San Francisco Travel Demand Forecasting Model Development

Destination Choice Models

Final Report

prepared for
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Overview

Each tour leaving home (home-based) or work (work-based) is modeled to have a number of stops ranging from one to nine – the primary destination and a maximum of four stops on each half tour. Following the hierarchy of trip purposes, and depending upon the time or distance traveled, one of these stops is classified as the primary destination. All other stops on the tour are considered to be intermediate stops made on the way to or from the primary destination. Two types of destination choice models are estimated – tour or primary destination choice models, that predict the location of the primary destination; and intermediate stop location choice models, that predict the locations of the intermediate stops on the tour. The traffic analysis zones (TAZs) are considered to be the potential alternatives of choice for these models.

This report documents the estimation of the tour and trip destination choice models that will generate the probability of visiting each of a number of alternative zones. Eight separate models are estimated, one for each of the following:

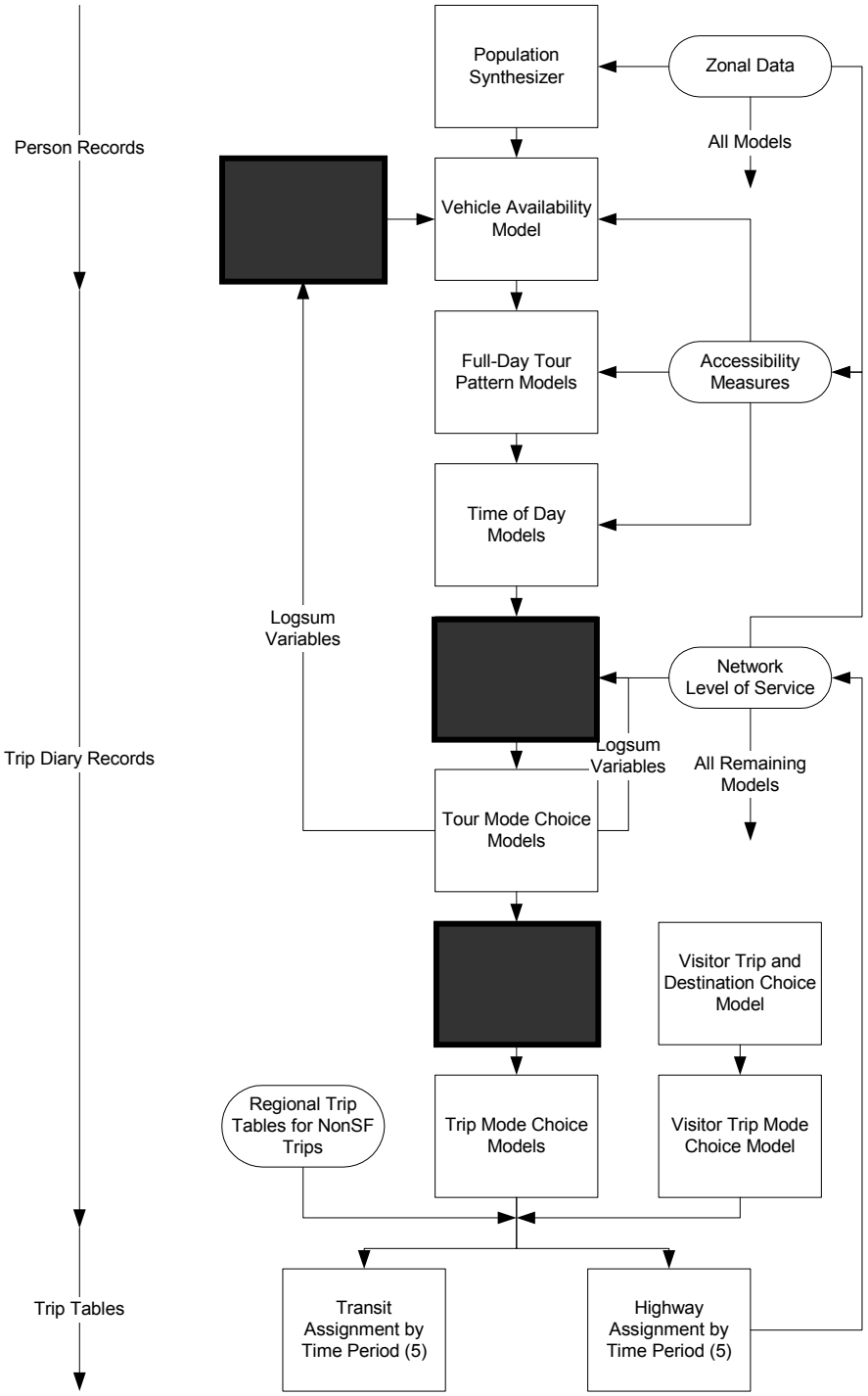
- Primary destination for Home-based work tours
- Primary destination for Home-based education tours
- Primary destination for Home-based other tours
- Primary destination for Work-based sub-tours
- Intermediate Stop location for Home-based work tours
- Intermediate Stop location for Home-based education tours
- Intermediate Stop location for Home-based other tours and
- Intermediate Stop location for Work-based sub-tours.

For the purpose of developing the tour level models, no differentiation is made among primary and secondary tours.

The work location choice model is at the "top" of the decision tree (see Figure 1). Therefore, this model is conditional on the variables in the PUMS-based sample, including residence location, household characteristics, and person characteristics, and origin-destination level of service. The primary destination choice models for the other purposes come further down the decision tree, and will be conditional on the predicted vehicle availability, tour type (number of intermediate stops), and times of day (the time periods of the forward and backward half tours) for the tour.

The trip level intermediate stop location models are applied after all tour level models are applied. In addition, information on the number of intermediate stops on each half leg of the tour and the specific time periods during which these trips are made are obtained by applying pertinent models prior to applying the trip destination models.

Figure 1. San Francisco Model System



Input Data

The data for model estimation was obtained from the 1990 MTC Bay Area Travel Survey (BATS) and included only the residents of San Francisco County. In total, 4,176 tours were reported by the sampled San Francisco residents, who made up 3,519 person-days.

The home and origin TAZs for all the tours were within the proper range. For 16 tours, the primary destination was not properly geocoded – 7 tours have destination TAZ specified as zero and 9 tours have TAZ numbers greater than 2000, outside the valid range. In addition, 6 tours that are not work-based tours do not originate at home. Since only home-based and work-based tours are modeled, these were excluded from the analysis. After excluding these 22 observations, the data set has a total of 4,154 tours available for use in model estimation.

