CSTDM09 – California Statewide Travel Demand Model

Model Development

Short Distance Personal Travel Model: Part 2 of 3

Final System Documentation: Technical Note

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1. Introduction

This technical note is Part 2 of a series of 3 Technical Notes that describe the Short Distance Personal Travel Model (SDPTM) component of the California Statewide Travel Demand Model (CSTDM). The documentation is split into 3 parts to keep individual document and computer file size to a manageable level. Together they describe the complete model features, calibration and implementation. The original estimations of the models are mainly described in separate Technical Notes.

Technical Note Part 1 contains details of:

- Model Overview;
- Long Term Decision Models:
    - Person Driving License Models;
    - Household Auto Ownership Models;
    - Person Work Location Models;
        - "Simplified" Work Tour Mode Choice Models;
    - Person School Location Models;
        - "Simplified" School Tour Mode Choice Models;
- Calibration of Long Term Decision Models.

Technical Note Part 2 (this document) contains details of:

- Day Pattern Choice Models
- Main Tour Mode Models:
    - Work Tour Mode Models;
    - School Tour Mode Models;
    - "Other" Tour Mode Models.
- Calibration of Day Pattern and Main Tour Mode Models.

Technical Note Part 3 contains details of:

- Primary Destination Choice Models for “Other” Tours
- Sub-Tour Mode Choice Models;
- Secondary Destination Choice Models;
- Trip Mode Choice Models;
- Calibration of Primary and Secondary Destination / Sub-Tour and Trip Mode Choice Models;
- Implementation in CSTDM Model Framework.

2. Day Pattern Choice Models

The day pattern model selects a day pattern for each modeled person, based on the observed data for each person type. The probabilities of selection will be based on the weights in the expanded combined statewide survey data set. The time of day for trips will be assigned based on, and as a specific part of, the selected day pattern, and will be limited to the time period, without further detail, i.e. trips assigned to the AM peak period (6 AM to 10 AM) will NOT be allocated exact start times to the minute e.g. 08:43 AM.

The day patterns are assigned based upon the person type; each person from the synthetic population is assigned a day pattern observed in the surveys for a person of a similar "type". The initial division of the survey records produced 7 basic person types. The basic person types are shown in the exhibit below; a small number of surveys were dropped during the following analysis for various reasons.

Surveys of people, who were both students and workers, were assigned based on the more important activity, with ties going to school. In other words, full-time students were assigned as student types regardless of their work status; part-time students were assigned as to student person types unless they were full-time workers.

Table 1: Basic Person Types

Basic Type	Definition	Surveys	Expanded	Groups
Preschooler	Not a K12 Student AND <18 Years	4460	1,910K	6
Grade School Student	Student in K12 education	13852	5,817K	17
Post Secondary Student	Student in post secondary education	4533	1,790K	7
Full-time Worker	Works 30 hours+ per week	32237	9,964K	37
Part-time Worker	Works < 30 hours per week	4262	1,400K	6
Adult Other	<65 years not a Worker or Student	10377	3,730K	17
Senior (65+)	65+ years not a Worker or FT Student	8571	2,580K	13

The person types were broken down further, after an analysis of the available data, based on both household and personal characteristics. This analysis considered a number of dimensions for each group; they were not all considered promising, and only some results are presented here. In general, groups were devised with three goals in mind:

- Maximize homogeneity within groups with regards to travel patterns (including amount and purpose of trips and tours)
- Maximize heterogeneity between groups with regards to travel patterns
- Divide groups along logical and consistent categories (e.g. income <$50K, rather than combining income <$25K with $75-100K)
- Retain 400 or more day patterns per group, to provide sufficient variety

The remainder of this document describes the 103 resulting groups. Activities are grouped in different ways; unless activities are specifically listed, "mandatory" are work and school, "maintenance" are shop, personal business and escort and "discretionary" are eat, social and recreation activities.

It should be noted that the tables and figures of this document describe travel both in terms of the average number of trips per person as well as the average number of out-of-home activities per person. Because there is at minimum one more trip than out of home activity (for instance, the given day-pattern of a person from home to work, work

to shop and shop to home has two out-of-home activities and three trips), the number of activities and trips will not be the same. Because of the variable numbers of tours (for instance, the above day could also have been home to work to home, then home to shop to home and have four trips for the same two activities), these two measures will not have a consistent ratio across all person types. The number of trips is important to determine the gross amount of travel on the network, while the kinds of activities are important from a behavioral perspective, as well as being important for destination and mode choice.

2.1 Preschoolers

Preschoolers are defined as children (under 18) who do not go to kindergarten or grade school. While this technically includes a broad range of ages, because of near-universal school attendance, 92% of this group is under 6 years of age. The survey data source conflated daycare and preschool, which is inconsistent with the PUMS reporting of preschool enrollment, but not daycare. Because of this, the youth other definition must include these preschool and daycare students. The "school" activity shown in the figures includes daycare and preschool.

The major elements with an effect on the behavior of this group are the age of the person, as well as the household income level and "available adults", that is, the presence of an adult who can take care of the child; for these purposes, that is defined as the presence of an Adult Other or Senior in the household.

Due to the limited set of data available, preschoolers could not be divided using all three dimensions. Income is an important equity variable, and the household composition is something that may change based upon demographic and socioeconomic trends; a future scenario with much higher employment rates, for instance, would cause a shift from households with available adults to households without. Because the age is policy insensitive (and, unlike the aging of the senior population, the distribution of 0-5 year

olds is not expected to change much), this category was dropped as an explanatory variable.

The resulting grouping includes a single low-income group, with the remainder of the observations divided into those in households with an available adult and those without. These were then divided into three income categories. The resulting groupings are described below.

Table 2: Preschool Groups

Group name	Available adult	HH Income	Surveys	Trips/person
YO_Lo	n/a	<$25K	816	1.45
YO_NA_MLo	No	$25-50K	497	1.93
YO_A_ MLo	Yes	$25-50K	672	1.73
YO_NA_MHi	No	$50-100K	735	2.19
YO_A_ MHi	Yes	$50-100K	882	2.81
YO_NA_ Hi	No	$100K+	420	2.17
YO_A_ Hi	Yes	$100K+	438	2.99

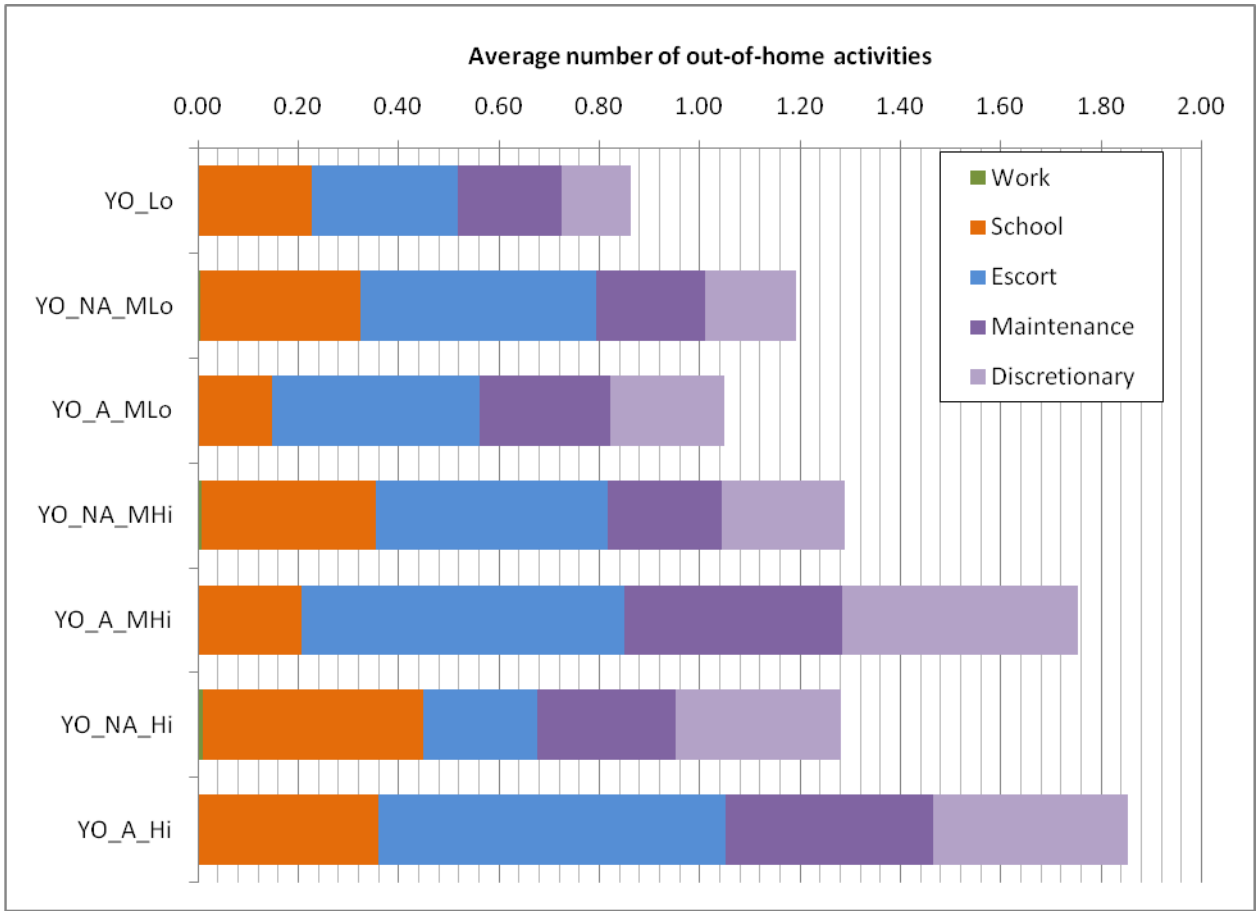

Figure 1: Preschool Activities

2.2 Grade School Students

Grade school students are the children attending school, from kindergarten up to grade 12.

The first group that suggested itself was a grouping of students who have jobs. There were enough observations to produce a single group of these people, who are mostly 16 and older, and who are by far the most frequent performers of work activities.

The second group that was clear was grade school students with driver's licenses. These students had a much higher amount of travel as compared with students of similar age and income level. This population was divided into lower and higher income groups, although the groups had small sample size.

The third special group was grade school students in households without Autos. There were enough observations here to produce a single group, with greatly reduced travel characteristics. While this group is not split by income, in practice, 80% of the group has a household income under $25K (and 32% under $10K).

The remaining surveys were analyzed in a number of dimensions. Gender was tested, as was the distribution of children (a combination of the number of children under 5 and the number of children 6-15), but neither had any clear effect on travel. Age was not as strong a factor as was seen with the preschool population, but there was a small break around 10-11 years of age, with younger students having more escort activity and older students having more school activity. This corresponds roughly to the elementary / middle school break.

The remainder of the grouping was similar to the youth other division. For each age bracket, the population was divided based on income, with the higher income levels being further divided by the presence of an available adult in the household.

The presence of an available adult is less important than seen in the youth other division, but is nevertheless useful.

The division of the grade school population is described in the table and figure below.

