The Ohio Statewide Short Distance Travel Model

by

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1 Introduction

This paper describes the structure of the Ohio Statewide Short Distance Travel Models, and illustrates it with selected model estimation and calibration results. The Ohio Statewide Travel Demand Model is a state-of-the-art economic, land use and transport model. It provides a representation of the entire transportation and associated spatial-economic system in the state of Ohio that goes from a very large and less-detailed representation of national and international economic and demographic trends down to a very fine level of detailed representation of the person and vehicle movements on specific links in the roadway network.

The short distance travel (SDT) models forecast the person movements arising from household (or population) production and consumption established as part of the determination of the spatial distributions of economic activity and population. The SDT models take as inputs the lists of households and persons, indications of travel conditions between TAZs and the quantities of employment and households by category by TAZ. They return a list of trips with attributes including origin TAZ, destination TAZ, start time, duration and mode, TAZ-to-TAZ O-D matrices of light vehicle trips and person transit trips by time period, and short distance home-based person tour utilities by household category. All tours except work tours are assigned locations within 50 miles of the home location.

Travel behavior data for the estimation and calibration of the SDT models were obtained from four home interview surveys and from the 2000 Census:

- The 2002 Ohio Statewide Home Interview Survey
- The 1995 Ohio-Kentucky-Indiana Regional Council Home Interview Survey
- The 1995 Mid-Ohio Regional Planning Commission Home Interview Survey
- The 1994 Northeast Ohio Areawide Coordinating Agency Home Interview Survey
- 2000 Census Transportation Planning Package

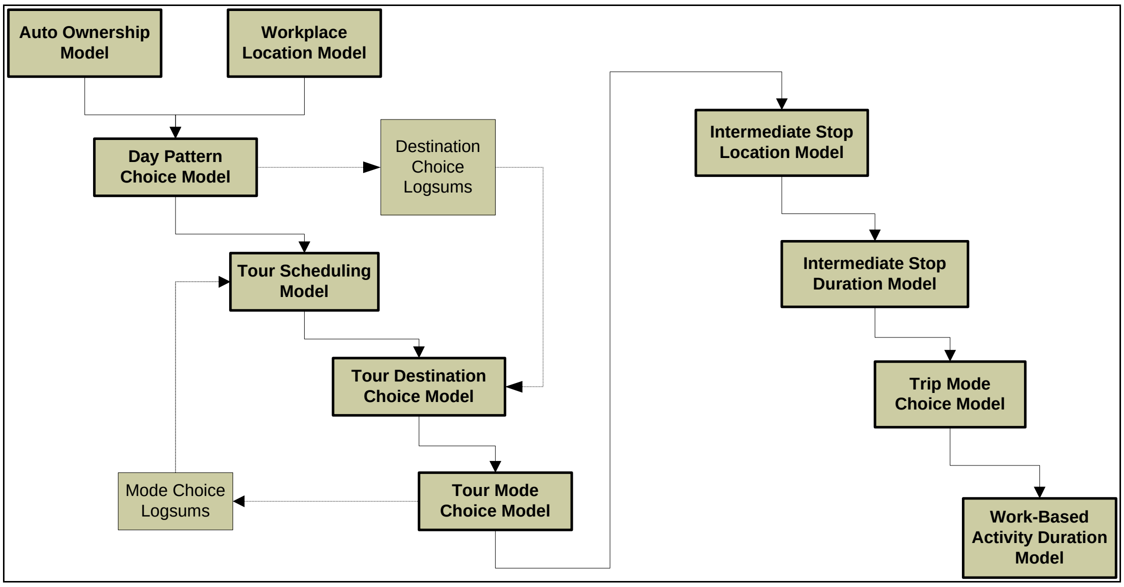
These four surveys comprise a total sample of 26,200 households. The OKI, MORPC and NOACA surveys were re-weighted and re-expanded using Census 2000 data. The surveys were processed to eliminate missing or illogical information, as well as to conform to a unique coding scheme of household, person and trip/activity attributes.

The trip and activity data were used to form tours and activity day-patterns. A tour is defined as a sequence of activities that begins and ends at home (home-based tours) or at work (work-based tours). A day pattern is a sequence of tours that fully describe a person's daily activities.

Each tour contains a primary destination, selected as the highest priority activity among all tour destinations: if the tour includes a work activity, then work is the primary tour purpose, otherwise if it includes school, then school is the primary tour purpose, and so on for shop, social/recreational and other activities, in priority order. The only exception is high school students that work, for whom school and not work is always the highest priority activity. When a tour includes multiple activities of the same type, the one with the longest duration was chosen as the primary activity. Each tour is allowed to include at most one intermediate stop between home and the primary tour activity (the outbound leg), and at most one intermediate stop between this activity and home (the inbound leg). In order to reduce VMT loss, the tour retains the intermediate stop that requires the largest distance deviation between home and the primary destination. The remaining VMT and trip loss were corrected for during model calibration.