Table 1 shows the number of tours by the primary destination purpose (also the tour purpose). Almost 44% are work tours, whose primary destination is assumed to be the work place location. As mentioned before, the work location model is the first component of the model chain for estimation and application. Information from this model such as the ease of travel to the work zone is utilized in the vehicle availability or auto ownership model. During model application, the work location is predicted for every worker in the sample, and is used as the primary destination for all work-related tours made by that person. For all other purposes, the primary destination choice model is applied only when tours are predicted by that purpose.

Table 1. Frequency of tours by purpose

Tour Purpose	Frequency	Percent	Cumulative Frequency	Percent
Work	1,811	43.6	1,811	43.6
Education	477	11.5	2,288	55.1
Other	1,465	35.3	3,753	90.3
Work based	401	9.7	4,154	100.0

Table 2 provides a summary of the tours by purpose and origin and destination location. Distinction is made by whether the tour crosses the county boundaries or not. More than 90% of the School and Other tours stay within the county. A majority of the Work-based tours also do not cross the county boundary lines. While 15 tours have a trip extending out of the San Francisco County, 9 tours include trips from outside the County to inside the County.

Table 2. Frequency of Origin and Destination Location by Tour Purpose

Tour Purpose	Origin	Destination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Work	In SFC	Out of SFC	398	9.6	398	9.6
Work	In SFC	In SFC	1413	34.0	1811	43.6
Education	In SFC	Out of SFC	35	0.8	1846	44.4
Education	In SFC	In SFC	442	10.6	2288	55.1
Other	In SFC	Out of SFC	132	3.2	2420	58.3
Other	In SFC	In SFC	1333	32.1	3753	90.3
Work based	Out of SFC	Out of SFC	77	1.9	3830	92.2
Work based	Out of SFC	In SFC	9	0.2	3839	92.4
Work based	In SFC	Out of SFC	15	0.4	3854	92.8
Work based	In SFC	In SFC	300	7.2	4154	100

(SFC – San Francisco County)

Table 3 provides a cross-tabulation of the tours by purpose with the type of persons making the tours. The table also shows that Work tours are reportedly made not only by full-time or part-time workers but also by non-workers. This could be a reporting error, coding error or just lack of enough information for proper interpretation. Similarly, School and Other tours are reported by employed adults, who may be part-time workers.

For the purposes of estimation of the primary destination choice model, the main attribute for segmentation analysis is the tour purpose and not the person type. Therefore, all tours by each purpose are included in the estimation data set irrespective of the type of persons making them. Within each purpose, further data cleaning is performed which will eliminate any unreasonable tours.

Table 3. Frequency of Person Type by Tour Purpose

Tour Purpose	Person Type	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Work	employed adult	1688	40.6	1688	40.6
Work	student adult	56	1.3	1744	42
Work	other adult	46	1.1	1790	43.1
Work	under 18	21	0.5	1811	43.6
Education	employed adult	54	1.3	1865	44.9
Education	student adult	152	3.7	2017	48.6
Education	other adult	24	0.6	2041	49.1
Education	under 18	247	5.9	2288	55.1
Other	employed adult	722	17.4	3010	72.5
Other	student adult	104	2.5	3114	75
Other	other adult	572	13.8	3686	88.7
Other	under 18	67	1.6	3753	90.3
Work based	employed adult	394	9.5	4147	99.8
Work based	student adult	5	0.1	4152	100
Work based	other adult	2	0	4154	100

The data sets for estimating trip level intermediate stop location choice models are prepared using the individual trip records from the survey. All trips on a half-tour are used except the last one – the trip to the primary destination on the forward half-tour, and the trip to the home/work location on the backward half-tour. Even though each trip has its own reported purpose, they are grouped together using the main purpose of the tour for ease of estimation and application. For example, the intermediate stop location choice model for work tours includes all trips made on work tours, but do not necessarily have work purpose as one end of the trip. The actual purpose may in fact be dropping a child at school or making errands. This is mainly because separate models are not estimated to predict the purpose of the individual trips on the tour.

Table 4 shows the number of half-tours by stop frequency for stops made on the forward half-tour (from home to primary destination for home-based tours and work to primary destination for work-based tours). Among a total of 709 half-tours with at least one intermediate stop, a little more than 90% have only one or two stops. Since each stop generates a separate observation, a total of 1064 records were generated from this data for estimation.

Table 4. Half-tour frequency of stops on the way to the primary destination (forward half-tour)

Stops before primary destination	Frequency	Percentage
1	510	71.9
2	130	18.3
3	40	5.64
4	15	2.11
5	7	1.00
6	1	0.14
7	1	0.14
8	1	0.14
9	1	0.14
10	2	0.28
11	1	0.14

Table 5 shows the number of half-tours by stop frequency for stops made on the backward half-tour (from primary destination to home for home-based tours and from primary destination to work for work-based tours). Among a total of 995 half-tours with at least one stop, a little less than 90% have only one or two stops. Since each stop generates a separate observation, a total of 1481 records were generated from this data for estimation.

Table 5. Half-tour frequency of stops on the way from the primary destination (backward half-tour)

Stops after primary destination	Frequency	Percentage
1	679	68.2
2	205	20.6
3	73	7.34
4	26	2.61
5	9	0.90
6	2	0.20
12	1	0.10

A total of 1,189 half-tours, or close to 70% of the half-tours with at least one stop have single stops before or after primary destination. Another 515 half-tours have multiple stops to or from primary destination, each of which is translated into a separate observation during model estimation.

Table 6 shows the distribution of stops on the way to the primary destination for all tours with no stops on the way from primary destination. Table 7 shows the distribution of stops on the way from the primary destination for all tours with no stops on the way to primary destination. In both instances, close to 90% of the half-tours have only one or two stops.

Table 6. Half-tour Frequency of Forward Intermediate Stops for Tours with No Backward Intermediate Stops

Number of Stops on Half-Tours	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	285	71.6	285	71.6
2	72	18.1	357	89.7
3	24	6.03	381	95.7
4	10	2.5	391	98.2
5	3	0.75	394	98.9
8	1	0.25	395	99.2
10	2	0.5	397	99.7
11	1	0.25	398	100

Table 7. Half-tour Frequency of Backward Intermediate Stops for Tours with No Forward Intermediate Stops

Number of Stops on Half-Tours	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	472	69.4	472	69.4
2	137	20.1	609	89.5
3	45	6.62	654	96.1
4	17	2.5	671	98.6
5	7	1.03	678	99.6
6	1	0.15	679	99.8
12	1	0.15	680	100

Table 8 shows the distribution of total number of stops on the tour for tours with stops on the way to and on the way from the primary destination.