Table 3: Grade School Groups

Group Name	HH Income	Age	Available Adult	Surveys	Trips / person
GS_Work	All observations where student also works			549	3.66
GS_Lic_Lo	<$75K	All observations where student has driver's license		364	2.91
GS_Lic_Hi	>$75K			413	3.48
GS_NoCar	All observations where household has no Autos			417	2.09
GS_10_Lo	<$25K	<11	n/a	906	2.31
GS_10_NA_MLo	$25-50K	<11	No	774	2.72
GS_10_A_MLo	$25-50K	<11	Yes	810	2.50
GS_10_NA_MHi	$50-100K	<11	No	1249	2.98
GS_10_A_MHi	$50-100K	<11	Yes	1106	2.91
GS_10_NA_Hi	$100K+	<11	No	674	2.87
GS_10_A_Hi	$100K+	<11	Yes	562	3.38
GS_11+_Lo	<$25K	11+	n/a	924	2.27
GS_11+_NA_MLo	$25-50K	11+	No	801	2.60
GS_11+_A_MLo	$25-50K	11+	Yes	737	2.41
GS_11+_NA_MHi	$50-100K	11+	No	1392	2.78
GS_11+_A_MHi	$50-100K	11+	Yes	933	2.79
GS_11+_NA_Hi	$100K+	11+	No	728	2.86
GS_11+_A_Hi	$100K+	11+	Yes	513	3.16

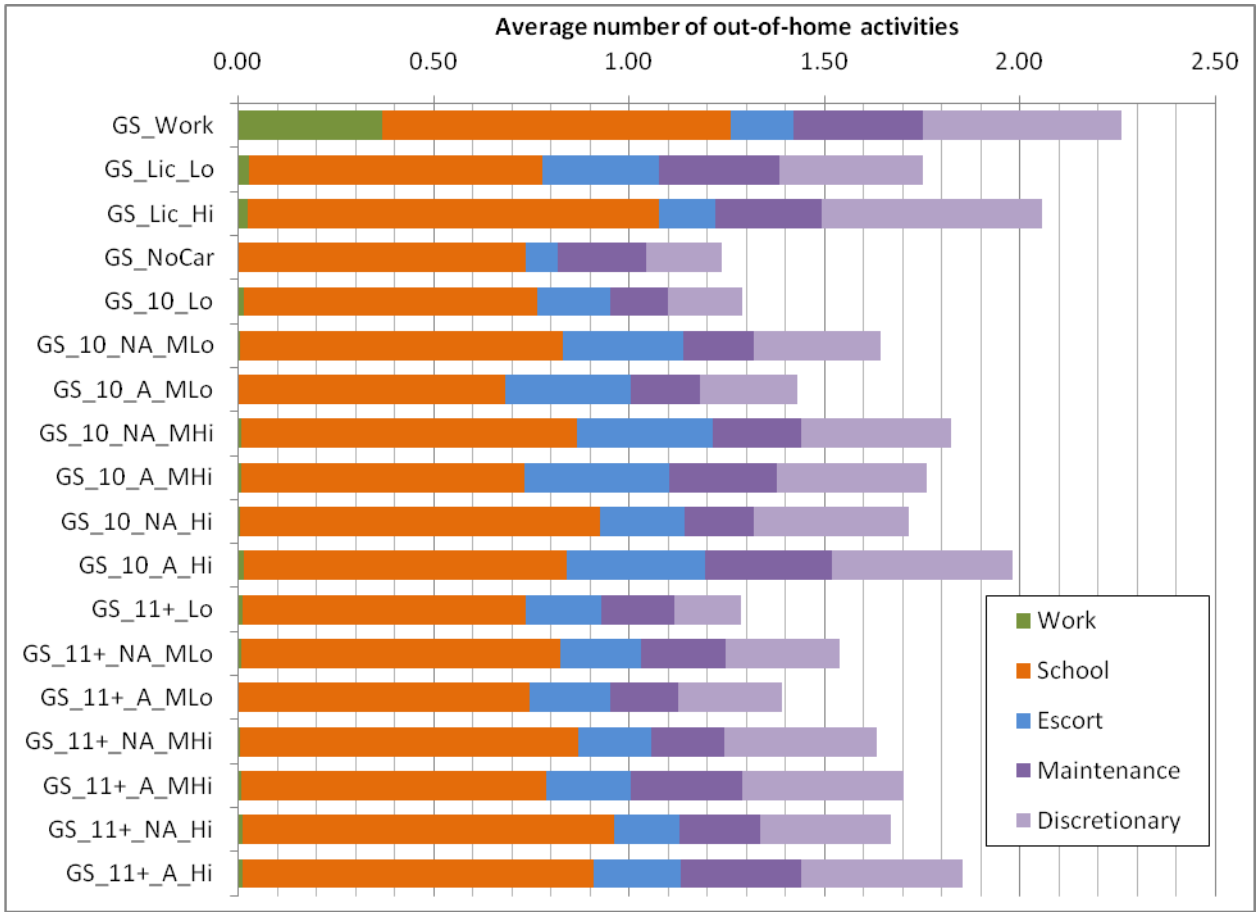

Figure 2: Grade School Activities

2.3 Post-secondary Students

Post-secondary students are defined on the basis of the type of education they are undertaking; post-secondary education includes universities, colleges, community colleges, technical and vocational schools. The bulk of these students are 18-29 years old. By definition, this group includes everybody who studies at the post-secondary level and also works, with the exception of full-time workers who study part-time.

The first clear criterion for dividing post-secondary students is work status. It may be expected, full-time workers have more work activities than part-time workers, whereas non-working students have very few, but tend to have more school activities. The division between full and part-time studies is also illuminating, but sadly PUMS does not support this, reporting only enrollment, not level of enrollment.

This division creates three groups, each with significant differences in the frequency of school and work travel. A number of different dimensions were investigated to determine the most appropriate breakdown of these three groups of full-time students. Income had little significance – post-secondary students can be living with parents or with a spouse who provides income to the household. While there was significant value in grouping by household composition (alone, with "parents" (someone 16+ years older), with children, or with peers), this produced several groups that were too small to use and difficult to reasonably combine with other groups. Age had a similar impact to household composition, but could be used to provide groups with sufficient samples.Ultimately, post-secondary students were divided into 7 groups, as per the table below.

Table 4: Post-secondary Student Groups

Group Name	Work status	Age range	Surveys	Trips / person
PS_F_17_29	Full-time	17-29	518	3.36
PS_F_30+	Full-time	30+	425	3.70
PS_P_17_22	Part-time	17-22	657	3.72
PS_P_23+	Part-time	23+	778	3.99
PS_N_17_22	None	17-22	779	2.83
PS_N_23_29	None	23-29	458	3.43
PS_N_30+	None	30+	918	4.04

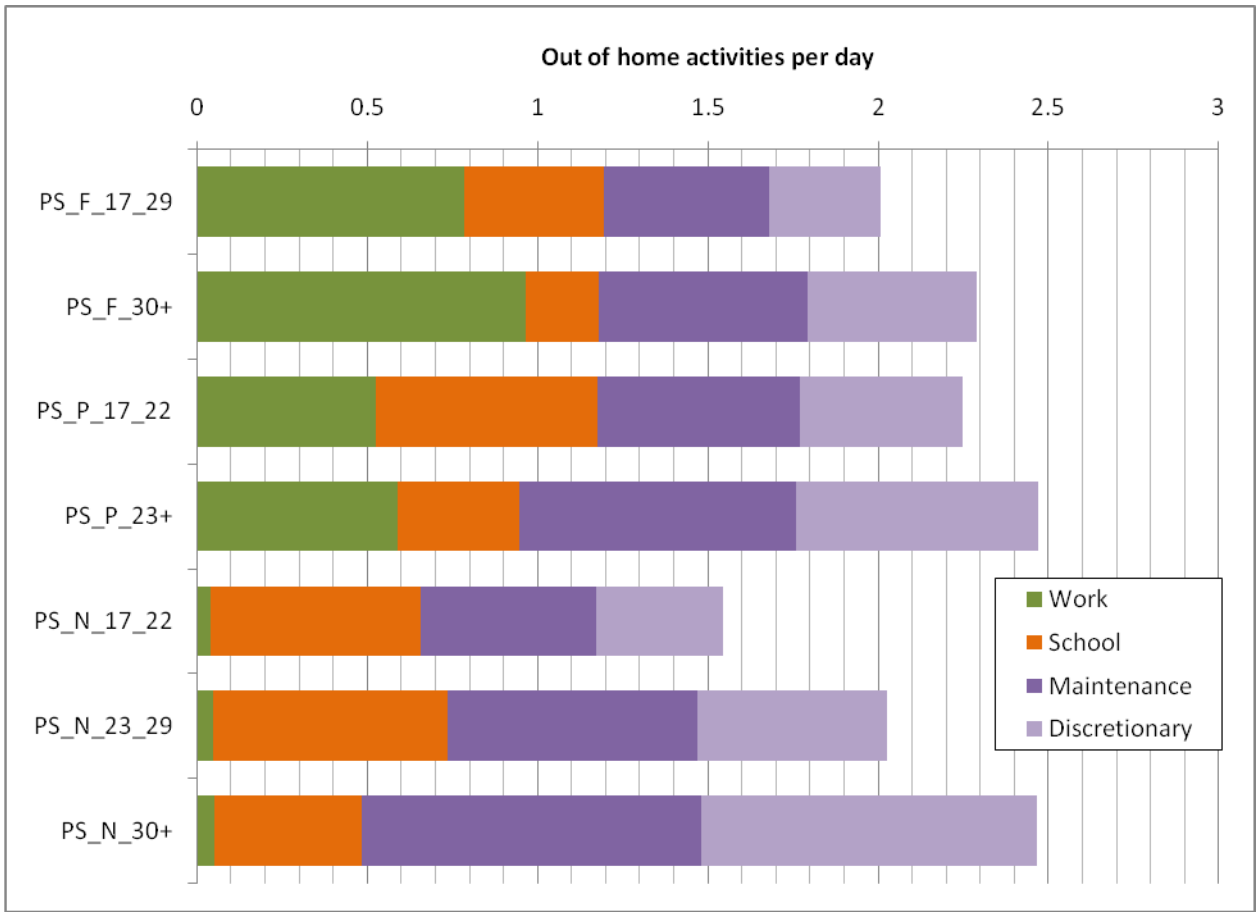

Figure 3: Post-secondary Student Activities

2.4 Full-Time Workers

Full-time workers work at least 30 hours per week and attend school part-time or not at all; they are by far the largest group, and the relatively long distance of the work trip makes them particularly important. This group includes full-time workers who are part-time students, although the data reveals that this population has a low level of school activity; these students have an average of 3 school activities per month, or 0.15 per day. This low level of school activity indicates that these are primarily occasional classes, such as a weekly cooking class, rather than a concerted effort. Full-time workers who study part-time are therefore considered as part of the full-time worker population with no further distinction.

Breaking the remainder into workers with and without children was the first obvious step. Households with children have a higher trip production rate, and in particular have a higher incidence of escort activities. The large number of observations (and hence groups), workers in households with children will be considered first, with results presented, followed by workers in households without children. Children were defined as 0-15 year olds for this work.

Of workers with children, single parents had a radically higher trip rate -- controlling for income, 35-55% more than more nuclear families, with single parents earning under $25K travelling more than nuclear parents earning over $150K. Unfortunately, the lack of data (611 observations) meant that single parents could not be subdivided by income.

Income was the most important determinant of travel production, with high income households producing more travel. There did seem to be a small drop in travel for the highest income households (over $150K) -- this may be due to the influence of domestic workers, such as nannies, taking over travel that the household members would otherwise do. Due to limited observations, these households tended to be merged with households in the penultimate income group.

The age of the child had a role primarily for the youngest children; a reduction in travel was seen most strongly for households where the youngest child was 0-3. This pattern was also seen for Adult Others. These households with young children were split off and divided into three groups by income.

For households where the children were 4+, the gender of the worker had a significant role; women travelled more, and had more maintenance and escort purpose activities, while men had more work activities. Except the lowest income category (where travel was suppressed across genders and household makeups), the day patterns were divided by gender.

The household makeup had a significant impact in these households, as well. A number of variables were tried, but the best explanatory power (and sample size division) was based on the number of children; 1 or 2+ children under 16, with the households with more children producing more escort activities, for both male and female workers. Higher income households, where there were more observations, were divided along these lines.

The grouping of full-time workers with children into a total of 14 groups is shown below:

Table 5: Full-time Worker with Children Groups

Group name	Children	Gender	Income	Surveys	Trips/person
WFT_SingleParent	All obs. where size = (# children + 1)			684	4.59
WFT_K_A_Lo	Youngest 0-3	n/a	<$35K	536	2.59
WFT_K_A_Med	Youngest 0-3	n/a	$35-75K	925	3.12
WFT_K_A_Hi	Youngest 0-3	n/a	$75K+	1088	3.62
WFT_K_B_Lo	Over 3 years old	n/a	<$25K	635	2.92
WFT_K_B_M_MLo	Over 3 years old	Male	$25-50K	1040	3.31
WFT_K_B_M_MHi_1	1, over 3	Male	$50-100K	1015	3.52
WFT_K_B_M_MHi_2+	2+, all over 3	Male	$50-100K	1169	3.81
WFT_K_B_M_Hi_1	1, over 3	Male	$100K+	586	3.45
WFT_K_B_M_Hi_2+	2+, all over 3	Male	$100K+	702	3.94
WFT_K_B_F_Med_1	1, over 3	Female	$25-75K	661	3.70
WFT_K_B_F_Med_2+	2+, all over 3	Female	$25-75K	684	4.08
WFT_K_B_F_Hi_1	1, over 3	Female	$75K+	707	3.76
WFT_K_B_F_Hi_2+	2+, all over 3	Female	$75K+	654	4.49