The SDT models consist of a series of (mostly) discrete choice models, which represent the trip-making decision as a sequential process, in the order shown in Figure 1. This paper discusses the model estimation and calibration results for a subset of the shown models.

Figure 1 - Short Distance Travel Model Flow



2 Day Pattern Models

The day pattern models predict the number, purpose and sequence of activities for a given person. The pattern consists of a sequence of characters, where each character represents an activity. There is one activity per location, implying that a trip is required between each pair of activities in the pattern. The activity purposes handled by the pattern models are described in Table 1.

Table 1 - Day Pattern Model Activity Purposes

Character	Activity Purpose
H	Home
W	Work, no work-based subtour
B	Work, with work-based subtour
C	School (K12 or College)
S	Shop
R	Recreation
O	Other

The models are segmented by person type, using the types defined in Table 2. This table also shows approximate sample sizes available for estimation for each person type model.

Table 2: Person Type Definition and Sample Sizes

Person Type	Definition	Sample Size
Pre-School	All persons less than 6 years old.	3,750
Grade/High School	All persons older than 5 and younger than 18	9,550
College Student	All students older than 17	3,800
Worker	All persons older than 17 and not students	26,800
Non Worker	All persons older than 17 and not students or workers	16,181

The choice set for each model consists of the unique day patterns observed for each person type. As shown in Table 3, approximately one-half of the observed day patterns are observed only once – see the columns labeled 'Full Day Patterns'. As expected, the most complex day patterns – those comprising many tours and intermediate stops – are observed only once or twice. While the models need to be able to reproduce day pattern complexity, including in the choice set a large number of patterns that are chosen only once significantly increases the size of the estimation problem without adding much new information to the models, and it is unlikely that the models will be able to uniquely identify each of these patterns. It also increases significantly the run time of the models.

In order to decrease the number of unique day patterns, and in particular of those observed only once, day patterns were generalized as follows:

- If the day pattern consists of one tour, the full specification of the day pattern is retained in the choice set.
- If the day pattern consists of two tours, the purpose of the intermediate stops is not retained; instead, they are assumed to be of purpose 'Other'.
- If the day pattern consists of three or more tours, all intermediate stops are dropped from the pattern specification.

Table 3: Day Pattern Model Choice Set Size

	Full Day Patterns			Generalized Day Patterns		
Person Type	*Unique Patterns*	*Unique Patterns Observed Once*		*Unique Patterns*	*Unique Patterns Observed Once*	
		Freq.	*Pct.*		*Freq.*	*Pct.*
Pre-School	309	168	54%	177	47	27%
Grade/High School	426	235	55%	196	51	26%
College	759	525	69%	383	151	39%
Worker	2,103	1,361	65%	442	84	19%
Non Worker	942	539	57%	193	21	11%

These generalizations reduce the choice set as shown in Table 3. In order to retain the ability to predict patterns as complex as those observed in the data, a full day pattern is reconstructed for the cases where the pattern was simplified. Therefore, the activity day pattern models in fact consist of four sets of models:

- The generalized day pattern models
- The intermediate stop purpose models for 2 tour patterns
- The intermediate stop number models for 3+ tour patterns
- The intermediate stop purpose models for 3+ tour patterns

The generalized day pattern models are discrete choice multinomial logit models. Five models were estimated, one for each person type. The utility of each alternative consists of an activity component, a traveler component and a transport supply component. The activity component includes variables identifying the number and purpose of activities in the pattern, the sequence of activities or tours in the pattern, the number and purpose of tours in the pattern, and the number, purpose and presence/absence of intermediate stops in the pattern. The traveler component includes variables that describe the person making the activity day pattern choice, such as age and gender, and variables that describe the person's household, such as household size, number of workers, auto ownership, income and presence of young children. Note that worker status and student status are primarily considered via the model segmentation into person types, although they are also used for the person types that allow both conditions (grade/high school students and college students). The transport component includes distance between home and work (for workers) and the destination choice logsum for each tour purpose. The traveler and transport component appear in the models interacted with the activity components.

Table 4 shows the estimation results for the Worker pattern model. Among the most powerful explanatory variables across all models are number of tours, presence and/or number of intermediate stops, and number of activities of each purpose. As expected, as the day pattern complexity increases, with complexity measured as either more tours, more activities or more intermediate stops on tours, the less likely the pattern is to be chosen. The models also show that people manage day pattern complexity by trading off number of intermediate stops against number of tours, as shown by the negative coefficients on the product of intermediate stops and tours, and the negative coefficient on the product of stops on work tours and number of non-work tours.