Table 8. Half-tour Frequency of Stops for Tours with Stops in Both Directions

Number of Stops on Half-Tours	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	312	66.2	312	66.2
3	83	17.6	395	83.8
4	44	9.34	439	93.1
5	12	2.55	451	95.7
6	9	1.91	460	97.6
7	5	1.06	465	98.7
8	4	0.85	469	99.6
9	1	0.21	470	99.8
11	1	0.21	471	100

Sampling Approach

The MTC study area comprises of 1,739 traffic analysis zones (TAZs), of which 766 are within the San Francisco County. For trips originating in the city, each of these 1,739 TAZs is a potential location for destination choice. However, it becomes very unwieldy to specify and estimate models with such a large number of choices. To make the estimation process less cumbersome, the number of alternatives is limited to 40. In similar previous efforts, this number has been found to be reasonable and practical.

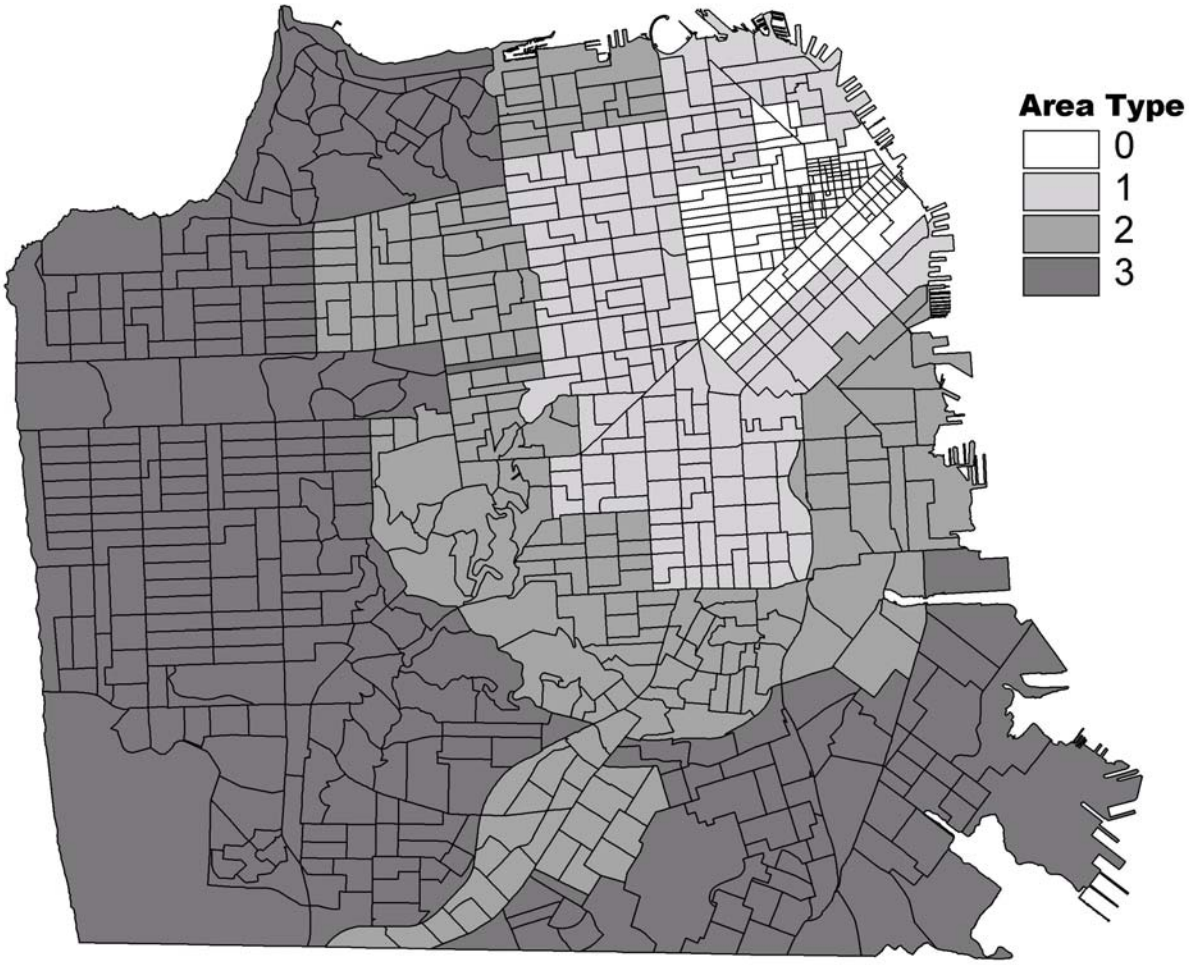
For the models to be accurate and reflective of the observed behavior, the sampled choices should try to match the observed choices as closely as possible. In order to provide for a good representation of the observed behavior, the 'stratified importance sampling' technique is utilized for sampling the 40 potential alternatives from among the available 1,739 TAZs. This technique has been successfully used in a number of previous studies by Cambridge Systematics. The choice set is first divided into a number of strata and each stratum is assigned a different level of importance, which determines the number of alternatives to be sampled from that stratum. For this study, the strata are defined by the San Francisco County boundary (whether the trips are internal or external to the city limits), the origin and destination TAZ area types, and travel time to the destination. The import assigned to each stratum is based on the observed distribution of the trips. The specific sampling approach used for preparing the estimation data set depends upon the tour purpose.

- Work tours and Other purpose tours are based on the type and extent of services available in a zone, which is reflected by the zonal employment. A good measure of the employment by zone is the area type of the zone. Area type is a measure of the intensity of development in an area, and reflects the density of employment and

residents in each zone. All TAZs are classified into six categories – Core CBD (core central business district), CBD (central business district), UBD (urban business district), Urban, Suburban, and Rural. Within San Francisco County, all the TAZs fall within the first four categories, implying that all suburban and rural classifications within the MTC study area are outside the city. Figure 2 illustrates the TAZs in San Francisco County by area type. The Data Development chapter includes a detailed description of how area types are defined and assigned to each zone.

- For the work and other tour purposes, the sampling approach is based on the area type distribution within San Francisco County and on travel time outside the San Francisco County. The sampling was done based on proportions among the different area type combinations as observed in the survey data.
- School tours tend to be destined to zones with schools and colleges, and therefore use the student enrolment and travel time as the basis for sampling zones.
- Tours made with the work location as the start and end points (Work subtours) are typically made in the middle of the day for work-related purposes or errands. These tours tend to be short and to locations that are in close proximity to the work place location. More often than not, travel time is the most important criterion for these tours and hence the sampling procedures are based on the observed travel time distribution.
- For School tours, the travel time data from the survey responses (excluding external destinations) was divided into quartiles, the ranges used for sampling. Similarly, for Work subtours, travel time data from all data, including external destinations was used to quartile ranges and 10 zones were sampled from each quartile.
- For all purposes, destinations internal to San Francisco and external to San Francisco were sampled in proportions found in the survey data.