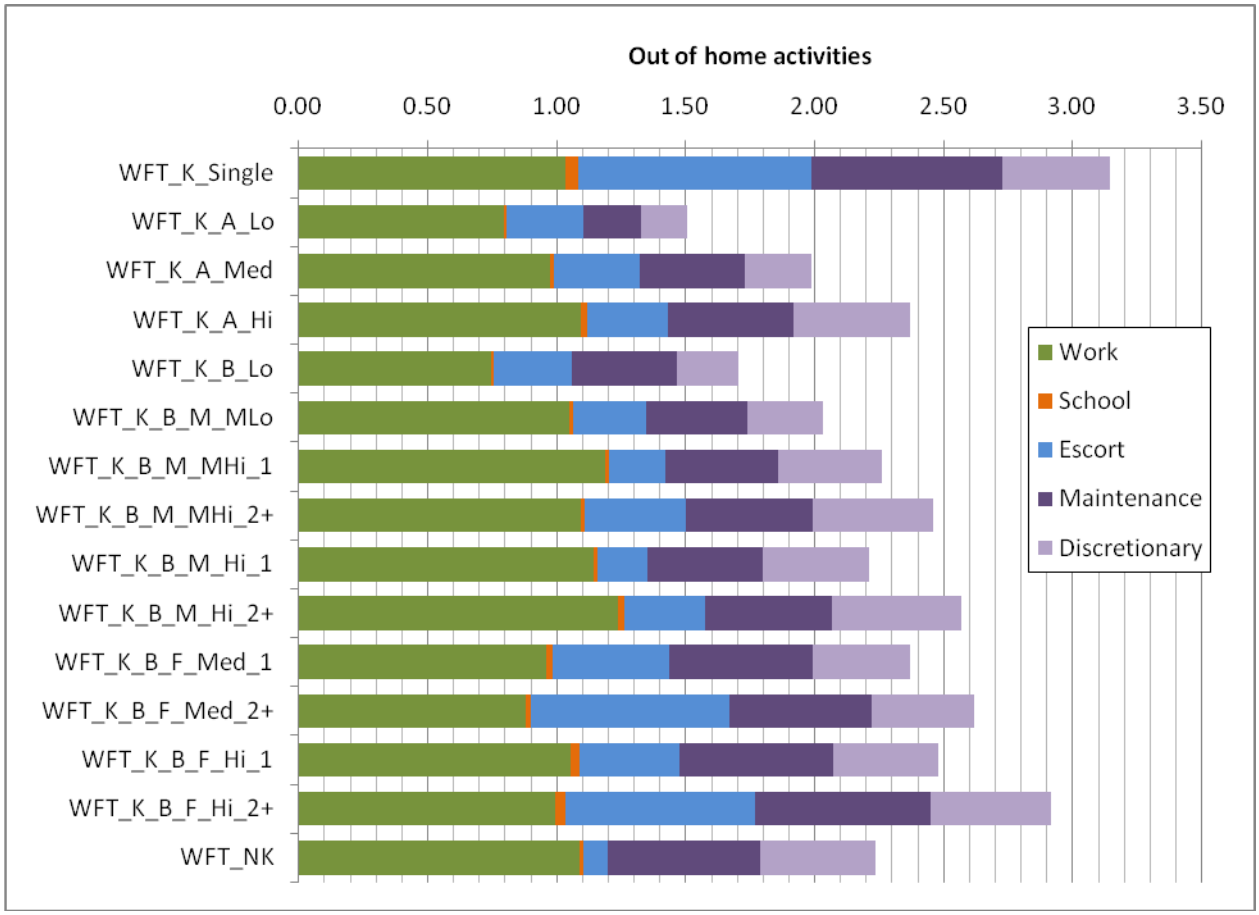

Figure 4: Full-time Worker with Children Activities

Full-time workers in households without children proved relatively homogeneous in a number of dimensions, despite the large set of samples available. Dimensions for analysis included household size, number of workers, income, worker age, occupation, dwelling unit type, and auto ownership. Two interesting subpopulations revealed themselves, however. The first was workers in households without Autos. These workers, who are mostly low income, had significantly reduced travel even controlling for their economic status. The other, which had less overlap than may have been expected, were workers without driver's licenses. These two populations with very low levels of travel were divided into two groups by income; both were slightly below the goal of 500 observations.

Of the remaining population of workers, those in blue collar occupations (SOC codes 45-53; production, construction, maintenance, and transportation occupations) had lower travel per person controlling for other factors. While the data set used for analysis did not directly support temporal analysis, other data sources such as the American Time Use Study indicate that blue collar workers also have different activity patterns in terms of time of day use -- in particular, working overnight or shifted hours and the resulting changes in time use elsewhere (e.g. shopping typically done in the evening moving to during the day). These blue collar workers were divided into those living alone and those who lived with someone else; the latter group was further subdivided by income.

Once these groups were removed, there was still a very large number of surveys remaining; over 17,000. This remaining full-time worker population was subdivided in two dimensions; one was the household makeup, with four possible groups -- single workers (one worker household), 2-1 (two person, one worker household), 2-2 (two person, two worker household) and 3 (3+ person household). Single workers had much higher rates of travel than the other groups, but controlling for the household size and number of workers also helps normalize income -- a $60K annual income implies different things in households with one versus 2+ workers, and permits different spending for a single person versus 3 or more people. These groups were subdivided by income into as many as six income levels.

The resulting 23 groups of full-time workers without children are summarized in the table below.

Table 6: Full-time Worker without Children Groups

Group name	HH size	# of workers	Occupation	Income	Surveys	Trips/person
WFT_NK_Nondriver_Lo	All HH with no vehicles and/or workers without licenses			<$35K	438	2.29
WFT_NK_Nondriver_Hi				$35K+	425	2.67
WFT_NK_Blue_Single	1	1	Blue collar	n/a	505	3.34
WFT_NK_Blue_Lo	2+	n/a	Blue collar	<$75K	1391	3.03
WFT_NK_Blue_Hi	2+	n/a	Blue collar	$75K+	606	3.09
WFT_NK_Single_Lo	1	1	Other	<$35K	944	3.78
WFT_NK_Single_MLo	1	1	Other	$35-50K	925	3.65
WFT_NK_Single_Med	1	1	Other	$50-75K	1184	3.80
WFT_NK_Single_Hi	1	1	Other	$75K+	983	4.02
WFT_NK_2-1_Lo	2	1	Other	<$50K	690	3.05
WFT_NK_2-1_Med	2	1	Other	$50-100K	1005	3.34
WFT_NK_2-1_Hi	2	1	Other	$100K+	502	3.46
WFT_NK_2-2_Lo	2	2	Other	<$35K	500	3.49
WFT_NK_2-2_MLo	2	2	Other	$35-50K	711	3.28
WFT_NK_2-2_Med	2	2	Other	$50-75K	1663	3.32
WFT_NK_2-2_MHi	2	2	Other	$75-100K	1806	3.45
WFT_NK_2-2_Hi	2	2	Other	$100-150K	1971	3.69
WFT_NK_2-2_VHi	2	2	Other	$150K+	1015	3.55
WFT_NK_3+_Lo	3+	n/a	Other	<$50K	691	3.04
WFT_NK_3+_Med	3+	n/a	Other	$50-75K	929	3.06
WFT_NK_3+_MHi	3+	n/a	Other	$75-100K	915	3.28
WFT_NK_3+_Hi	3+	n/a	Other	$100-150K	827	3.47
WFT_NK_3+_VHi	3+	n/a	Other	$150K+	469	3.72

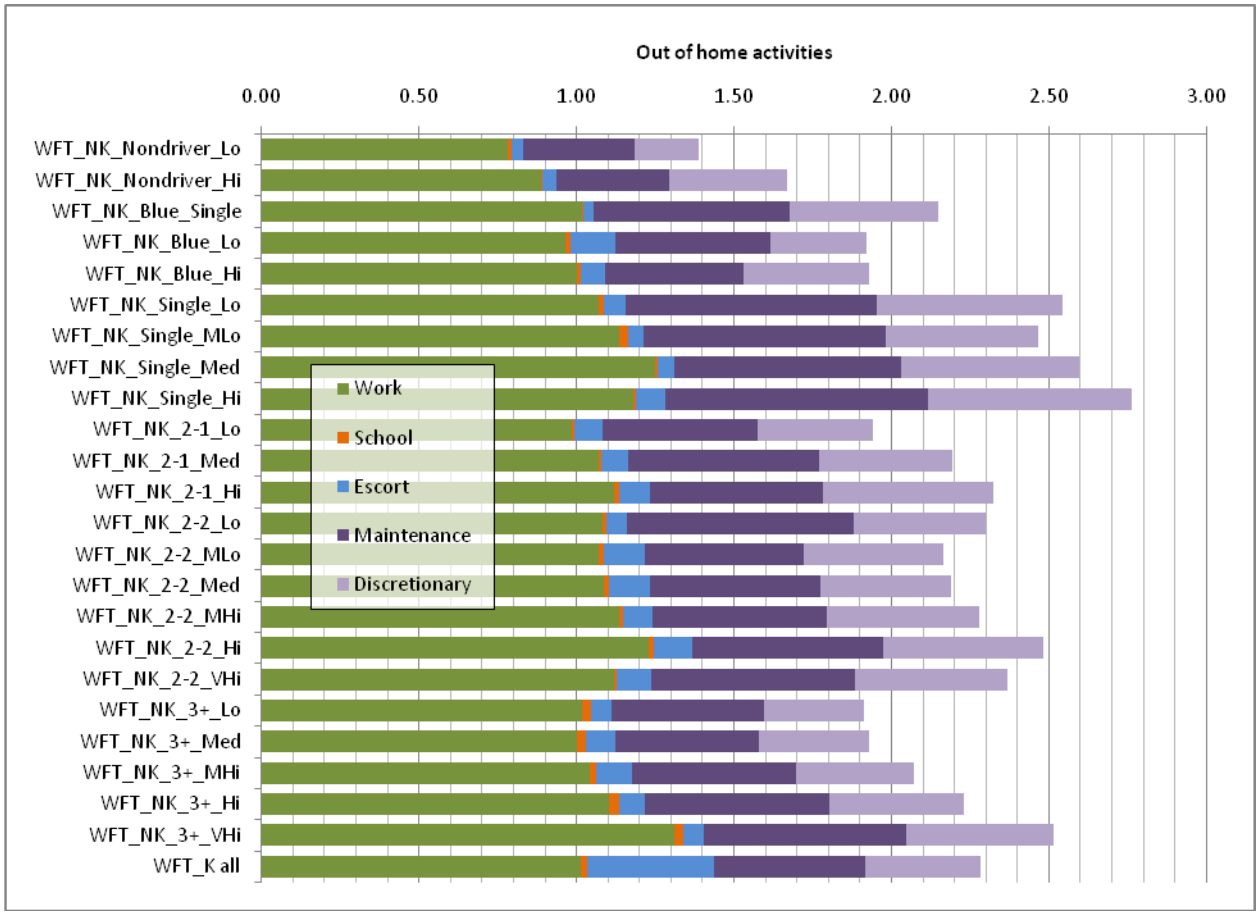

Figure 5: Full-time Worker without Children Activities

2.5 Part-time Workers

Part-time workers are those who work fewer than 30 hours a week and do not attend school. This is a relatively small group, compared with full-time workers, so the breakdown is necessarily coarse.

One key dimension for dividing this group was the presence of children; part-time workers with children make significantly more trips than those without -- with the bulk of the increase for additional escort travel. This is consistent with part-time workers having a household role similar to the Adult Others discussed in the next section. The impact of having children was more significant for women than for men; however, the men with children did behave differently than their childfree counterparts. Because of the limited

set of observations of men with children, all part-time workers with children were combined.

The other dimension used was the household income; as seen elsewhere, lower income households have persons who travel less. In the lowest income group (<$25K), the presence of children had a smaller effect than in higher income groups, so the observations were combined for this group to increase the size of the sample. Part-time workers in households earning over $25K were divided into income groups; three for those without children, and two for those with.

The six groups for part-time workers are summarized in the table below.