The tour sequence variables are also very significant. These variables explain the likelihood of engaging in shop, recreational and other activities before or after work or school, as well as the sequencing of work and school when both activities are part of the day pattern. All models show there is significantly less likelihood of making shop, recreational or other tours before either a school or work tour, with social/recreational tours being less likely to appear before work or school tours than shop tours.

For workers, the most likely pattern consists of a single home-based work tour (no stops), followed by a pattern that includes one work tour (no stops) among other tours. If there are stops on the work tours, inbound stops are more likely than outbound stops. Work-based tours are relatively rare; work-based tours with stops are more likely than work-based tours without stops.

The models show multiple, significant and logical effects when the traveler components (age, gender, auto ownership, etc.) are interacted with the activity components:

- Multiple tours or stops on tours are less likely when the household is car-insufficient (owns no cars or owns less cars than adults or workers);
- Recreational activities (tours or stops) are more likely for persons in high income households;
- Shopping activities are more likely for persons in high income households;
- Adult women are more likely than adult men to engage in shopping activities;
- When compared against adults 18 to 25 years old, the likelihood of participating in social/recreational activities decreases with age;
- The youngest adults (18 to 25 years old) are the most likely to stay at home, regardless of whether they are college students, workers or non-workers;
- Adults with pre-school children at the most likely to stay at home;
- A worker is less likely to participate in recreational activities if he/she lives in a multiple adult household or if he/she has children;
- A workers is more likely to have shopping activities if he/she is single and has children;

- The likelihood of a multiple tour pattern decreases with increasing home-to-work distance.

Table 4: Worker Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Number of tours is 1	-0.2932	-2.7
Number of tours is 2	-0.8883	-5.3
Number of tours is 3	-1.5495	-6.7
Number of tours is 4	-2.8014	-9.4
Number of tours is 5 or more	-3.0060	-7.9
One work/work-based tour only, no stops	1.6437	27.8
One work/work-based tour, no stops	1.0033	17.2
One work/work-based tour only, with outbound stop only	-0.2002	-4.1
One work/work-based tour only, with inbound stop only	0.8861	21.9
One work/work-based tour, with outbound stop only	-0.2368	-3.9
One work/work-based tour, with inbound stop only	0.3117	5.9
Two or more work/work-based tours, no stops	-0.5664	-4.7
Two or more work/work-based tours, with stops	-2.2361	-22.8
Number of work-based tours	-2.3074	-72.9
Presence of shop tours dummy	0.3812	6.0
Presence of recreation tours dummy	1.0577	18.5
Presence of other tours dummy	-0.1061	-2.5
Shop before work dummy	-1.6996	-24.7
Recreation before work dummy	-2.2462	-22.7
Other before work dummy	-1.4255	-30.4
One shop activity	-1.7932	-22.5
Two shop activities	-2.9235	-23.0
Three shop activities	-3.5010	-15.5
Four or more shop activities	-3.1567	-5.1
One recreation activity	-2.0660	-26.3
Two recreation activities	-3.6442	-26.0
Three or more recreation activities	-4.5591	-12.2
One other activity	-0.8225	-12.1
Two other activities	-0.8996	-7.8
Three other activities	-1.1073	-6.8
Four or more other activities	-1.2815	-5.7
# of stops on work tours * # of non-work tours	-0.0290	-0.9
Presence of stops on work tours * # of stops on nwrk tours	-0.1586	-3.2
Presence of stops on work-based tours	0.5994	12.8
Presence of stops on shop tours	-0.2984	-6.1
Presence of stops on recreation tours	-1.3708	-23.4
One stop on other tours	-1.3234	-24.6
Two stops on other tours	-1.9032	-19.0
Three or more stops on other tours	-2.8206	-7.6
Two or more tours dummy if autos = 0	-0.6952	-4.8
Presence of stops on work tours if autos = 0	-0.7170	-4.0
Presence of stops on work based tours if autos = 0	-1.2384	-2.5
Shop stops on work tours if female	0.1944	2.9
Presence of shop tours or stops if female	0.3507	10.0