Figure 2. Area Types in San Francisco County



Source: Metropolitan Transportation Commission & San Francisco County Transportation Authority

Tables 9 through 12 show the distribution of the all observed tour data by origin and primary destination area types. Table 9 shows the frequency of the tours by origin and destination area types. Tours destined to points beyond the city limits are grouped together and categorized as 'Outside SF'. Note that further data cleaning resulted in the reduction of usable records for estimation from 4,514 to 3,970. Table 10 provides the percentage within each area type combination. Of the 3,970 tours, 1,649 tours are destined to the same area type that they originate in, which is indicative of the length of travel. This accounts for more than 40% of the observed tours.

Table 9. Frequency of tours by origin and primary destination area type

	DESTINATION AREATYPE					
ORIGIN AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	221	90	33	29	21	394
CBD	222	373	140	69	113	917
UBD	215	209	315	170	144	1053
Urban	221	216	213	663	207	1520
OutsideSF	4		3	2	77	86
Grand Total	883	888	704	933	562	3970

Table 10. Percentage of tours by origin and primary destination area type

	DESTINATION AREATYPE					
ORIGIN AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	5.6%	2.3%	0.8%	0.7%	0.5%	9.9%
CBD	5.6%	9.4%	3.5%	1.7%	2.8%	23.1%
UBD	5.4%	5.3%	7.9%	4.3%	3.6%	26.5%
Urban	5.6%	5.4%	5.4%	16.7%	5.2%	38.3%
OutsideSF	0.1%	0.0%	0.1%	0.1%	1.9%	2.2%
Grand Total	22.2%	22.4%	17.7%	23.5%	14.2%	100.0%

Table 11 shows the percentage by origin area type within each of the destination area types. While trips to the Core CBD are evenly distributed from among the different origin types, others predominantly attract trips from within the same area type, with almost three-quarters of the Urban area destined trips originating within the same area. This means that the urban area in San Francisco does not represent a very attractive destination option for people residing in other parts of the city.

Table 11. Percentage of tours by origin area type

	DESTINATION AREATYPE					
ORIGIN AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	25.0%	10.1%	4.7%	3.1%	3.7%	9.9%
CBD	25.1%	42.0%	19.9%	7.4%	20.1%	23.1%
UBD	24.3%	23.5%	44.7%	18.2%	25.6%	26.5%
Urban	25.0%	24.3%	30.3%	71.1%	36.8%	38.3%
OutsideSF	0.5%	0.0%	0.4%	0.2%	13.7%	2.2%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 12 shows the percentage by destination area type within each of the origin area types. The information in this table is more illuminating in terms of the actual distribution of the tours. For all origins, a dominant proportion of the tours end within the same area type. More than half the persons within the Core CBD tend to make very short trips to places within the Core area. Core CBD also represents the area type with the least proportion of trips leaving the city. The distribution in the table when examined in conjunction with the location of the TAZs within each area type seems to also confirm the hypothesis that shorter trips are preferred over longer trips.

Table 12. Percentage of tours by destination area type

	DESTINATION AREATYPE					
ORIGIN AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	56.1%	22.8%	8.4%	7.4%	5.3%	100.0%
CBD	24.2%	40.7%	15.3%	7.5%	12.3%	100.0%
UBD	20.4%	19.8%	29.9%	16.1%	13.7%	100.0%
Urban	14.5%	14.2%	14.0%	43.6%	13.6%	100.0%
OutsideSF	4.7%	0.0%	3.5%	2.3%	89.5%	100.0%
Grand Total	22.2%	22.4%	17.7%	23.5%	14.2%	100.0%

While the tables above portray the overall trend in the travel patterns, the distributions by tour purpose show significant variation. Tables 13 through 16 illustrate this using the percentage of tours by destination area type within each origin area type for each purpose (similar to Table 12). For the Work and Other tour purposes, information from these tables is used directly to determine the number of destinations to sample from each area type. For example, for origins in CBD, 31% of 40 or 12 TAZs are sampled from the Core CBD area, 14 from CBD, 4 from UBD, 2 from Urban area, and 20% of 40 or 8 TAZs are sampled form outside San Francisco. For School tours, only the internal/external split is utilized.

Table 13. Percentage of Work tours by destination area type

	WORK AREATYPE					
HOME AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	60.8%	16.7%	10.8%	5.0%	6.7%	100%
CBD	31.2%	34.4%	9.3%	5.0%	20.1%	100%
UBD	31.9%	18.6%	23.5%	6.1%	19.8%	100%
Urban	24.1%	20.9%	13.4%	22.5%	19.1%	100%
Grand Total	30.8%	23.0%	15.3%	12.2%	18.6%	100%

Table 14. Percentage of School tours by destination area type

	DESTINATION AREATYPE					
HOME AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	26.7%	20.0%	10.0%	40.0%	3.3%	100%
CBD	15.6%	28.9%	26.7%	23.3%	5.6%	100%
UBD	5.5%	18.1%	28.3%	36.2%	11.8%	100%
Urban	3.5%	10.4%	19.6%	60.4%	6.1%	100%
Grand Total	7.8%	16.6%	22.6%	45.7%	7.3%	100%

Table 15. Percentage of Other tours by destination area type

	DESTINATION AREATYPE					
HOME AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	38.2%	33.3%	11.8%	7.8%	8.8%	100%
CBD	20.6%	45.3%	19.7%	7.5%	6.9%	100%
UBD	11.9%	22.7%	36.9%	21.0%	7.6%	100%
Urban	9.2%	9.2%	12.0%	58.3%	11.2%	100%
Grand Total	14.7%	23.4%	20.6%	32.2%	9.0%	100%

Table 16. Percentage of Work Subtours by destination area type

	DESTINATION AREATYPE					
ORIGIN AREATYPE	**Core**	**CBD**	**UBD**	**Urban**	**OutsideSF**	**Grand Total**
Core	71%	21%	4%	2%	2%	100%
CBD	18%	61%	11%	2%	8%	100%
UBD	12%	12%	44%	27%	5%	100%
Urban	7%	5%	21%	60%	7%	100%
Outside SF	5%	0%	3%	2%	90%	100%
Grand Total	32%	23%	11%	11%	23%	100%

Table 17 shows the travel time quartiles used for Other and Work subtours. These travel times are based on 1990 off-peak highway networks.