Table 7: Part-time Worker Groups

Name	Income	Children	Observations	Trips/person
WPT_Lo	<$25K	n/a	617	3.32
WPT_MedLo	$25-50K	No	692	3.45
WPT_MedHi	$50-75K	No	568	3.76
WPT_Hi	$75K+	No	922	3.98
WPT_K_Med	$25-75K	Yes	758	4.30
WPT_K_Hi	$75K+	Yes	679	5.44

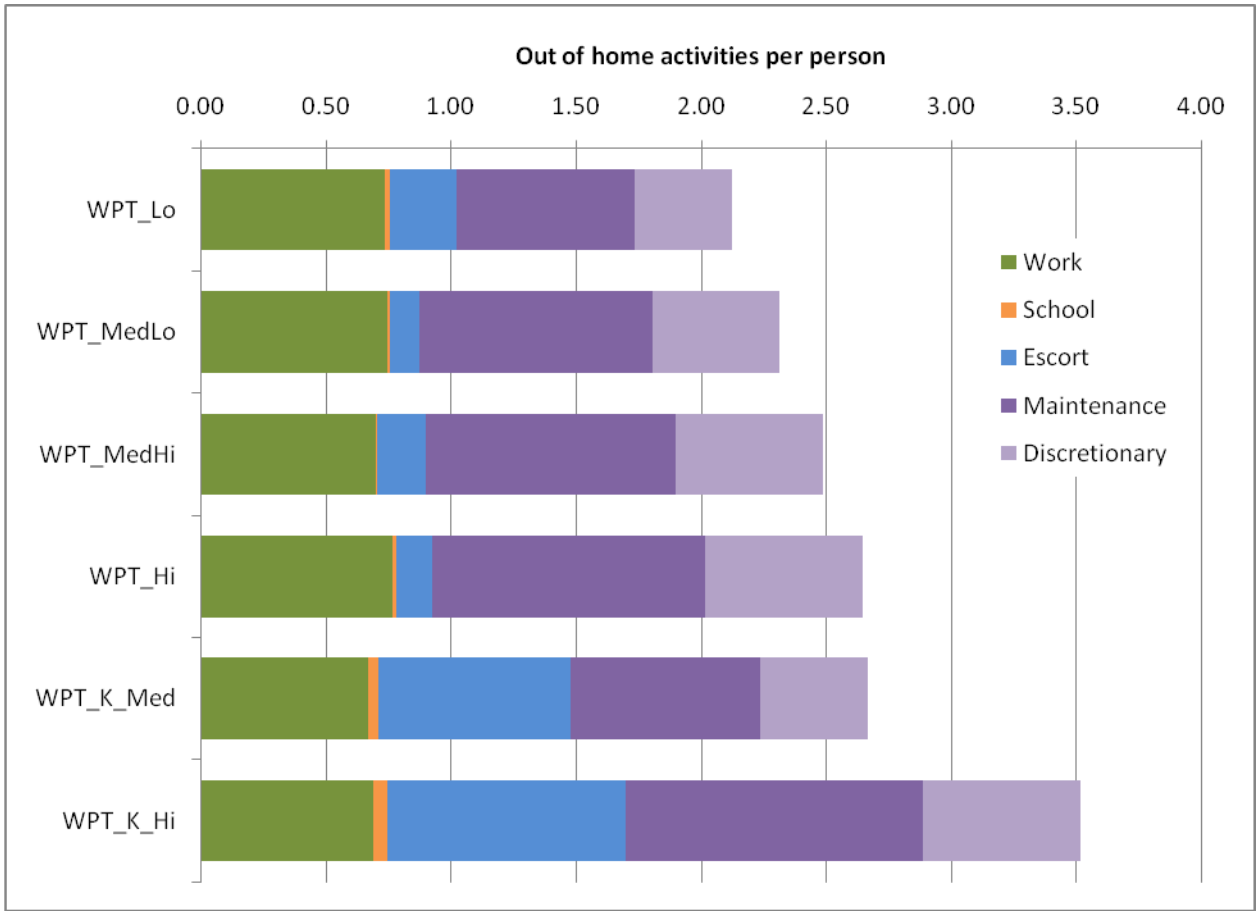

Figure 6: Part-time Worker Activities

2.6 Adult Others

Adult Others are the "leftover" group of adults 18-64 who are neither workers nor students. This group includes stay-at-home parents, homemakers, the unemployed and the early retired.

The first dimension used to split this group was the presence of children (defined here as 15 or younger) in the household. Adult others in households with children made a third more trips than those without, and had four times the frequency of escort activities outside of the home. With this clear break, the two groups (with and without children) were further subdivided.

Adult others with children were examined on multiple fronts. The age of the youngest child mostly appeared to have an impact in the case of children roughly 0-3 years old; once children were of pre-school or kindergarten age, the adult others seemed to have similar behavior. Household size and the age of the adult themselves had limited explanatory power in general. There were too few single parents -- who did appear to have different travel characteristics -- to form a group of them. Income was, as is commonly seen, a significant factor. The number of children also had significant explanatory power. Adult others with children were divided into those with a child under 4, those with one child 4-15, and those with two or more aged 4-15. These three groups were all divided by income into a lower and higher group, with the largest (2+ kids 4-15) divided into three.

Adult others without children are a little more difficult to categorize; however, there are several clear trends; travel increases with higher income, smaller households and older persons. The first two are relatively common; the third indicates the role of highly active early retirees. Adult others without children were divided by household size; one person and three or more person households were split into a lower and a higher income category. Adult others in two person households, the majority, were divided both by income, but with early retirees (55+ year olds) separated from younger adult others.A total of 17 groups for Adult Others were defined, as in the table below.

Table 8: Adult "Other" Groups

Name	Kids	Income	HH Size	Age	Surveys	Trips / person
AO_K_A_Lo	0-3 YO	<$50K	n/a	n/a	627	2.06
AO_K_A_Hi	0-3 YO	$50K+	n/a	n/a	564	3.80
AO_K_B1_Lo	1 kid 4+	<$50K	n/a	n/a	580	2.76
AO_K_B1_Hi	1 kid 4+	$50K+	n/a	n/a	522	3.87
AO_K_B2_Lo	2 kids 4+	<$35K	n/a	n/a	617	3.21
AO_K_B2_Med	2 kids 4+	$35-75K	n/a	n/a	456	4.76
AO_K_B2_Hi	2 kids 4+	$75K+	n/a	n/a	445	5.73
AO_N_1_Lo	none	<$25K	1 person	n/a	595	2.76

AO_N_1_Hi	none	$25K+	1 person	n/a	592	3.45
AO_N_2_Lo	none	<$25K	2 person	n/a	700	2.04
AO_N_2_Med_U55	none	$25-75K	2 person	<55	817	2.38
AO_N_2_Hi_U55	none	$75K+	2 person	<55	495	3.18
AO_N_2_MLo_55+	none	$25-50K	2 person	55+	576	3.02
AO_N_2_MHi_55+	none	$50-75K	2 person	55+	534	3.29
AO_N_2_Hi_55+	none	$75K+	2 person	55+	710	3.47
AO_N_3_Lo	none	<$50K	3+ person	n/a	740	1.95
AO_N_3_Hi	none	$50K+	3+ person	n/a	807	2.39

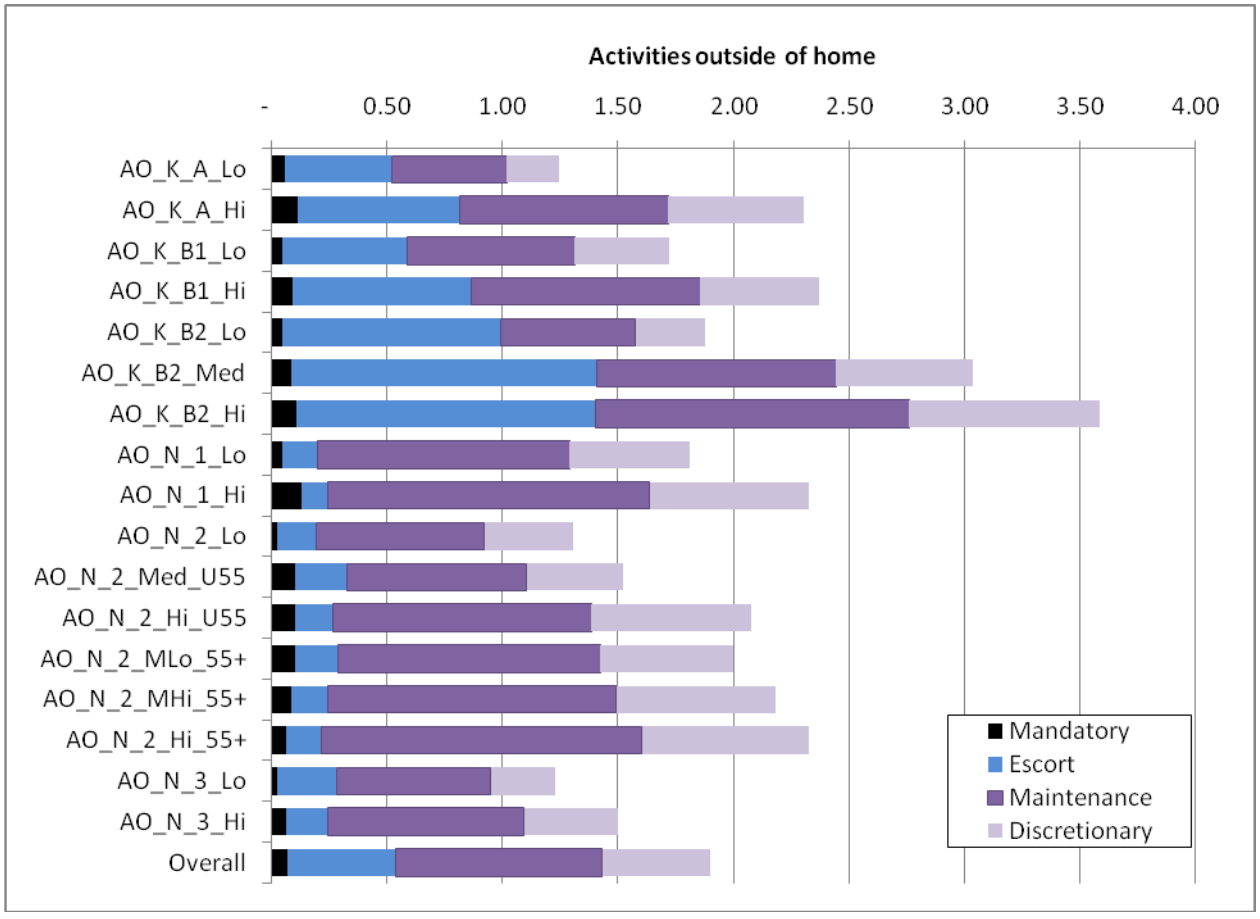

Figure 7: Adult "Other" Activities

2.7 Seniors

Seniors are defined as persons over 65 who do not work, and who do not go to school full-time. (Part-time students over 65 are included in this group; most of these cases were felt to be seniors taking a class or two as a pastime.) Because of this criterion, seniors tended to travel for similar purposes regardless of age, household size or income; 34% of out-of-home stops were for shop, 27% were for personal business, and 39% were for other purposes.

The first key dividing criteria for groups of seniors was age; as seen in the figure below, travel is relatively high for seniors in the first years of retirement, with a decline in travel visible from the early 70s and increasing after 80.

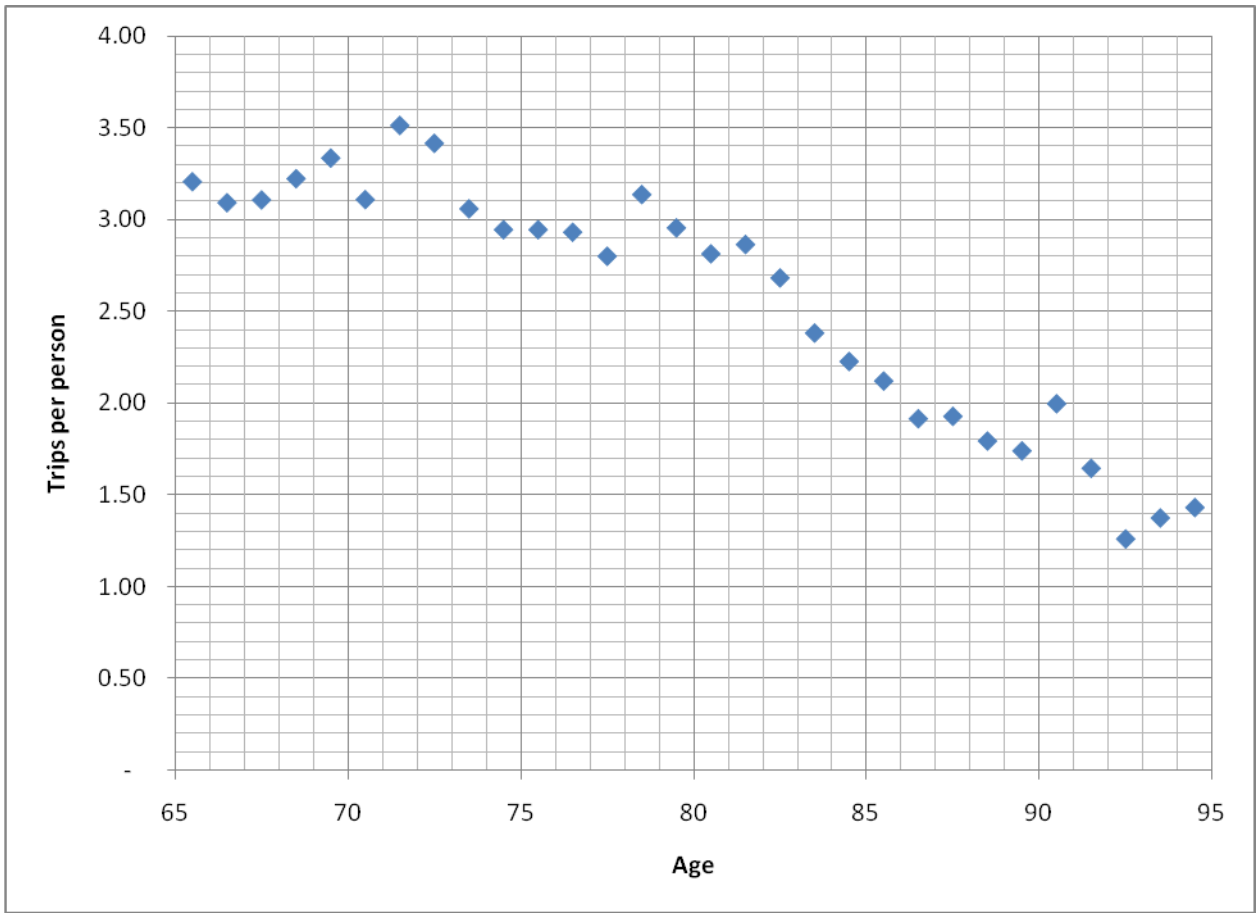

Figure 8: Trips of Seniors by Age

Further analysis revealed the expected income effect; higher incomes were associated with higher travel levels. Seniors living in one and two person households were found to have similar travel characteristics, however, the amount of travel for seniors in 3 or more person households was sharply lower than that for 1 and 2 person households -- in general, around 2/3 as much. There are likely two key effects here; firstly, other household members are doing maintenance tasks that the seniors would have to do on their own (and indeed, the large household seniors have the greatest reduction in shop activities); secondly, these seniors may be those who are the least healthy are staying with their family in lieu of staying at a nursing home or other institution.