Table 4 (cont.): Worker Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of shop tours or stops if age less than 25 yrs old	-0.2493	-3.1
Presenc of shop tours or stops if age 55+ yrs old	0.1952	4.8
Presence of shop tours or stops if high income	0.0554	1.6
Presence of shop tours or stops if one adult worker, 1+ child.	0.2021	2.0
Presence of shop tours or stops if 2+ adults, 1+ children	-0.1606	-3.2
Presence of recreation tours or stops if age less than 25 yrs	0.3230	4.2
Presence of recreation tours of stops if age 55+ yrs	0.1216	2.5
Presence of recreation tours or stops if high income	0.2059	5.4
Presence of rec. tours or stops if one adult worker, 1+ children	-0.2887	-2.2
Presence of rec. tours or stops if 2+ adults, no children	-0.2752	-6.6
Presence of rec. tours or stops if 2+ adults, 1+ children	-0.3351	-5.5
Presence of other tours or stops if female	0.2900	10.8
Presence of other tours or stops if age less than 25 yrs old	-0.3934	-6.4
Presence of other tours or stops if age 55+ yrs	0.2000	5.5
Presence of other tours or stops if high income	0.0768	2.8
Presence of other if 1 adult worker, 1+ child., no preschooler	1.2913	10.7
Presence of other if one adult worker, 1+ child., 1+ preschooler	1.4223	6.9
Presence of other if 2+ adults, workers=adults, 1+ child., no preschooler	0.5926	14.7
Presence of other if 2+ adults, workers=adults, 1+ child., 1+ preschooler	0.6985	14.2
Presence of other if 2+ adults, workers<adults, 1+ child., no preschooler	0.3801	5.7
Presence of other if 2+ adults, workers<adults, 1+ child., 1+ preschooler	0.1335	1.9
Stay at home if age 35-55 yrs	-0.3381	-6.9
Stay at home if age 55+ yrs	-0.1908	-2.9
Stay at Home if one adult, worker, 1+ children, no preschooler	0.4227	1.8
Stay at Home if one adult, worker, 1+ children, 1+ preschooler	1.1501	4.0
Stay at Home if two+ adults, workers=adults, no children	0.2185	3.0
Stay at Home if two+ adults, workers=adults, 1+ children, no preschooler	0.2303	2.5
Stay at Home if two+ adults, workers=adults, 1+ children, 1+ preschooler	0.4660	4.8
Stay at Home if two+ adults, workers<adults, no children	0.3892	5.0
Stay at Home if two+ adults, workers<adults, 1+ children, no preschooler	0.3175	2.6
Stay at Home if two+ adults, workers<adults, 1+ children, 1+ preschooler	0.1442	1.2
Number of tours if home to work distance is 1.0 - 2.5 miles	0.3240	6.9
Number of tours if home to work distance is 2.5 - 5.0 miles	0.1870	4.3
Number of tours if home to work distance is 5.0 - 10.0 miles	0.1227	5.2
Number of tours if home to work distance is 10.0 - 25.0 miles	-0.4275	-7.4
Number of tours if home to work distance is 25.0 - 50.0 miles	-0.4985	-7.0
Number of tours if home to work distance is 50.0+ miles	-0.4456	-4.1
Number of stops on work tours if home to work distance is 50.0+ miles	0.8909	2.9
Number of stops on all tours if home to work distance is 1.0 - 2.5 miles	-0.2701	-3.9
Number of stops on all tours if home to work distance is 2.5 - 5.0 miles	-0.1651	-2.7
Number of stops on all tours if home to work distance is 5.0 - 10.0 miles	-0.1895	-4.3
Number of stops on all tours if home to work distance is 10.0 - 25.0 miles	-0.1807	-3.9
Number of stops on all tours if home to work distance is 25.0 - 50.0 miles	-0.2215	-3.4
Number of stops on all tours if home to work distance is 50.0+ miles	-1.0771	-3.7
Final Likelihood	-97414	
Rho-Squared wrt Zero	0.3939	

The pattern models were calibrated to aggregate measures of the amount and type of tours produced per person, including the number of tours in the pattern, the distribution of tour purposes, and the number of trips per tour. The calibration consisted of adjusting the coefficients on the variables for number of tours and tour purposes until a good match to the target data was achieved. See Tables 5 and 6.

Table 5 - Tours per Pattern Calibration

	Target		Estimate
Tours	***Freq.***	***Pct.***	***Pct.***
0	2,123,143	19.4%	19.6%
1	5,393,934	49.2%	48.5%
2	2,608,544	23.8%	24.0%
3	634,983	5.8%	6.0%
4	150,846	1.4%	1.5%
5+	52,585	0.5%	0.6%
Total	10,964,036	100.0%	100.0%