Table 17. Travel Time (in minutes) quartiles for Other tours and Work Subtours

		Work Subtours	
Quartile Limits	**Other Tours**	**Origin Inside SF**	**Origin Outside SF**
Quartile 1 (25th Percentile)	10.57	9.74	9.99
Quartile 2 (50th Percentile)	14.65	11.34	13.28
Quartile 3 (75th Percentile)	19.02	13.17	17.45
Quartile 4 (100th Percentile)	33.38	37.00	29.00

For the intermediate stop locations choice models, since trips of all types and purposes are combined, the travel time information was used to create quartile ranges from each of which 10 zones were sampled. Table 18 shows the travel time percentile limits as observed from the survey using peak level-of-service data for Work and Education tours, and off-peak data for Other tours and Work subtours.

Table 18. Travel time (in minutes) quartiles by tour purpose from trip data

	Work		School		Other		Work Subtours	
Quartile Limits	**Forward**	**Backward**	**Forward**	**Backward**	**Forward**	**Backward**	**Forward**	**Backward**
Quartile 1 (25th Percentile)	9.59	9.63	6.38	8.33	8.17	8.08	8.56	8.52
Quartile 2 (50th Percentile)	11.90	11.83	9.48	10.52	10.8	10.17	11.34	10.50
Quartile 3 (75th Percentile)	17.11	17.08	12.39	16.08	16.28	14.59	13.38	13.1
Quartile 4 (100th Percentile)	46.00	85.00	26.00	43.00	34.00	37.00	22.00	36.89

Potential Variables

The explanatory variables for destination choice models can be classified into two types – attraction variables, representing the characteristics of the destination, and accessibility variables or those that measure the relative ease of traveling to the destination.

Attraction Variables

Attraction variables capture two key types of information – size or magnitude of the attraction zone (size variables) and characteristics of the attraction zone (type variables).

Typical size variables for destination choice models include employment, hotel rooms, schools, enrolment, and area. The specification of the size variables will vary by purpose but the likely candidates available for inclusion in the models are employment data by category, enrollment in schools, part-time colleges, full-time colleges, number of school buildings, and school area. Variables such as number of households that reflect the number of tours generated are probably not very suitable for explaining destination choice models, but can be examined for appropriateness. Employment by occupation could be a key determinant for work location, because for a person employed in a particular occupation, zones with a predominance of jobs in that occupations would hold more attraction than others. However, such detailed classifications would be difficult to implement both for estimation and forecasting (synthetic sample). These variables could be used during estimation either in their simplistic forms, or modified forms such as with logarithmic functions or with size specifications in ALOGIT (a software package used to estimate travel demand models).

The employment data was recompiled for TAZs in San Francisco and uses a different categorization compared to the MTC data. The original MTC databases classified employment by six categories - retail, service, other, agricultural, manufacturing and

trade. The new San Francisco socioeconomic databases developed by Hausrath Economics classified employment by a different set of six categories - CIE, MED, MIPS, PDR, retail, and visitor. The employment sectors were defined by the San Francisco Planning Department in the 1998 Citywide Land Use Study, and are described in greater detail in the Data Development chapter. In order to have a common set of categories across all areas, basic information on the SIC codes falling under each category was used to regroup these twelve fields into four categories - PDR, MIPS, Retail, and Service.

Other potential attraction variables that define the zone include density variables such as population, household or employment densities, also captured in part by the area type definitions; existence of specific facilities or special attractors that set the zones apart from others such as colleges, airports, stadiums, and parks; concentration of specific types of businesses (high technology in Silicon Valley); and the relative location of the attraction zone with respect to the origin zone such as Home zone, Work zone, same area type. Most of these characteristics are captured in the model using dummy variables.

Accessibility Variables

Accessibility variables such as level-of-service by various modes reflect the ease of travel to an attraction zone. A high utility associated with a zone would render it relatively more attractive than others. Since travel between zones is usually split among the various available and competing modes, a composite utility capturing level-of-service of all modes would be an ideal representation of accessibility. The logsum from the mode choice model, defined as the logarithm of the sum of the exponents of the individual modal utilities, captures the travelers' perceptions of the level-of-service characteristics of the various modes and is traditionally used for this purpose. Additional accessibility variables that can be very useful in matching the observed trip length distributions include travel time and distance, but used in non-linear forms (piece-wise and step-wise) to reduce the interaction with the logsum variable.

All potential variables were used in the model estimation process. The set of coefficients reported in the final model specification include those variables that both made sense and provided the best explanatory power to the models.

Tour Destination Choice Model Estimation Results

Tables 19 through 22 provide the results of the tour primary destination models estimated for work, school, other purposes, and work subtours. Each model specification contains the estimates of the coefficients, the corresponding t-statistics and some summary statistics.

By definition, all primary destination tours except Work Subtours have Home as origin and therefore originate within San Francisco County. Work Subtours originate at Work and therefore the origin is not restricted to San Francisco County. The same is the case

with intermediate stop location models, where depending upon the half tour on which the stop happens, the origin could be home or primary destination.

Overall, the models have a number of key attributes with the proper signs and providing an expected range of explanatory power. The three key types of variables contributing significantly to the model power are the employment data, area type, and LOS data.

In all models, the individual employment categories worked better than the four common categories. Employment specific to San Francisco is indicated by 'Zones in SF County' in parenthesis. 'Zones outside SF County' in parenthesis indicates Employment specific to zones outside San Francisco (MTC Zones). 'All Zones' indicates common employment categories.

All the models contain a number of dummy variables based on area type that capture the characteristics of both the origin and destination. While it is legitimate to expect them to interact with and take away critical explanatory power from the level-of-service attributes such as travel time, they were found to be capturing effects over and above those explained by the level-of-service attributes. These variables also make a significant contribution to the overall explanatory power of the model.

Additional dummy variables were created by classifying all counties in the MTC study area into three groups relative to San Francisco: *South* contains San Mateo and Santa Clara counties; *East* consists of Alameda, Contra Costa, and Solano counties; and *North* encompasses Napa, Sonoma, and Marin counties. In addition, Santa Clara and Alameda counties are treated separately in some models to represent Silicon Valley and Oakland respectively.

A summary of the estimation procedures and results is provided below:

- Zonal employment information was incorporated into Work location models in a variety of forms. Initial models used the individual employment variables in their simplistic and logarithmic forms. Knowledge gained from these models regarding the relative importance of various employment categories was used to incorporate the employment variables in the Work location choice models using the size variable specification in ALOGIT.
- As a starting point, the employment category that was strongest in terms of t-statistic from the original model as the base size variable - SF MIPS (management, information and professional services). By definition, its value is set to zero for all zones outside San Francisco. Due to this reason, the size coefficients for the MTC employment categories were very high in value. Similarly, when one of the MTC employment categories was used as the base size variable, the size coefficients for MTC employment were within a reasonable range, but those for San Francisco employment categories were large and negative.
- The size function was then redefined to use the 4 common employment categories with MIPS as base - which resulted in a reasonable set of coefficients. However, the Service employment had to be eliminated from the size function because of convergence

problems (due to too-many step-reducing loops, which is common with non-linear specifications involving log-size-multiplier for size variables).