Based on these observations, seniors were divided into 13 groups, as shown in the table below:

Table 9: Senior Groups

Group Name	Household size	HH Income	Age range	Surveys	Trips / person
Sen_65_70_Lo	1 or 2	<$25K	65-74	941	2.67
Sen_65_Med	1 or 2	$25-50K	65-69	679	3.25
Sen_65_Hi	1 or 2	$50K+	65-69	851	3.44
Sen_70_Med	1 or 2	$25-50K	70-74	752	3.19
Sen_70_Hi	1 or 2	$50K+	70-74	775	3.38
Sen_75_80_Lo	1 or 2	<$25K	75-84	809	2.30
Sen_75_Med	1 or 2	$25-50K	75-79	650	3.02
Sen_75_Hi	1 or 2	$50K+	75-79	509	3.26
Sen_80_MH	1 or 2	$25K+	80-84	639	2.68
Sen_85+	1 or 2	n/a	85+	531	1.54
Sen_3+_65_75_Lo	3+	<$50K	65-79	441	1.64
Sen_3+_65_75_Hi	3+	>$50K	65-79	430	2.43
Sen_3+_80+	3+	n/a	80+	350	0.96

These groups provide a fine-grained variation in behavior of seniors by age (with brackets as small as 5 years), by income level, and by household size. The out of home activities of these groups are shown in the figure below.

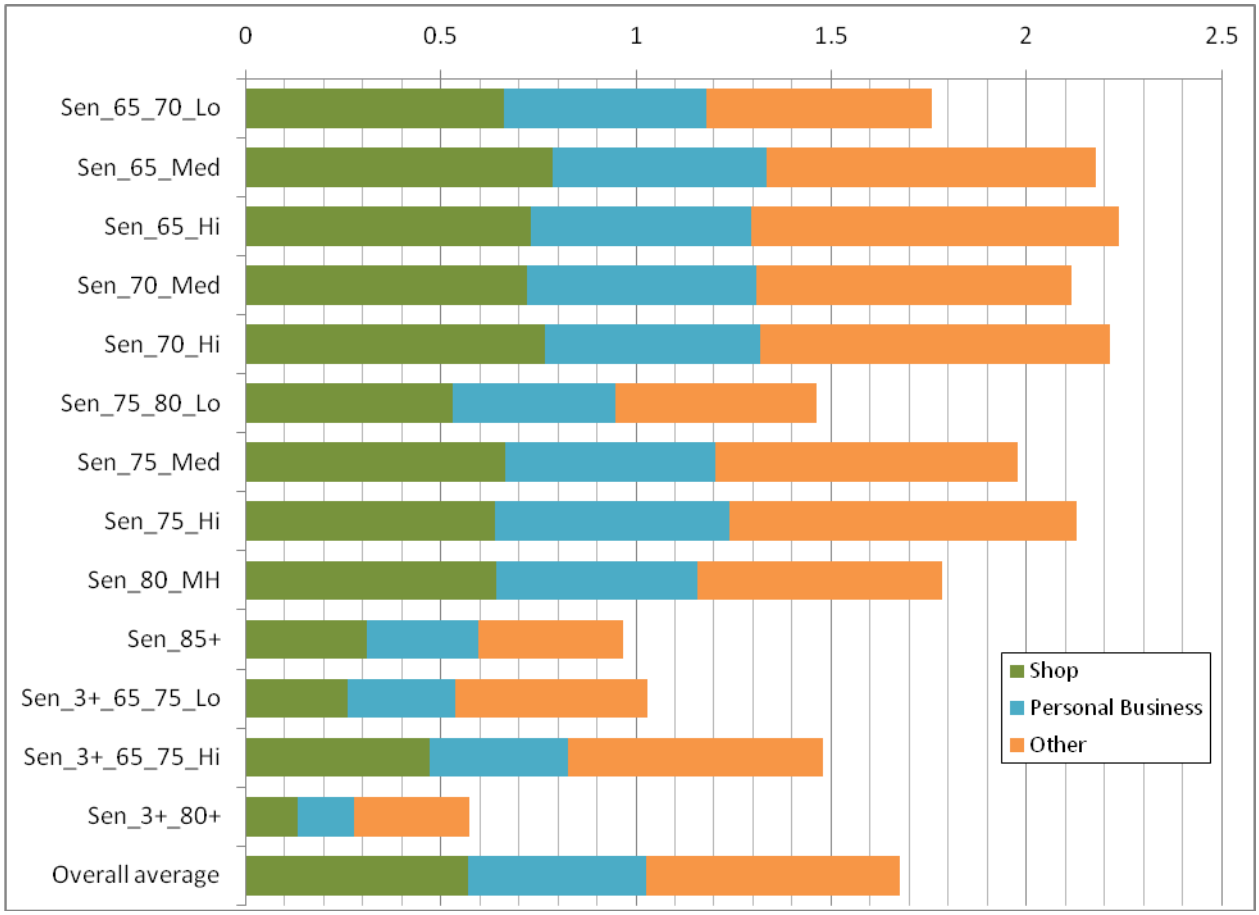

Figure 9: Senior Activities

3. Main Tour Mode Models

This section describes the development and estimation of tour mode choice models for the SDPTM.

The tour based mode choice models differ from traditional trip-based mode choice models in that there are two different levels of forecasting models: tour mode choice models (upper-level choice) and trip mode choice models (lower-level choice on the basis of upper-level choice). The tour mode choice models determine the "main tour mode", whereas the trip model choice models determine the mode for each individual trip made on that tour on the basis of the mode chosen for the tour.

Full logit tour mode choice models are applied to forecast the "main tour mode", which is the overall mode from the tour origin (usually home) to the primary destination, and back to the origin, among available mode alternatives. Note that while the simplified work and school tour mode choice models described in part 1 of this document (which are used to provide logsums for work and school destination choice) use an assumed time period to get travel times for all workers and students, the mode choice models described in this section use the specific outbound and return time periods of the tour being modeled.

The SDPTM considers 8 travel modes (although not all modes are available for some person / purpose combinations):

1. Single Occupant Auto (SOV) (not available for persons with no driving license or from a 0-auto owning household);
2. High Occupant Auto with 2-persons in the auto (HOV2);
3. High Occupant Auto with 3+persons in the auto (HOV3):
4. Walk Access Local Transit (bus, light rail, heavy rail) (not available for origin-destination pairs with no transit service);
5. Drive Access Local Transit (access to or egress from a rail station is by auto) (not available for origin-destination pairs with no transit service);
6. Walk (not available for a round tour distance > 10 miles);
7. Bicycle;
8. School Bus (only available for Grade School Tours).

Three separate main tour mode models have been estimated, for three tour purposes: Work, School and Other.

The main tour mode choice models were estimated by the application of the ALOGIT package to observed mode choice behavior from the California travel surveys. A very brief overview of the underlying theory underpinning these models is given below.

The overall postulation in disaggregate choice modelling is that the probability of an individual choosing a given alternative is a function of the socioeconomic characteristics of the individual and the relative attractiveness of the alternative. The relative attractiveness of alternatives is represented using the concept of utility, which is a numeric measure of the attractiveness an individual associates with an alternative. This derivation of a utility value from the attributes of the alternative by the individual is represented using a utility function, as follows:

$U(a,i) = F \{ X(a) , C(i) , K \}$

where:

$U(a,i)$ = utility individual i associates with alternative a

$X(a)$ = vector of numeric measures of attributes of alternative a

$C(i)$ = vector of numeric measures of characteristics of individual i

K = vector of utility function parameters.

The individual's choice behaviour is viewed as an exercise in maximizing this utility, either consciously or unconsciously, by selecting the alternative that provides the bundle of attributes with the greatest utility – the concept of “rational choice behaviour”.

The form of a single-level logit model of choice behaviour amongst a set of alternatives is:

$$P(j^*) = \frac{e^{U_{j^*}}}{\sum_{j \in J} e^{U_j}}$$

where:

P(j*) = probability choosing alternative j* amongst set of alternatives J

U_{j^*} = Utility of alternative j*

U_j = Utility of every alternative j in set J

In the CSTDM main tour mode models a “nested logit” model approach is used. Figure 10 illustrates the choice structure for the Work model:

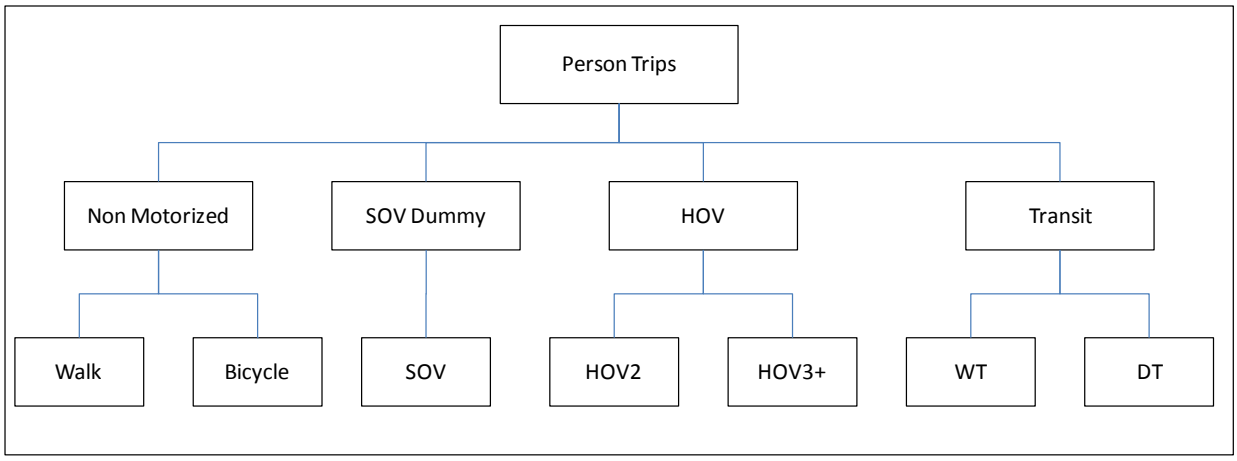

Figure 10: Example of Nested Logit Model Structure: Main Tour Mode Model: Work

For a given TAZ-TAZ and time period combination of tour outbound and return trips, the probability of choosing a mode between the 4 options, in the “upper level” is calculated:

- Non-motorized ;
- SOV (dummy);
- HOV;
- Transit.

Once the probability at the “upper level” has been determined, the further probabilities are calculated for the choices at the “lower level”:

- For non-motorized modes, the choice between walk and bicycle;
- For SOV, there are no sub-options so the choice probability is 100% SOV;
- For HOV, the choice between HOV2 and HOV3;
- For Transit, the choice between Walk Access Transit (WT) and Drive Access Transit (DT).

The analytic form of the nested logit formulation, for a set of alternatives B in the lower level, and a set of alternatives C in the higher level, is:

for the lower level:

$$P[b^*|B,i] = \frac{\exp(U(b^*,i))}{\sum_{b \in B} \exp(U(b,i))}$$

and, for the higher level:

$$P[c,i] = \frac{\exp(\lambda \cdot U(c,i))}{\sum_{b \in B} \exp(\lambda \cdot CU(B,i))}$$

with:

$$CU(B,i) = \lambda \cdot \log \{ \sum_{b \in B} \exp(\cdot U(b,i)) \}$$

where:

b	=	index representing alternative in set B
c	=	index representing alternative in set C
P[b*|B,i]	=	probability that alternative b* is selected given B set chosen
P[c,i]	=	probability that alternative c is selected
CU(B,i)	=	composite utility for the B set alternative.
λ	=	nesting parameter for lower level

The composite utility term represents the utility associated with the 'B' alternative as a composite of the utility values for each of the b alternatives in combination.

In order for the model's cross-elasticities for alternatives in the different sub-sets to be sensible, the nesting parameter dispersion parameter λ must have a value within the range 0 and 1.0. This ensures that there will be greater shifts in choice probability between alternatives that share more attributes (and error terms) and are therefore more similar.

In the CSTDM disaggregate application of these models, a “Monte-Carlo” approach is used to sample from the calculated probability distributions, to allocate a specific mode to each individual.

