips in the SCAG cordon survey to arrive at an estimate of the combined total of US-US, US-SD, and SD-US trips with routes through San Diego County.
5. Finally, the actual amounts of US-US, US-SD, and SD-US trips at each external station were estimated from the remaining trips (4) according to their proportions in the successfully geocoded responses in the SCAG cordon survey.

10.3 External-External (EE) Trips

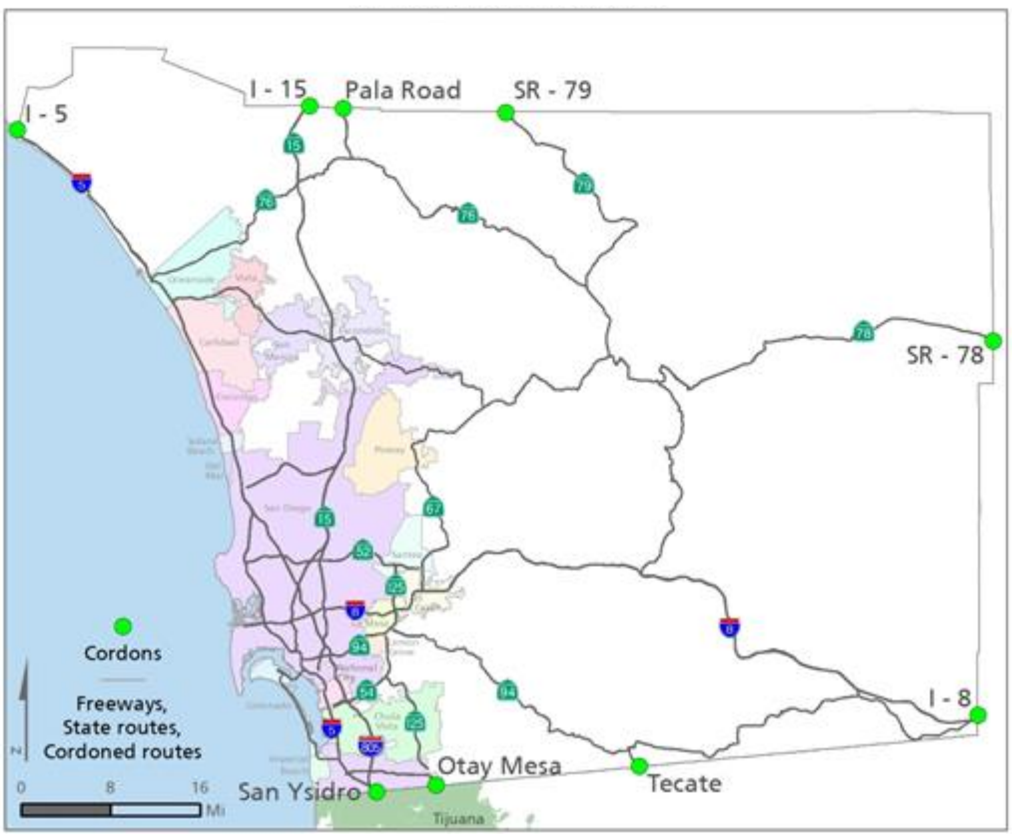
Number of Models:	1
Model Form:	Fixed Trip table

The EE trip matrix (covering US-US and US-MX trips) is estimated as described in the previous sections appears in Table 145.

Table 145: External-External Trip Matrix

Origin	San Ysidro	Otay Mesa	Tecate	I-8	CA-78	CA-79	Pala Road	I-15	I-5	Total
	Destination									
San Ysidro	-	-	-	167	17	25	37	1,563	1,527	3,336
Otay Mesa	-	-	-	42	4	6	9	396	387	844
Tecate	-	-	-	13	1	2	3	124	121	264
I-8	167	42	13	-	-	-	-	-	22	244
CA-78	17	4	1	-	-	-	-	-	-	22
CA-79	25	6	2	-	-	-	-	-	-	33
Pala Road	37	9	3	-	-	-	-	-	-	49
I-15	1,563	396	124	-	-	-	-	-	1,086	3,169
I-5	1,527	387	121	22	-	-	-	1,086	-	3,143
Total	**3,336**	**844**	**264**	**244**	**22**	**33**	**49**	**3,169**	**3,143**	**11,104**

Figure 43: San Diego County Cordons



10.4 US-SD External-Internal (EI) Trips

The US-SD External-Internal trip model covers vehicle trips with destinations in San Diego made by persons residing in other areas of the United States. Intermediate stops and transit trips are not modeled in this segment due to the small contribution of these events to the total demand in the segment.

The US-SD model accepts as an input the total number of work and non-work vehicle trips from the SCAG cordon survey at each external station (Table 146).