- Another size variable specification that was tested used the total employment as the base size variable. In addition, the SF and MTC employment size variables were multiplied by the corresponding dummies to make them specific to the zones that they are defined for. This specification improved the explanatory power of the model and is recommended for use with the final model, as detailed in Table 19.
- The logsum multiplier represents a scaling factor for the size variable and is significantly different from 1. The coefficients of the individual size variables specified in the table capture the importance of the attribute relative to the first size variable, the total employment. These are exponents of the actual values reported by Alogit, and hence the t-statistics cannot be reported.
- For School tour models, the main determinants of the size are related variables such as the school area and enrollment. Zonal enrollment values for school and college are applied only to relevant individuals. For Other and Work Subtours, zonal employment becomes the main determinant of size. In all models, the size-related variables have a positive effect as expected.
- Area type and location variables play a significant role in explaining destination choice. San Francisco residents prefer to work within the city and as expected, areas with major employment concentration are also attractive work locations. This is illustrated by large positive values on related dummy variables for the Core CBD and CBD. Also, the level of attraction decreases as the concentration level goes down – UBD is not as attractive as CBD, and Urban is not as attractive as UBD.
- Outside of San Francisco, employment centers such as Silicon Valley and Oakland are major attractions for work location as proven by strongly positive coefficients for the dummy variables.
- For Education tours, zones with a presence of schools and colleges have a higher probability of choice compared to those that do not. Accordingly, the coefficients for related dummy variables are positive and significant. Similarly, zones with a higher presence of schools both in terms of school area and number of school buildings attract more school trips.
- All models include a dummy variable to capture the preference to choose destinations within the zone of residence (Home Zone dummy). Education tours are an exception because they are constrained by the presence of a school or college. This coefficient is large in value, positive, and strongly significant suggesting a deep inclination to travel to locations close to home. For work tours, this coefficient reinforces the simultaneous choice of residential and work locations along with the need to keep the daily commute as short as possible. For non-work tours, it reflects the tendency to travel to areas with the most familiarity and awareness.
- For the work subtour destination choice model, this hypothesis is also substantiated by positive and significant coefficients on the Work Zone dummy variable.
- There is also a strong tendency for the tours to remain within the same area type

- The probability of choosing a destination also increases if it is in the same area type as the origin – all dummy variables representing intra-Core CBD, intra-CBD, intra-UBD, and intra-Urban travel have positive coefficients.
- Work subtours originating outside San Francisco have a strong tendency to stay outside the city reflecting the difficulty to travel across the bridges.
- The influence of the ease of travel in the choice of a destination is captured using the mode choice logsum variable. This is a single measure representing the relative utility of travel between and origin-destination pair across all modes. The hypothesis is that easy access makes a destination more attractive for travel. This is confirmed by positive coefficients that are significantly less than 1 in value in all models.
- The ease of travel and preference to choose points within the city is illustrated by relatively larger logsum coefficient values for destinations in San Francisco as compared to those outside San Francisco.
- In order to capture and better match the distribution of trips, distance to the destination is used in a piece-wise linear form to minimize the interaction with the mode choice logsum variable. Ideally, we would like to match the travel time distribution (using travel time data in model estimation instead), but it is highly correlated with the logsum and takes away essential explanatory power of the logsum variable. The coefficient values for distance are all negative, significant, and in proper relative magnitude, showing an decreasing sensitivity as trip length increases.

Table 19. Work Location Choice Model Estimation Results

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Size Specification			
Log-Sum-Multiplier	0.6534	0.0223	15.52
Total Employment (All Zones)	1.0000	--	--
SF CIE Employment (Zones in SF County)*	2.7037	--	--
SF MIPS Employment (Zones in SF County)*	1.4717	--	--
SF PDR Employment (Zones in SF County)*	1.9357	--	--
SF Retail Employment (Zones in SF County)*	2.5079	--	--
MTC Other Employment (Zones outside SF County)*	0.9736	--	--
Destination Characteristics			
Average Household Income in Thousands of Dollars	0.0020	0.0012	1.57
Destination is in Core or CBD	1.4664	1.0252	1.43
Destination is in UBD	1.1603	1.0239	1.13
Destination is in an Urban or Suburban area	0.8707	1.0170	0.86
Destination Zone is in SF County	1.4758	0.4500	3.28
Destination Zone is in Silicon Valley (Santa Clara)	2.1118	0.3760	5.62
Destination Zone is in Oakland (Alameda)	0.9627	0.3502	2.75
Southern Destinations (San Mateo)	1.9281	0.3466	5.56
Northern Destinations (Marin + Sonoma + Napa)	1.0739	0.3817	2.81
Origin-Destination Characteristics			
Destination Zone is Home Zone Dummy	4.4950	0.1651	27.22
Origin & Dest are in Core Dummy	0.7094	0.2031	3.49
Origin & Dest are in CBD Dummy	0.4593	0.1285	3.57
Origin & Dest are in UBD Dummy	0.3352	0.1376	2.44
Origin & Dest are in an Urban area Dummy	0.7243	0.1283	5.65
Origin-Destination Level of Service			
Piecewise linear distance 0-3 miles	-0.4735	0.1658	-2.86
Piecewise linear distance 3Plus miles	-0.0551	0.0068	-8.08
Mode Choice Logsum	0.0921	0.0336	26.99
Missing Mode Choice Logsum	-1.6603	0.7712	-2.15
Summary Statistics			
Number of Observations	1627		
Log-Likelihood with Zero Coefficients	-6001.8		
Initial Log-Likelihood	-6726.9		
Log-Likelihood at Convergence	-5010.9		
Rho-squared at Convergence	0.255		
Adjusted Rho-squared at Convergence	0.252		
Rho-squared w.r.t. Zero at Convergence	0.165		
Adjusted Rho-squared w.r.t. Zero at Convergence	0.161		

** The reported coefficients are exponentiated to obtain the actual value. Therefore, the reported t-values are not useful in these cases.*