Table 6 - Tour Purpose Calibration

	Number of Tours			**Number of Trips**		
	Target		**Estimate**	**Target**		**Estimate**
Tour Purpose	***Freq.***	***Pct.***	***Pct.***	***Freq.***	***Pct.***	***Pct.***
Work - W	3,292,091	24.6%	24.5%	7,896,582	25.3%	25.6%
Work - B	430,702	3.2%	3.2%	1,109,741	3.5%	3.5%
School	2,397,358	17.9%	16.7%	5,517,206	17.6%	17.3%
Shop	2,247,384	16.8%	17.2%	5,811,583	18.6%	18.7%
Recreation	1,879,844	14.0%	14.1%	4,232,803	13.5%	13.3%
Other	3,154,672	23.5%	24.2%	6,699,640	21.4%	21.6%
Total	13,402,051	100.00%	100.00%	31,267,556	100%	100%

3 Primary Tour Scheduling Model

This model forecasts simultaneously departure-from-home time and arrival-back-home time for all home-based tours, with a time-of-day resolution of 1 hour. It is a discrete choice multinomial logit model, where the choice set consists of 190 possible schedules: all possible combinations of 19 departure hours and 19 arrival hours, with the arrival time always greater or equal to the departure time. Early departures or arrivals (before 5:00 AM) are considered a single choice, as are very late departures or arrivals (after 11:00 PM). The base alternative is the most frequent alternative and therefore varies with the tour purpose; it is identified by a zero departure time constant and zero duration constant. The utility function is based on continuous departure time and tour duration shift variables, where departure time is expressed in hours relative to midnight (assigned 0 departure time), and duration is expressed in hours. Three main types of explanatory variables are interacted with the departure time and duration shift variables: tour and day pattern variables, traveler attribute variables, and travel condition variables. The constant term consists of two components: a departure time term and a duration term.

The model is applied to all tours in a day pattern, according to a pre-determined tour priority: work and school tours are scheduled first, followed by shop tours, then recreational tours, and finishing with other tours. Time windows that have been filled with higher priority tours are not available for lower priority tours. Also, if a low priority tour (for example, shop), occurs earlier in the day than a high priority tour (for example, work), then all time windows after the beginning of the work tour are unavailable for the shop tour. When the pattern includes tours of the same priority, they are scheduled sequentially.

Estimation results for work tours are shown in Table 7. The day pattern, traveler attribute and travel condition variables were typically interacted with both departure time shift and duration shift variables; variables were kept if they showed logical estimates for both shift variables, and significant estimates for at least one of them. The constant terms for all models show the expected result: increasingly negative departure time or duration constant with decreasing observed departure time or duration frequencies. Note that the base alternative is the most frequent departure time or duration alternative.

Among the day-pattern composition variables, those that describe the place of the tour in the pattern sequence relative to the length of the pattern (in tours) are very powerful and have logical signs. The departure time shifts essentially indicate that how early or late, relative to a one-tour pattern, the tour occurs. Note that a non-significant estimate simply means that the tour tends to occur at about the same time as the one tour pattern tour. The duration shifts indicates that first tours tend to be the longest tours, followed by second tours, etc. This trend was observed in the data. Note as well that the duration shift variables are negative, indicating that tours in multiple tour patterns are shorter than tours in single tour patterns.

The other day pattern composition variables included in the models are dummy variables to indicate the presence of tours of a given purpose in the pattern, and dummy variables to flag the presence of inbound and/or outbound stops in the tour. The models show many significant effects related to these variables, both for tour departure time and for tour duration. For example, the presence of multiple work tours in the day pattern tends to shift work tour departure times early, and to shorten the duration of the tour. The presence of tours of any other purpose tends to shift the work tour departure time late, and to lengthen the duration of the work tour. Note that this is after controlling for the number of tours in the pattern. The result is logical because it is essentially comparing a work tour coupled with another work tour vs. a work tour coupled with a non-work tour; the work tour in the latter case is expected to be longer than the work tour in the former case. The presence of intermediate stops on the tour tends to increase the duration of the tour. However, tours with both inbound and outbound stops are on average shorter than tours with either just one inbound or just one outbound stop (one or the other, depending on purpose), suggesting that when multiple stops occur on a tour they tend to be of short duration.

The models also show multiple significant effects related to the traveler attribute or travel condition variables. Among these are:

- Female workers tend to have later work departures and shorter work tours than male workers;
- The youngest workers (less or equal to 25 years old) tend to have the latest work departures, while the oldest workers (55 years old or older) tend to have the shortest work tours;
- Workers in the following industries have significantly later departure times for work than workers in all other industries: arts & recreation, accommodations & food, and real estate. Workers in the latter two industries also have the shortest work tours.
- The models show longer tour distance associated with earlier departure times and with longer tours.