The final main tour mode models used in the SDPTM, after calibration adjustments, are described in the following sections.

3.1 Work Main Tour Mode Model

The nesting structure for this model is given in Figure 11:

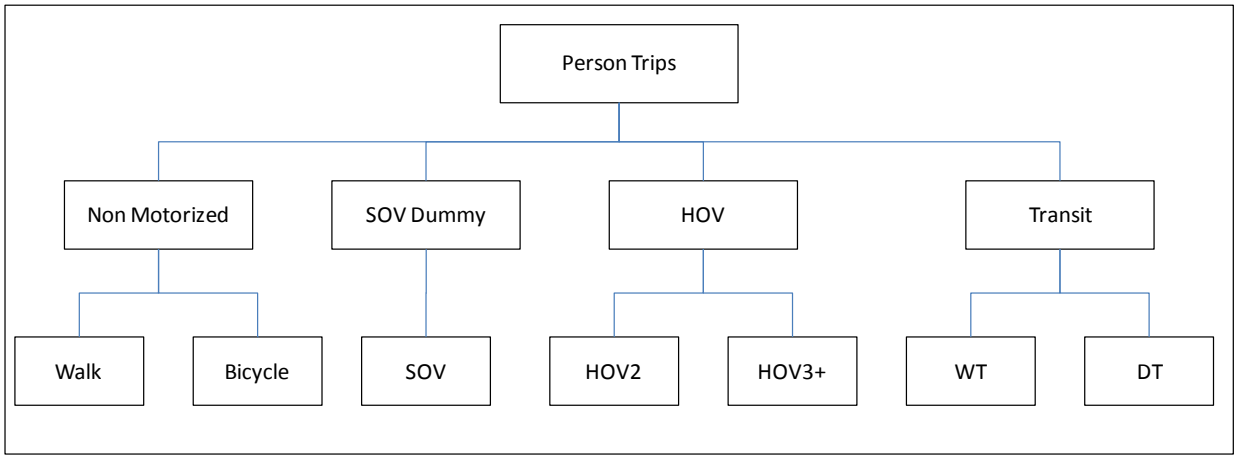

Figure 11: Nested Logit Model Structure for Main Tour Mode Model: Work

Note: WT = Walk Access Transit; DT = Drive Access Transit

The utility parameter values for each mode for the Work Main Tour Mode are given in Table 10:

Table 10: Work Main Tour Mode Parameters

Parameters	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)	-0.07541
Auto In-vehicle time, HH income < 25K (min)	-0.01007
Auto In-vehicle time, HH income 25K -100K (min)	-0.02261
Auto In-vehicle time, HH income >= 100K (min)	-0.03211
Transit In-vehicle time, HH income <100K (min)	-0.00577
Transit In-vehicle time, HH income >=100K (min)	-0.00938
walk/bicycle time less than 20 minutes (min)	-0.09428
walk/bicycle time between 20 minutes and 70 minutes (min)	-0.05246
walk/bicycle time more than 70 minutes (min)	-0.03497

SOV	
Constant	0.21280
HH income < 25K	-0.31976
HH income 25K- 50K	-0.17660
Office worker (workplace population + employment density <20000)	0.32962
Office worker (workplace population + employment density >=20000)	-0.39352
Blue collar worker	0.29243
HOV2	
Constant	-5.01217
No Autos in HH	5.61689
Autos in HH > 0 but < drivers	1.78267
One person HH	-1.35019
Age 40-50	-0.25500
Age > 50	-0.41308
Non-work adults (including age 65+)	1.16879
Number of outbound stops	0.09333
Departure in PM peak (3 PM – 7 PM)	0.41708
HOV3+	
Constant	-6.73394
No Autos in HH	6.67298
Autos in HH > 0 but < drivers	1.93068
One person HH	-1.86484
Two person HH	-0.73114
Age 40-50	-0.58760
Age > 50	-1.06107
Non-working adults(including 65+)	1.16879
Number of outbound stops	0.09333
Departure in PM peak (3 PM – 7 PM)	0.41708
Walk Access Transit	
Constant, MTC	-6.08195
Constant, SACOG	-6.35255
Constant, SCAG	-8.05955
Constant, SANDAG	-5.76785
Constant, remainder of state	-7.86445
No Autos in HH	7.54636
Autos in HH > 0 but < drivers	2.56427
HH income < 25K	0.67749
HH income 25K- 50K	0.25346
SQRT of origin population and employment density	0.00793
SQRT of destination population and employment density	0.00544
Departure in PM peak (3 PM – 7 PM)	-1.12495
Number of outbound stops	-0.24644
Number of return stops	-0.43816
Drive Access Transit	

Constant, MTC	-3.81771
Constant, SACOG	-4.08823
Constant, SCAG	-5.79531
Constant, SANDAG	-3.50361
Constant, remainder of state	-5.60021
No Autos in HH	5.83874
Autos in HH > 0 but < drivers	1.86501
SQRT of origin population and employment density	-0.00854
SQRT of destination population and employment density	0.00544
Departure in PM peak (3 PM – 7 PM)	-1.12495
Number of outbound stops	-0.24644
Number of return stops	-0.43816
Walk	
Constant	-1.21373
No Autos in HH	6.54141
Autos in HH > 0 but < drivers	1.84915
SQRT of origin population and employment density	0.00999
Number of outbound stops	-0.80019
Number of return stops	-1.44065
Bicycle	
Constant	-5.56648
No Autos in HH	6.54141
Autos in HH > 0 but < drivers	1.84915
SQRT of origin population and employment density	0.00440
Number of outbound stops	-0.76698
Number of return stops	-0.74709
Age 60+	-1.64800
Male	1.73900
Nesting Parameters	
All Modes	0.73077

In the model, separate parameters are specified for walk/bicycle travel time in three time bands - less than 20 minutes, 20-70 minutes and greater than 70 minutes. Figure 12 gives the observed cumulative distribution of walk trips by walk travel time, which illustrates that travelers are much more sensitive to the first time band (0-20 minutes) of travel time.

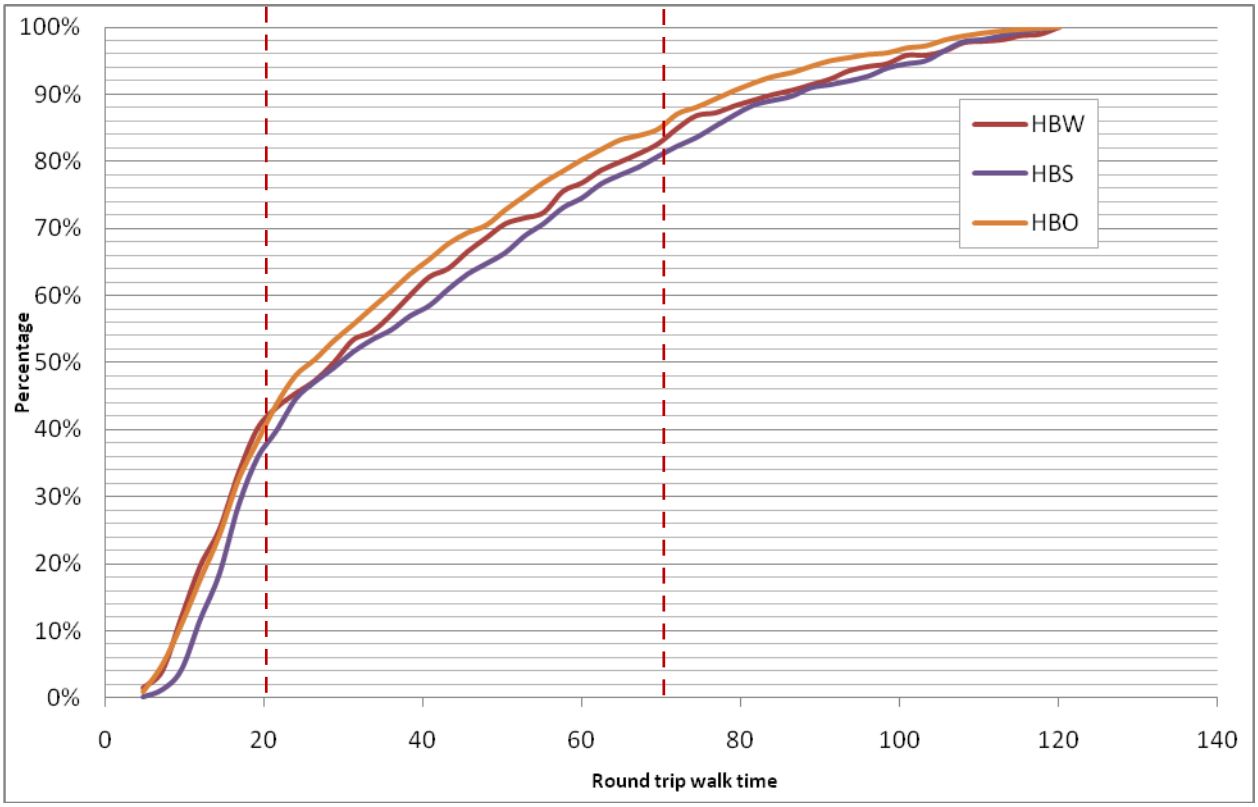

Figure 12: Walk Time Cumulative Frequency by Purpose

3.2 School Main Tour Mode Models

Two school main tour mode models have been developed – one for Grade School Students; and one for Post-Secondary Education Students.

The nesting structure for the Grade School model is shown in Figure 13:

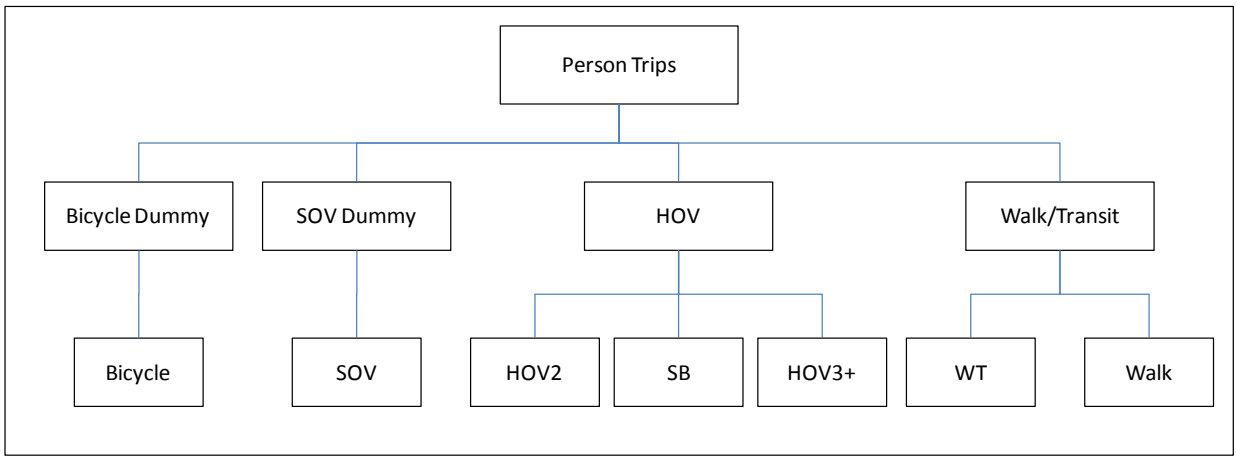

Figure 13: Nested Logit Model Structure for Main Tour Mode Model: Grade School

Note: SB = School Bus; WT = Walk Access Transit; DT = Drive Access Transit

The utility parameter values for each mode for the Grade School Main Tour Mode model are given in Table 11:

Table 11: Grade School Student Main Tour Mode Parameters

Parameter	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)*	-0.06961
Auto In-vehicle time (min)	-0.00696
Transit In-vehicle time (min)	-0.00302
Walk time (min)	-0.00170
Bike time (min)	-0.01342
SOV	
Constant - with driving license	5.62856
HH income < 25K	-1.84133
HH income 25K- 50K	-1.54397
HH income 50K- 100K	-0.67127
Escort stop in a tour	1.85171
HOV2	
Constant - with driving license	5.88286
Constant - without driving license, grade K-8	3.31671
Constant - without driving license, grade 9-12	3.46581
No Autos in HH	-1.91005
Autos in HH > 0 but < drivers	3.12603

HH income 25K- 50K	0.44073
HH income 50K- 100K	1.38206
HH income > 100K	2.12184
Age	-0.52890
Age square	0.01873
Number of outbound stops in a tour	0.79469
HOV3+	
Constant - with driving license	4.90429
Constant - without driving license, grade K-8	3.55584
Constant - without driving license, grade 9-12	3.33014
No Autos in HH	-1.61884
Autos in HH > 0 but < drivers	3.10644
HH income 25K- 50K	0.44073
HH income 50K- 100K	1.38206
HH income > 100K	2.12184
Age	-0.52890
Age square	0.01873
Number of outbound stops in a tour	0.79469
School Bus	
Constant, grade K-8	-0.16633
Constant, grade 9-12	0.24877
No Autos in HH	0.23641
Autos in HH > 0 but < drivers	2.96046
Age square	-0.00237
SQRT of school location population and employment density	-0.01878
Departure in AM peak (6 AM – 10 AM)	1.52497
Walk Access transit	
Constant - with driving license	-5.76613
Constant - without driving license, grade K-8	-4.99162
Constant - without driving license, grade 9-12	-5.04672
No Autos in HH	1.82569
Autos in HH > 0 but < drivers	3.54018
Age square	0.01106
SQRT of destination population and employment density	0.00640
Walk	
Constant, grade K-8	-1.2195
Constant, grade 9-12	-1.3781
Autos in HH > 0 but < drivers	3.09037
HH income <25K	0.59793

HH income 25K- 50K	0.30990
SQRT of origin population and employment density	0.00886
Number of stops in a tour	-1.19139
Bicycle	
Constant - with driving license	-11.8426
Constant - without driving license, grade K-8	-13.5833
Constant - without driving license, grade 9-12	-13.2515
No Autos in HH	-1.32334
Autos in HH > 0 but < drivers	3.84415
Age	1.30953
Age square	-0.05074
HH income <25K	0.59793
HH income 25K- 50K	0.30990
Number of stops in a tour	-1.13997
Male	1.99964
Nesting Parameters	
All Modes	0.61490

* Value of time for grade students was set to $6/hour.