Table 20. Primary Destination Choice Model Estimation Results for School Tours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
School Area in Thousands of Square Feet (Zones in SF County)	4.14E-04	1.17E-04	3.53
High School Enrolment (in Thousands)	8.53E-01	1.79E-01	4.77
Full-time College Enrolment (in Thousands)	4.12E-02	7.66E-02	0.54
Part-time College Enrolment (in Thousands)	7.64E-02	7.45E-02	1.03
Logarithm of Number of Households	8.57E-02	3.30E-02	2.59
Service Employment (Zones outside SF County)	2.56E-04	3.63E-05	7.06
Destination Characteristics			
School Zone Dummy (Zones in SF County)	0.5675	0.1713	3.31
College Zone Dummy	1.6334	0.5013	3.26
Number of School Buildings (Zones in SF County)	0.2779	0.0761	3.65
Origin-Destination Level of Service			
Piecewise linear distance 0-1 miles	-0.6807	0.3440	-1.98
Piecewise linear distance 1-2 miles	-0.5675	0.2092	-2.71
Piecewise linear distance 2-5 miles	-0.1760	0.0604	-2.91
Piecewise linear distance 5Plus miles	-0.1099	0.0142	-7.76
Mode Choice Logsum (Zones in SF County)*	0.5358	--	--
Mode Choice Logsum (Zones outside SF County)*	0.3436	--	--
Missing Mode Choice Logsum	0.1861	--	--
Summary Statistics			
Number of Observations	477		
Initial Log-Likelihood	-2115.5		
Log-Likelihood at Convergence	-1393.5		
Rho-squared at Convergence	0.341		
Adjusted Rho-squared at Convergence	0.334		

** Coefficients constrained. No t-values available.*

Table 21. Primary Destination Choice Model Estimation Results for Other Purpose Tours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of Retail Employment (Zones in SF County)	0.3018	0.0222	13.57
Logarithm of Service Employment (Zones in SF County)	0.1870	0.0193	9.67
Logarithm of Retail Employment (Zones outside SF County)	0.5177	0.0305	16.97
Total Area in Thousands of Acres	3.33E-02	1.27E-02	2.62
Destination Characteristics			
Average Household Income in Thousands of Dollars	4.29E-03	1.36E-03	3.17
Destination Zone is Home Zone Dummy	1.2381	0.1945	6.37
Eastern Destinations (Solano + Contra Costa + Alameda)	-1.2836	0.2512	-5.11
Origin-Destination Characteristics			
Origin & Dest are in CBD Dummy	0.2756	0.1516	1.82
Origin is in CBD & Dest is in UBD Dummy	0.3686	0.1772	2.08
Origin is in CBD & Dest is in an Urban/Suburban/Rural area Dummy	0.5075	0.2198	2.31
Origin is in an Urban area & Dest is in Core Dummy	0.3444	0.1686	2.04
Origin & Dest are in an Urban area Dummy	0.7958	0.1051	7.57
Origin-Destination Level of Service			
Piecewise linear distance 0-1 miles	-0.4822	0.1672	-2.88
Piecewise linear distance 1-2 miles	-0.8468	0.1214	-6.98
Piecewise linear distance 2-5 miles	-0.2481	0.0418	-5.93
Piecewise linear distance 5Plus miles	-0.1156	0.0128	-9.04
Mode Choice Logsum (Zones in SF County)	0.6755	0.0709	4.58
Mode Choice Logsum (Zones outside SF County)	0.2634	0.0947	7.78
Missing Mode Choice Logsum	0.9614	0.2156	4.46
Summary Statistics			
Number of Observations	1465		
Initial Log-Likelihood	-6280.4		
Log-Likelihood at Convergence	-4236.5		
Rho-squared at Convergence	0.325		
Adjusted Rho-squared at Convergence	0.322		

Table 22. Primary Destination Choice Model Estimation Results for Work Subtours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of Health Services Employment (Zones in SF County)	0.1047	0.0358	2.93
Logarithm of MIPS Employment (Zones in SF County)	0.1110	0.0421	2.63
Logarithm of Retail Employment (Zones in SF County)	0.2741	0.0510	5.37
Logarithm of Retail Employment (Zones outside SF County)	0.1724	0.1273	1.35
Logarithm of Service Employment (Zones outside SF County)	0.0996	0.1351	0.74
Logarithm of Other Employment (Zones outside SF County)	0.1722	0.1344	1.28
Logarithm of Agricultural Employment (Zones outside SF County)	0.0989	0.0914	1.08
Logarithm of Manufacturing Employment (Zones outside SF County)	0.1303	0.0683	1.91
Logarithm of Trade Employment (Zones outside SF County)	-0.1607	0.0792	-2.03
Households per Acre	-0.0092	0.0038	-2.45
Destination Characteristics			
Average Household Income in Thousands of Dollars	4.65E-03	2.52E-03	1.84
Destination Zone is Home Zone Dummy	4.8357	0.3772	12.82
Destination Zone is Work Zone Dummy	0.5167	0.2584	2.00
Origin-Destination Characteristics			
Origin & Dest are in CBD Dummy	0.7002	0.2527	2.77
Origin & Dest are in UBD Dummy	0.5185	0.3920	1.32
Origin is in UBD or Urban & Dest is in UBD or Urban	0.5095	0.3142	1.62
Origin & Destination are outside SF County	0.8755	0.6360	1.38
Origin-Destination Level of Service			
Piecewise linear distance 0-1 miles	-0.7913	0.2942	-2.69
Piecewise linear distance 1-2 miles	-0.9591	0.2400	-4.00
Piecewise linear distance 2-5 miles	-0.3555	0.0905	-3.93
Piecewise linear distance 5Plus miles	-0.1745	0.0400	-4.36
Mode Choice Logsum (Zones in SF County)	0.5136	0.0864	5.63
Mode Choice Logsum (Zones outside SF County)	0.1620	0.1015	8.26
Missing Mode Choice Logsum	0.4324	1.0976	0.39
Summary Statistics			
Number of Observations	391		
Initial Log-Likelihood	-1809.7		
Log-Likelihood at Convergence	-1114.4		
Rho-squared at Convergence	0.384		
Adjusted Rho-squared at Convergence	0.374		

Trip Destination Choice (Intermediate Stop Location Choice) Model estimation results

Tables 23 through 26 provide the results of the intermediate stop location choice models estimated for work, school, other purposes, and work subtours. Each model specification contains the estimates of the coefficients, the corresponding t-statistics and some summary statistics. A summary of the estimation results is provided below:

- As mentioned before, the trip purpose is not the same as the purpose assigned for model estimation (tour purpose). For this reason, no specific employment category can be attributed to attract such trips making it difficult to construct a suitable size variable. Individual employment categories are use in model estimation. Coefficients that are both reasonable and relatively significant are retained in the final recommended model. Since the employment reflects the size of the zone, a logarithmic form is used in the model. Wherever possible, the SF and MTC employment categories were used separately (instead of the four common categories) to take advantage of the classification scheme that is more appropriate for the city. A higher level of employment increases the probability of choosing the zone as shown by the positive coefficients on employment variables.
- A majority of the tours have both the main ends of the tour within San Francisco, so locations inside the city are preferred for intermediate stops, as illustrated by a strong positive coefficient on the corresponding dummy variable.
- The preference to keep the tours short, visit locations that are familiar and on the original path is shown by the inclination to stop in either the tour origin or primary destination zone.
- For home-based tours, the propensity to stop in the home zone is greater than that to stop in the primary destination zone on both directions – probably reflecting a higher level of familiarity with the locality. For instance, for stops made on work tours, on the forward half-tour, the coefficient for the origin zone is larger and stronger than that for the destination zone and vice-versa for the backward half-tour.
- As observed with the tour destination models, the trips tend to remain within the same area type, again showing an inclination to keep travel times short.
- The trip mode is constrained by the tour main mode, therefore, using a logsum variable from the trip mode choice model to capture overall utility of travel may not be appropriate for the intermediate stop location models. Auto travel time is instead used to capture the relative ease of travel to the potential choice of destinations. The coefficients are negative and significant and exhibit reasonable sensitivity in all models.