Table 7: Work Tour Scheduling Model

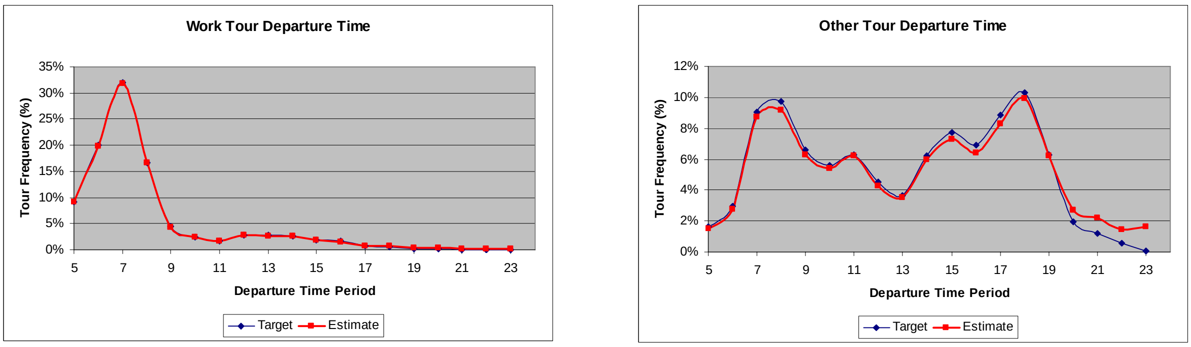
	Departure Time Shift		Duration Shift	
Variable	**Coeff.**	**t-Stat**	**Coeff.**	**t-Stat**
Day Pattern Composition Effects				
One or more other work tours	-0.2211	-10.1	-0.4085	-25.2
Presence of shop tours	0.1080	6.0	0.0363	2.5
Presence of recreation tours	0.0425	2.3	0.0471	3.2
Presence of other tours	0.0945	4.8	0.0536	3.4
Inbound stop only on tour	-0.0751	-4.5	0.2429	19.6
Outbound stop only on tour	0.1095	5.2	0.0194	1.0
Inbound & outbound stop on tour	-0.0014	-0.1	0.0903	4.8
First tour of the day if 2 tour pattern	-0.2177	-11.3	-0.2463	-16.2
Second tour of the day if 2 tour pattern	0.3860	17.3	-0.2706	-14.2
First tour of the day if 3 tour pattern	-0.2658	-8.5	-0.4506	-18.6
Second tour of the day if 3 tour pattern	-0.0032	-0.1	-0.5840	-20.1
Third tour of the day if 3 tour pattern	0.5888	12.9	-0.3474	-8.0
First tour of the day if 4+ tour pattern	-0.3469	-8.0	-0.5822	-18.1
Second tour of the day if 4+ tour pattern	-0.1143	-2.4	-0.7676	-19.3
Third tour of the day if 4+ tour pattern	0.1208	2.1	-0.6505	-11.4
Fourth tour of the day if 4+ tour pattern	0.6810	8.4	-0.5674	-6.4
Presence of a work-based sub-tour	0.0706	4.5	0.3357	26.5
Traveler Attribute Effects				
Grade/High school student	-0.1320	-2.8	-0.1251	-3.1
College student	0.0134	0.8	0.0031	0.2
High income household	-0.0023	-0.3	0.0373	5.5
Zero car household	0.0763	2.6	-0.0875	-2.9
Female	0.0592	7.5	-0.0780	-11.8
Children 5 years old or younger in hhld	-0.0154	-1.3	-0.0079	-0.8
Children 6-15 years old in hhld	-0.0281	-2.8	-0.0082	-1.0
Non working adult in hhld	0.0236	1.9	-0.0310	-2.9
Multiple, all working adult hhld	0.0071	0.6	-0.0448	-4.7
Age greater than 55 years old	-0.1580	-10.4	-0.0807	-5.6
Age between 26 & 35 years old	-0.1101	-7.8	0.0281	2.0
Age between 36 & 55 years old	-0.2007	-15.4	0.0255	2.0
Retail occupation or industry	0.2438	14.2	-0.0573	-4.2
Public Administration occupation or industry	0.0725	3.4	-0.0378	-2.6
Education occupation or industry			-0.0928	-6.7
Arts/Recreation industry	0.3118	8.3	-0.0828	-2.2
Accommodations/Food industry	0.2723	11.2	-0.1313	-5.6
Real Estate industry	0.2563	5.3	-0.1736	-3.8
Office industry or occupation	0.1170	8.4	-0.0216	-2.2
Travel Condition Effects				
Home to work distance	-0.0034	-7.6	0.0030	11.1