The nesting structure for the Post-Secondary Education Main Tour Mode model is shown in Figure 14:

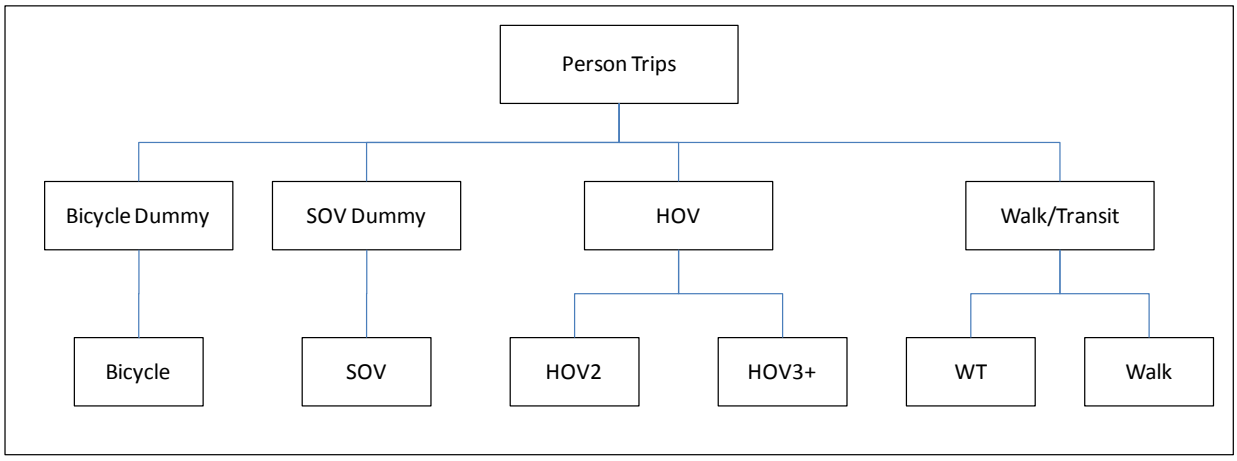

Figure 14: Nested Logit Model Structure Main Tour Mode Model: Post-Secondary

Note: SB = WT = Walk Access Transit; DT = Drive Access Transit

The utility parameter values for each mode for the Post-Secondary Student Main Tour Mode model are given in Table 12:

Table 12: Post-Secondary Student Main Tour Mode Parameters

Parameter	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)	-0.19549
Auto In-vehicle time (min)	-0.02077
Transit In-vehicle time (min)	-0.00603
walk time less than 20 minutes (min)	-0.11959
walk time between 20 minutes and 70 minutes (min)	-0.07140
walk time more than 70 minutes (min)	-0.00434
bicycle time less than 70 minutes (min)	-0.05322
bicycle time more than 70 minutes (min)	-0.02970
SOV	
Constant	0.16600
Autos in HH > 0 but < drivers	-2.30710
HH income < 25K	-1.35189
HH income 25K- 50K	-1.01491
Full or part-time job	0.88143
HOV2	
Constant	-3.56214
No Autos in HH	6.50149
Autos in HH > 0 but < drivers	-0.90679
One person HH	-1.70719
HOV3+	
Constant	-5.27544
No Autos in HH	7.14905
Autos in HH > 0 but < drivers	-0.75085
One person HH	-3.16040
Two person HH	-0.78847
Walk Access Transit	
Constant	-3.80048
No Autos in HH	7.51486
Number of stops in a tour	-0.60919
Walk	
Constant	1.71630
No Autos in HH	6.33204
Number of stops in a tour	-1.28257

Bicycle	
Constant	-4.30809
No Autos in HH	6.33204
Number of stops in a tour	-0.98434
Male	1.36600
Nesting Parameters	
All Modes	0.69090

3.3 Other Main Tour Mode Model

The Other purpose main tour mode model has a different form and structure than the Work and School tour mode models. For this purpose the tour mode is determined ***before*** the primary destination choice, rather than after destination choice, as illustrated in Figure 15.

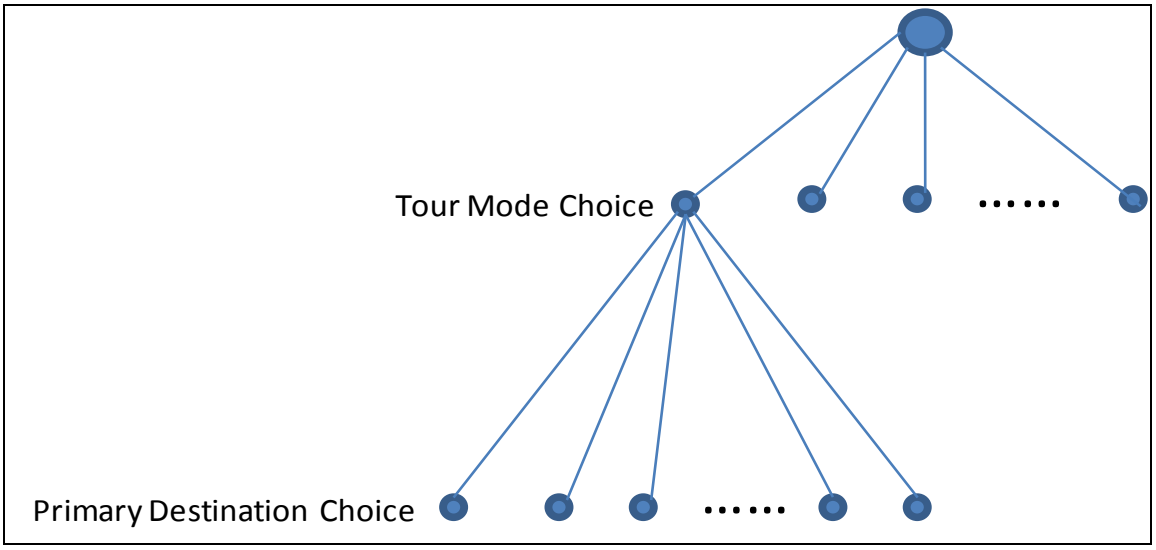

Figure 15: Model structure for "Other" purpose Main Tour Mode Model

For this model structure, the mode choice is not made for each TAZ-TAZ pair. Instead, the tour mode choice for each home zone TAZ is determined using mode-specific logsums of generalized travel cost to all available destinations, obtained from the Primary Destination Choice model.

Seven different purposes are considered as part of the “Other Purposes” model:

- Eat;
- Recreation (including entertainment) (Rec);
- Shop;
- Personal Business (PB);
- Social (Soc);
- Escort for persons in households with children (Esc_K); and
- Escort for persons in households without children (Esc_NK).

From the primary destination choice model, logsums of generalized travel cost to all available destinations from each TAZ are calculated, for each of the 7 purposes, for each of the 7 modes (SOV, HOV2, HOV3, Walk Access Transit, Drive Access Transit, Walk and Bicycle).

For each logsum, the following calculation is made:

$$\mathbf{logsum_i} = \ln\left(\sum_j e^{U_{ij}}\right) \text{ where } U_{ij} = p_c\left(cost_{ij} + cost_{ji}\right) + \ln\left(TotEmp + \sum_s p_s Size_s\right)$$

where the costs are composite costs of travel, the Size elements are zonal properties, such as the number of jobs in an industry category, and p_c and p_s are estimated parameters.

The logsums are calculated for the time period pairs, for the outbound and return trips of the tour. Every possible time period pair combination is calculated, keeping the early and late offpeak separate. While the travel times and costs for a tour starting and ending in the early offpeak would be the same as that for one starting in the early and ending in the late offpeak, the parking cost is different.

Table 13 gives the parameter values for the Other Main Tour Mode model:

Table 13: Other Main Tour Mode Parameters

Parameters	Parameter Value
Destination Accessibility (logsums)	
SOV	0.84879
HOV2	0.69044
HOV3	0.69044
Walk Access Transit	0.21371
Drive Access Transit	0.17387
Walk	0.40981
Bicycle	0.61343
SOV	
Constant - eat	0.5417
Constant - escort	0.4936
Constant - personal business	0.5650
Constant - recreation	0.5417
Constant - shopping	0.5650
Constant - social	0.5417
Non-work adult	-0.18630
Age 16-29	0.56016
Age 40-49	1.09865
Age 50-64	1.61192
Age >64	1.51529
HH income 75K - 100K	0.11048
HH income 100K - 150K	0.12702
HH income > 150K	0.21256
HOV2	
Constant - eat	3.4394
Constant - escort	0.9717
Constant - personal business	1.5273
Constant - recreation	2.0768
Constant - shopping	1.5717
Constant - social	1.5172
No Autos in HH	2.91184
Autos in HH > 0 but < drivers	0.77555
One person HH	-2.21703
Age 40-49	0.29016
Age 50-64	0.54413
Age 65+	0.94721

Departure in PM peak (3 PM – 7 PM)	0.57460
HOV3+	
Constant - eat	3.7040
Constant - escort	0.6065
Constant - personal business	1.2035
Constant - recreation	2.2609
Constant - shopping	1.6116
Constant - social	1.7084
No Autos in HH	3.33007
Autos in HH > 0 but < drivers	0.65707
One person HH	-3.16195
Two person HH	-1.71050
Child Age 0-5	0.58583
Child age 6-15	0.64340
Age 50-64	-0.33685
Departure in PM peak (3 PM – 7 PM)	0.57460
Walk Access Transit	
Constant – eat	3.3479
Constant – escort	-0.1058
Constant - personal business	2.6265
Constant – recreation	2.5483
Constant – shopping	1.7485
Constant – social	0.8209
No Autos in HH	7.92212
Autos in HH > 0 but < drivers	0.72303
HH income < 25K	0.38630
HH income 25K-50K	0.78023
Full-time worker	-1.53704
Child Age 0-5	-1.09244
Child age 6-15	-0.58547
Age 50-64	-0.41698
Age 65+	-0.42619
Number of stops	-0.33842
Drive Access Transit	
Constant – eat	3.0864
Constant – escort	-3.5621
Constant - personal business	0.8021
Constant – recreation	2.2946
Constant – shopping	-1.1055
Constant – social	0.4868

No Autos in HH	5.41327
Autos in HH > 0 but < drivers	0.60384
HH income < 25K	0.38630
HH income 25K-50K	0.78023
Full-time worker	-1.53704
Child Age 0-5	-1.09244
Child age 6-15	-0.58547
Age 50-64	-0.41698
Age 65+	-0.42619
Number of stops	-0.33842
Walk	
Constant – eat	3.7356
Constant – escort	1.6258
Constant - personal business	1.3233
Constant – recreation	2.9835
Constant – shopping	1.7734
Constant – social	1.7000
No Autos in HH	5.26817
Autos in HH > 0 but < drivers	1.51802
HH income < 25K	1.35272
HH income 25K-50K	0.60985
SQRT of origin population and employment density	0.01309
Number of stops	-1.46582
Bicycle	
Constant – eat	-2.0545
Constant – escort	-4.7394
Constant - personal business	-3.4418
Constant – recreation	-1.6358
Constant – shopping	-3.4598
Constant – social	-3.3598
Age 6-15	0.40588
Age 16-19	0.44179
Age 40-49	0.46155
Age 65+	-0.71187
No Autos in HH	5.26817
Autos in HH > 0 but < drivers	1.51802
SQRT of origin population and employment density	0.00457
Number of stops	-0.63743
Male	1.04633

Nesting Parameters	
All Modes	0.69168

4. Calibration of Day Pattern and Main Tour Mode Models

4.1 Day Pattern Model

The day pattern model uses pure demographic inputs based on observed data in household travel survey to produce the resulting day patterns, and does not need to be calibrated as such.