Table 146: US-SD Trips by Production Location

Production	Trips
I-5	28,820
I-15	33,661
Pala Rd	813
CA-79	543
I-8	3,413
CA-78	344
Total	**67,593**

10.5 External-Internal Destination Choice Model

The external-internal destination choice model distributes the EI trips to destinations within San Diego County which was estimated from the interregional survey. See Table 147 below.

Table 147: Estimated US-SD Destination Choice Utility Function

	Work		Non-Work	
Variable	Coef.	SE	Coef.	SE
Impedance				
Distance (miles)	-0.029	0.005	-0.006	0.004
Size Terms				
Households			1.000	
Constr., utilities, mfg., whsle., and transport emp.	1.000		1.069	0.487
Retail employment	1.364	1.045	4.001	1.245
Hotel, restaurant, and amusement employment	4.264	1.410	6.274	1.221
Service employment	0.781	0.388	0.901	0.388
Education employment	1.403	0.595	1.129	0.597
Health employment	1.779	0.739	2.754	0.817
Government employment	0.819	0.632	1.407	0.828
Religious, private hh., scrap, and other emp.	0.708	0.444	0.304	0.502

Diurnal and vehicle occupancy factors (Table 148 and Table 149) are then applied to the total daily trip tables to distribute the trips among shared ride modes and different times of day.

Table 148: US-SD Vehicle Occupancy Factors

Vehicle Occupancy	Percent
One	58%
Two	31%
Three or more	11%
Total	**100%**

Table 149: US-SD Diurnal Factors

	Work Percent		Non-Work Percent	
Time Period	P to A	A to P	P to A	A to P
Early AM	26%	8%	25%	12%
AM Peak	26%	7%	39%	11%
Midday	41%	41%	30%	37%
PM Peak	6%	42%	4%	38%
Evening	2%	2%	2%	2%
Total	**100%**	**100%**	**100%**	**100%**

10.6 External-Internal Toll Choice Model

The EI trips are then split among toll and non-toll paths according to a simplified toll choice model. The toll choice model uses the in-vehicle-time parameters and average value of time from the resident choice models for the corresponding income distribution found among trip-makers in the interregional survey. The toll alternative-specific constant in this utility function (Table 150) was calibrated to match the observed weekday average of 536 toll users on I-15 with transponders addressed to locations outside of San Diego County.

Table 150: Asserted US-SD Toll Choice Utility Function with Calibrated Constant Term

	Coefficient (Toll Alternative)	
Variable	Work	Non-Work
Time Savings (min.)	0.030	0.030
Toll amount (cents)	-0.002	-0.001
Constant	-3.390	-3.390

10.7 Internal-External (IE) Trips

This model covers both San Diego to the rest of the-US and San Diego to Mexico trips.

IE Trip Generation Model

A binary logit choice model for the making of an IE trip with persons as the decision-maker was estimated from the San Diego resident household survey (Table 7). The utility function for making an IE trip is based on demographic characteristics, household vehicle ownership, and the accessibility to external zones, defined by

$$Access_h = \sum_z IePct_z \times \exp\left(-0.047 \times Dist_{h,z}\right)$$

where h is the home zone, z ranges over external zones, $IePct_z$ is the percent of base-year IE trips that used the external station at zone z, and $Dist_{h,z}$ is the distance between the home and the external zone in miles. The constant was calibrated to match the share of persons (2.4%) making an IE trip in the survey.

Table 151: Internal-External Trip Generation Binary Logit Model

Variable	Coef. (make trip)
Access to external stations (Distance to Cordons Logsum)	1.368
HH Income > $60K	0.563
Age 25 to 64	0.693
Vehicles per household member	0.462
Constant	-2.025

IE Destination Choice Model

These IE trips are distributed to external stations with a destination choice model where the size variable is equal to the percent of IE trips using the external zone in the base year, and the distance coefficient of -0.047 utils per mile estimated in aggregate from the household survey using a gamma model with shape parameter 2.0.

Table 152: Internal-External Estimated Destination Choice Model

Variable	Coefficient
Distance	-0.047
Size variable- Attractiveness of the cordon (% of IE Trips using External Zone)	1.000

IE Mode Choice Model

After choosing an external station, the IE trip-maker chooses a mode according to an asserted nested logit mode choice model with constants calibrated to match the observed shares in the household survey (Table 153).