Table 7 (cont): Work Tour Scheduling Model

Variable	Coeff.	t-Stat	Variable	Coeff.	t-Stat
Constants					
Departure at 5:00 AM	-1.4399	-30.7	Duration is less than 1 hour	-8.8872	-40.9
Departure at 6:00 AM	-0.5592	-20.2	Duration is 1 hours	-6.7645	-38.9
Departure at 7:00 AM	0.0000		Duration is 2 hours	-5.7618	-38.0
Departure at 8:00 AM	-0.6278	-21.7	Duration is 3 hours	-4.6501	-35.9
Departure at 9:00 AM	-1.7686	-33.9	Duration is 4 hours	-3.5663	-32.9
Departure at 10:00 AM	-2.4517	-32.3	Duration is 5 hours	-2.8333	-31.4
Departure at 11:00 AM	-2.7216	-28.5	Duration is 6 hours	-2.6626	-35.1
Departure at 12:00 PM	-2.3876	-22.1	Duration is 7 hours	-2.2280	-36.7
Departure at 1:00 PM	-2.4286	-19.1	Duration is 8 hours	-1.4795	-33.8
Departure at 2:00 PM	-2.3040	-15.6	Duration is 9 hours	-0.3154	-11.8
Departure at 3:00 PM	-2.7399	-15.8	Duration is 10 hours	0.0000	
Departure at 4:00 PM	-3.2063	-16.2	Duration is 11 hours	-0.3751	-13.2
Departure at 5:00 PM	-4.1073	-18.0	Duration is 12 hours	-1.0331	-23.4
Departure at 6:00 PM	-4.8950	-18.8	Duration is 13 hours	-1.6137	-26.0
Departure at 7:00 PM	-5.8886	-18.9	Duration is 14 hours	-2.0966	-25.9
Departure at 8:00 PM	-6.2850	-17.6	Duration is 15 hours	-2.8072	-26.3
Departure at 9:00 PM	-6.9442	-15.9	Duration is 16 hours	-3.4241	-24.2
Departure at 10:00 PM	-7.1616	-14.2	Duration is 17 hours	-3.7579	-18.7
Departure at 11:00 PM	-6.6796	-10.8	Duration is 18 hours	-3.5903	-12.8
Final likelihood	-81685				
ρ^2 w.r.t. zero	0.2571				

The scheduling models were calibrated to match the observed departure time and tour duration distributions, by adjusting the alternative specific constants. The match for the highest priority tours is very accurate (left panel, Figure 2); it is less so for the lowest priority tours but still very close to the observed distribution (right panel, Figure 2).

Figure 2 - Tour Scheduling Model Calibration



4 Intermediate Stop Location Model

This model chooses a TAZ location for each intermediate stop on a tour. It is a discrete choice multinomial logit model, with utilities that are a function of the origin and primary destination of the tour, the tour purpose, the tour mode, and the characteristics of each alternative TAZ location for the stop.

The model is structured so that out-of-direction travel between the tour origin and its primary destination is minimized. The amount of out-of-direction travel is the additional travel time required to reach the intermediate stop using the tour's primary mode; that is, travel time in excess of the time required to travel directly between the tour origin and primary destination. For transit tours, a generalized travel time function is used, to account for out-of-vehicle travel time, as follows:

$$TravelTime_{Transit} = In-VehicleTime + 1.5 * FirstWaitTime + 2.5 * TransferWaitTime + 3.0 * WalkTime$$

Zones that are not reachable by transit (except for the intrazonal TAZ) are not considered as alternatives for stops on tours whose primary mode is transit.

The model coefficients were borrowed from the Oregon Statewide Model; they are shown in Table 8. The calibration of this model focused on matching the observed average out of direction distance by tour purpose and mode, and the percent of intrazonal stops, that is, stops located in the home TAZ or in the primary destination TAZ (see Table 9).

Table 8: Intermediate Stop Location Model Parameters

	Tour Purpose				
Variable	*Work*	*School*	*Shop*	*Recreation*	*Other*
Out of Direction Time					
Auto	-0.0362	-0.0373	-0.0380	-0.0313	-0.0341
Walk	-0.0216	-0.0128	-0.0160	-0.0209	-0.0167
Bike	-0.0638	0.0205	-0.0402	-0.0129	-0.2439
Transit	-0.0128	-0.0138	-0.0100	-0.0148	-0.0206
Intrazonal Constant					
Auto	0.9333	0.7845	0.8308	0.6499	0.6316
Non Motorized	0.6041	0.7845	0.6184	0.6499	0.6316
Transit	0.7971	0.7845	0.8308	0.6499	0.6316
Size Term					
Total Retail	1.0000	0.0000	1.0000	1.0000	1.0000
Retail Land Use, Retail Industry	0.0000	1.0000	0.0000	0.0000	0.0000
Retail Land Use, Other Industry	0.0000	0.4842	0.0000	0.0000	0.0000
Non Retail	0.0000	0.0000	0.0000	0.0000	0.0913
Grade School	1.2000	0.7194	0.8382	0.0000	0.0000
Households	0.0000	0.3421	0.0000	0.2892	0.3507