4.2 Work Tour Mode Model

The work tour mode choice model was calibrated by adjusting the alternative specific constants for each mode to match the shares observed in the survey data. An additional set of region-specific constants were applied to both transit alternatives to match regional transit use, using the four largest MPOs and the remainder of the state as the five regions. Before these were added in, the mode share for transit was consistent at the aggregate statewide level between the model and the observed data, but there were significant differences at the MPO level; SCAG and the remainder were being overpredicted and the other MPOs were being underpredicted. The regional constants could be considered to represent regional attitudes to transit; MTC, for instance, has, *ceteris paribus*, a higher utility of transit than SCAG because of how it is innately viewed.

These calibrated coefficients are included in the values in table 10. Figure 16 below shows the fit of the model versus the observed data, which is generally quite good. It must be noted that SACOG is based on the small sample (fewer than 400 households after processing) in the statewide dataset, whereas the other three MPOs had additional surveys incorporated and provide a much more robust estimate of work tour mode.

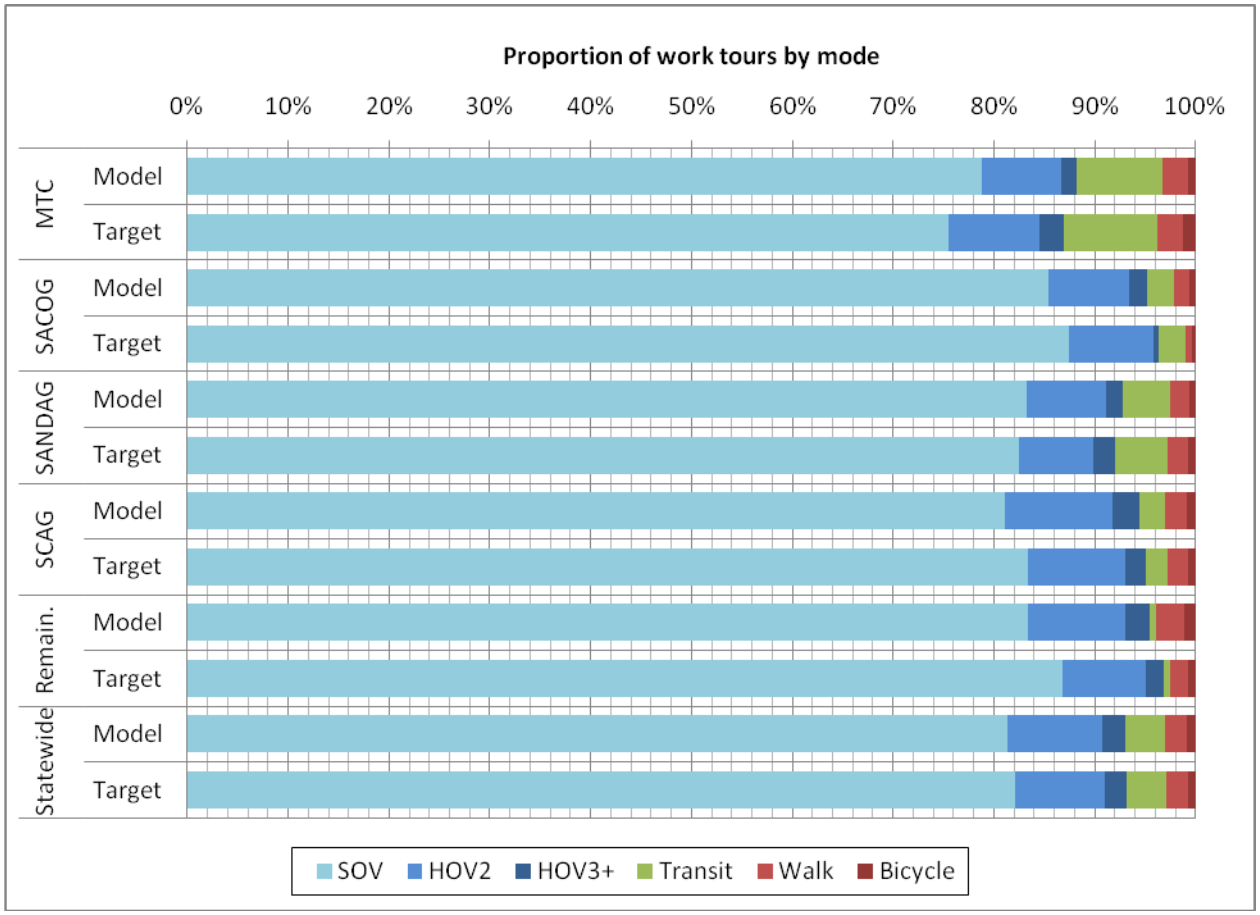

Figure 16: Work Tour Mode Model calibration

4.3 School Tour Mode Model

The school tour mode choice model was calibrated by adjusting the alternative specific constants for each mode to match the shares observed in the survey data. Calibration constants were developed for K-8 students, 9-12 students and PSE students separately.

These calibrated coefficients are included in the values in tables 11 and 12. Figure 17 below shows the high level of fit of the model versus the observed data.

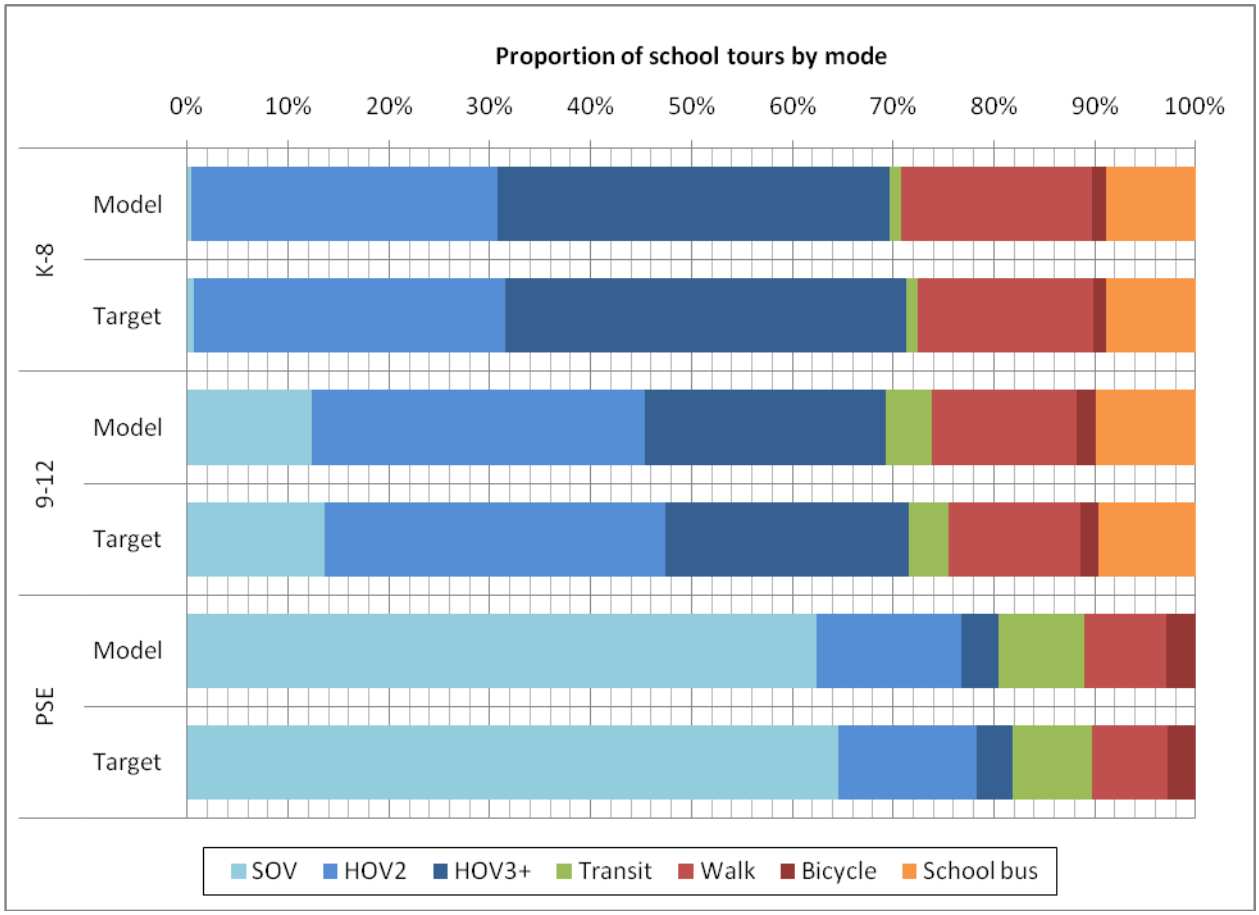

Figure 17: School Tour Mode Model calibration

4.4 Other Tour Mode Model

The other tour mode model was calibrated by adjusting the alternative specific constants for each mode to match the shares observed in the survey data. Calibration constants were developed for escort tours, maintenance (shop / personal business) and discretionary (social / recreation / eat) separately.

These calibrated coefficients are included in the values in table 13. Figure 18 below shows the fit of the model versus the observed data. The mode shares match quite well.

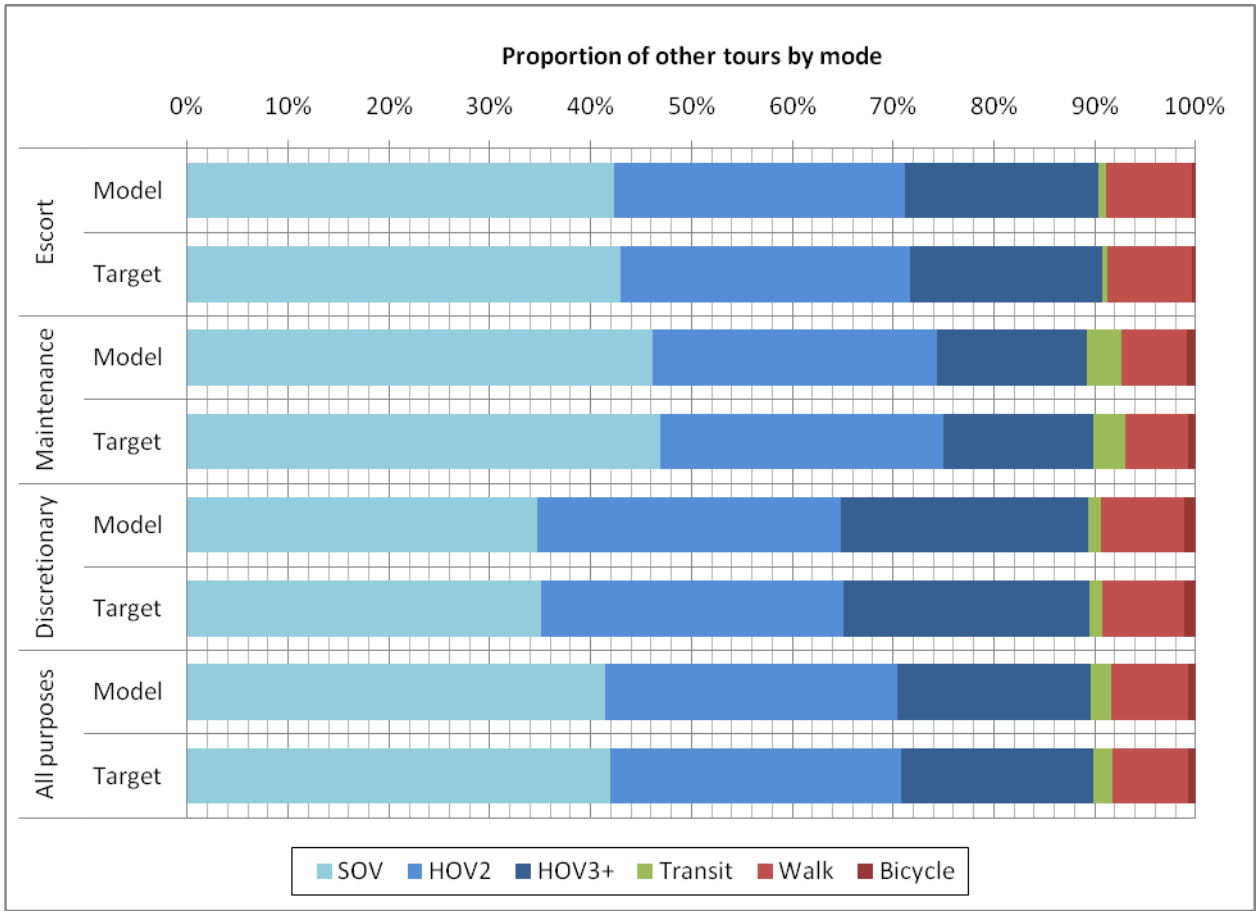

Figure 18: Other Tour Mode Model Calibration