Table 153: Internal-External Trip Mode Choice Model

Parameter	Value
In-vehicle time coefficient	-0.030
First wait time coefficient	-0.045
Transfer wait time coefficient	-0.055
Walk access time coefficient	-0.052
Walk egress time coefficient	-0.052
Walk auxiliary time coefficient	-0.052
Drive access time coefficient	-0.045
Transfer penalty	-0.150
Express bus IVT factor	0.900
BRT IVT factor	0.900
LRT IVT factor	0.850
Commuter rail IVT factor	0.750
Walk mode time coefficient	-0.219
Bike mode time coefficient	-0.219
Bike logsum coefficient	0.2000
Cost coefficient for income < $30k	-0.007
Cost coefficient for income $30k-$60k	-0.003
Cost coefficient for income $60k - $100k	-0.002
Cost coefficient for income > $100k	-0.0008
Constant, Drive Alone	1.078
Constant, Shared Ride 3	0.299
Constant, Transit	3.171
Line Haul Constant, Express and BRT	0.300
Line Haul Constant, Light Rail	0.450
Line Haul Constant, Commuter Rail	0.600

Appendix: Sampling correction factors for choice probability and log-sum for the MNL choice model

This appendix describes the calculation of sampling factors used in destination choice estimation. It relies on the following notation:

$i \in C$	=	unique alternatives from the full set
$i \in D \subset C$	=	unique alternatives from the sample
$q(i)$	=	selection probability (probability to be drawn)
n_i	=	selection frequency in the sample
N	=	sample size
V_i	=	utility of a choice alternative
$P(i)$	=	choice probability

Note that the selection frequencies in the sample over unique alternatives are totaled to the sample size:

$$\sum_{i \in D} n_i = N .$$

However, the number of unique alternatives in the sample D can be any number between 1 and N inclusive.

The choice probability with sampling correction factors can be calculated by the following formula:

$$P(i) = \frac{\exp\left[V_i + \ln\left(\frac{n_i}{N \times q(i)}\right)\right]}{\sum_{j \in D} \exp\left[V_j + \ln\left(\frac{n_j}{N \times q(j)}\right)\right]} = \frac{\left(\frac{n_i}{N \times q(i)}\right) \times \exp(V_i)}{\sum_{j \in D}\left(\frac{n_i}{N \times q(j)}\right) \times \exp(V_j)} . \qquad \textbf{(1)}$$

Since N is a fixed number it can be cancelled out and the formula **(1)** can be equivalently rewritten in a simpler form:

$$P(i) = \frac{\exp\left[V_i + \ln\left(\frac{n_i}{q(i)}\right)\right]}{\sum_{j \in D} \exp\left[V_j + \ln\left(\frac{n_j}{q(j)}\right)\right]} = \frac{\left(\frac{n_i}{q(i)}\right) \times \exp(V_i)}{\sum_{j \in D}\left(\frac{n_i}{q(j)}\right) \times \exp(V_j)} . \qquad \textbf{(2)}$$

Formula (1) assumes a utility correction factor of $\ln\left(\frac{n_i}{N \times q(i)}\right)$, while formula (2) assumes a correction factor of $\ln\left(\frac{n_i}{q(i)}\right)$. Since both formulas yield the same probabilities, the simpler correction factor from formula (2) is normally applied in the choice context.

However, if a log-sum of this choice model is also applied in some upper level choice model, then this log-sum should be calculated as a denominator of the formula (2):

$$LS^1 = \ln\left\{\sum_{j \in D} \exp\left[V_j + \ln\left(\frac{n_j}{N \times q(j)}\right)\right]\right\} = \ln\left(\sum_{j \in D}\left(\frac{n_i}{N \times q(j)}\right) \times \exp(V_j)\right). \qquad \textbf{(3)}$$

If formula (2) was applied for the choice probability correction, then the log-sum takes the following form:

$$LS^2 = \ln\left\{\sum_{j\in D}\exp\left[V_j + \ln\left(\frac{n_j}{q(j)}\right)\right]\right\} = \ln\left(\sum_{j\in D}\left(\frac{n_i}{q(j)}\right)\times\exp(V_j)\right). \qquad \textbf{(4)}$$

Then the log-sum (4) calculated based on the formula (2) should be scaled in order to replicate the value of (3) based on the formula (1):

$$LS^2 = LS^1 - \ln N. \qquad \textbf{(5)}$$

Thus, there are two ways to implement corrections in both the choice model and log-sum calculations:

1. Use formula (1) for utility correction factors and use the log-sum directly from the denominator of the formula (1)
2. Use formula (2) for utility correction factors and then scale the log-sum from the denominator by formula (5)

If we assume that all selection frequencies are equal to one ($n_j = 1$) and all selection probabilities are equal ($q(j) = q = \frac{1}{R}$, where R is the size if the full set) the formula (3) can be simplified:

$$LS^1 = \ln\left(\sum_{j\in D}\left(\frac{R}{N}\right)\times\exp(V_j)\right) = \ln\left(\sum_{j\in D}\exp(V_j)\right) + \ln\left(\frac{R}{N}\right) \qquad \textbf{(6)}$$

This formula can be applied for simple model estimation when the original log-sum was calculated without correction factors and sampling was random without replacement. In this case the log-sum just has to be expanded by a factor equal to the full set size divided by the sample size.