Table 9 - Stop Location Model Calibration

Tour Purpose	Average Out of Direction Distance (mi)			Proportion of Stops in Home TAZ		Proportion of Stops in Primary Destination TAZ	
	Target	Estimate	Error	Target	Estimate	Target	Estimate
Work	4.91	4.89	0%	23.7%	24.5%	12.1%	12.8%
Work_based	4.35	4.24	-2%	21.9%	13.0%	10.3%	11.1%
GradeSchool	4.21	4.36	3%	8.5%	6.6%	28.7%	32.8%
College	7.09	6.77	-5%	13.8%	11.3%	13.9%	14.3%
Shop	4.52	4.60	2%	14.6%	16.1%	17.6%	18.2%
Recreate	4.59	4.55	-1%	18.3%	13.1%	17.4%	18.3%
Other	6.44	6.56	2%	10.1%	9.5%	9.7%	10.2%

5 Intermediate Stop Duration Model

This model predicts the duration of intermediate stops on tours. It is a discrete choice multinomial logit model, where the choice set has a resolution of one hour and includes a total of twelve possible activity durations, ranging from 0-1 hour, 1-2 hours, etc. , up to 11 hours or longer. The base alternative is stop duration of one hour or less. The choice set is constrained by the total duration of the tour; that is, alternatives longer than the tour duration are not allowed. The utility function includes daily activity pattern attributes, traveler attributes, and stop attributes. The estimated model parameters are shown in Table 10.

The results show that stop duration increases with deviation distance from the tour anchors; that is, the longer it takes to reach a given stop, the longer the duration of that stop is likely to be. Stops on shop tours that take place in the morning tend to be longer than stops at any other time of day. Stop duration decreases with increasing number of tours and activities in the daily activity pattern, consistent with the necessary tradeoff of number of activities and activity duration given fixed time budgets. A work tour is highly unlikely to have an intermediate stop longer than 6 hours, which is also consistent with the notion of fixed time budgets, given the typical long duration of work activities. Note that stops of very long duration (up to 10 hours) may occur for school tours; these are likely to be work activities. The estimation also shows that outbound stops tend to be shorter than inbound stops, and that shop stops tend to be shorter than stops for other purposes.

The duration constants were adjusted to match observed durations by tour purpose and stop (outbound vs. inbound). Figure 3 shows the calibration results for all purposes, outbound and inbound stops respectively in the left and right panels.

Table 10: Intermediate Stop Duration Model Parameters

	Tour Purpose				
Variable	*Work*	*School*	*Shop*	*Recreation*	*Other*
Outbound stop dummy	-0.6233		-0.0790		
Tours starts in the morning			0.1520		
Adult worker dummy		0.3260			
Number of daily tours					
Two		-0.2562			
Three			-0.2124		
Three or more		-0.4674			
Four or more			-0.4403		
Number of daily stops is 2+			-0.2975		
Number of daily activities					
Six or seven	-0.1358				
Six or more					-0.2231
Eight or more	-0.1640				
Presence of shop stops	-0.4323	-0.5873	-0.1710		
Deviation distance	0.0086	0.0067	0.0069		0.0099
Constants					
Less than 1 hour	0.0000	0.0000	0.0000	0.0000	0.0000
One hour	0.5498	0.5890	0.6118	-0.0680	0.4289
Two hours	-0.3945	-0.2090	-0.5798	-1.1392	-0.6584
Three hours	-0.9905	-0.8065	-0.9059	-1.8986	-0.9197
Four hours	-1.5511	-1.5145	-1.4475	-2.9445	-1.1705
Five hours	-2.2261	-1.9664	-2.4431	-2.4329	-1.2648
Six hours	-2.4666	-2.7236	-2.0130	-999.0000	-1.7239
Seven hours	-999.0000	-2.8660	-2.0150	-999.0000	-1.3821
Eight hours	-999.0000	-3.6686	-2.1453	-999.0000	-1.6287
Nine hours	-999.0000	-3.3032	-2.1702	-999.0000	-1.2673
Ten hours	-999.0000	-5.7909	-999.0000	-999.0000	-0.8450
Eleven hours	-999.0000	-999.0000	-999.0000	-999.0000	-1.4624

Figure 3 - Stop Duration Model Calibration (Outbound & Inbound Stops)