Table 23. Intermediate Stop Location Choice Model Estimation Results for Work tours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of Health Services Employment (Zones in SF County)	0.1434	0.0235	6.09
Logarithm of MIPS Employment (Zones in SF County)	0.1088	0.0277	3.93
Logarithm of Retail Employment (Zones in SF County)	0.2333	0.0338	6.91
Logarithm of Service Employment (Zones in SF County)	0.0625	0.0300	2.08
Logarithm of Retail Employment (Zones outside SF County)	0.4149	0.1165	3.56
Logarithm of Service Employment (Zones outside SF County)	0.2360	0.1249	1.89
Destination Characteristics			
Destination Zone is in SF County	2.0915	0.6929	3.02
O-D Characteristics for First Half-tour			
(From Origin/Home to Primary Destination)			
Stop Zone is Origin Zone Dummy	1.1558	0.3815	3.03
Stop Zone is Destination Zone Dummy	0.9733	0.3411	2.85
Origin Zone & Stop Zone are in CBD - Dummy	0.3926	0.2788	1.41
Origin Zone & Stop Zone are in UBD - Dummy	0.3497	0.2274	1.54
Origin Zone & Stop Zone are in an Urban area - Dummy	0.4848	0.2018	2.40
Stop Zone & Destination Zone are in Core - Dummy	0.9558	0.2494	3.83
Stop Zone & Destination Zone are in UBD - Dummy	0.5144	0.2821	1.82
Stop Zone & Destination Zone are in an Urban area - Dummy	-0.8718	0.3781	-2.31
O-D Characteristics for Latter Half-Tour			
(From Primary Destination to Home)			
Stop Zone is Origin Zone Dummy	0.6492	0.2590	2.51
Stop Zone is Destination Zone Dummy	1.2026	0.2765	4.35
Origin Zone & Stop Zone are in Core – Dummy	0.2400	0.1982	1.21
Stop Zone & Destination Zone are in Core – Dummy	-0.7299	0.3642	-2.00
Origin Zone & Stop Zone are in CBD – Dummy	0.3493	0.1859	1.88
Stop Zone & Destination Zone are in an Urban area – Dummy	0.3224	0.1416	2.28
Origin-Destination Level of Service			
Auto Travel Time	-0.0287	0.0046	-6.29
Summary Statistics			
Number of Observations	976		
Initial Log-Likelihood	-4068.5		
Log-Likelihood at Convergence	-3721.5		
Rho-squared at Convergence	0.085		
Adjusted Rho-squared at Convergence	0.080		

Table 24. Intermediate Stop Location Choice Model Estimation Results for School tours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of CIE Employment (Zones in SF County)	0.1737	0.0650	2.67
Logarithm of Health Services Emp (Zones in SF County)	0.1920	0.0527	3.64
Logarithm of MIPS Employment (Zones in SF County)	0.1033	0.0727	1.42
Logarithm of PDR Employment (Zones in SF County)	-0.1995	0.0644	-3.10
Logarithm of Retail Employment (Zones in SF County)	0.1480	0.0805	1.84
Logarithm of Retail Emp (Zones outside SF County)	1.2781	0.3311	3.86
Logarithm of Agricultural Emp (Zones outside SF County)	-0.6833	0.2530	-2.70
Logarithm of Trade Emp (Zones outside SF County)	0.2440	0.1487	1.64
Destination Characteristics			
School Zone Dummy (Zones in SF County)	0.5993	0.2092	2.86
Destination Zone is in SF County	4.4671	2.2419	1.99
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)			
Stop Zone is Origin Zone Dummy	2.6048	0.4578	5.69
Stop Zone is Destination Zone Dummy	2.9099	0.6137	4.74
Origin Zone & Stop Zone are in CBD - Dummy	4.0550	1.0889	3.72
Origin Zone & Stop Zone are in UBD - Dummy	1.0910	0.5582	1.95
Origin Zone & Stop Zone are in an Urban area - Dummy	0.4233	0.5698	0.74
Stop Zone & Destination Zone are in UBD - Dummy	-1.8220	0.7678	-2.37
Stop Zone & Destination Zone are in an Urban area – Dummy	1.4271	0.5772	2.47
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)			
Stop Zone is Origin Zone Dummy	1.8116	0.4843	3.74
Stop Zone is Destination Zone Dummy	2.0854	0.4469	4.67
Origin Zone & Stop Zone are in Core - Dummy	2.2140	1.0646	2.08
Stop Zone & Destination Zone are in Core - Dummy	2.8957	1.6921	1.71
Origin Zone & Stop Zone are in UBD - Dummy	-1.0409	0.5374	-1.94
Stop Zone & Destination Zone are in an Urban area – Dummy	0.9340	0.3525	2.65
Origin-Destination Level of Service			
Auto Travel Time	-0.0740	0.0164	-4.51
Summary Statistics			
Number of Observations	178		
Initial Log-Likelihood	-761.1		
Log-Likelihood at Convergence	-575.6		
Rho-squared at Convergence	0.244		
Adjusted Rho-squared at Convergence	0.212		

Table 25. Intermediate Stop Location Choice Model Estimation Results for Other tours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of Health Services Employment (Zones in SF County)	0.2060	0.0236	8.72
Logarithm of MIPS Employment (Zones in SF County)	0.0957	0.0356	2.69
Logarithm of Retail Employment (Zones in SF County)	0.1871	0.0402	4.65
Logarithm of Retail Employment (Zones outside SF County)	0.2854	0.0393	7.26
Total Area in Acres	0.0006	0.0001	4.71
Destination Characteristics			
Eastern Destinations (Solano + Contra Costa)	1.4305	0.5452	2.62
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)			
Stop Zone is Origin Zone Dummy	1.8611	0.3015	6.17
Stop Zone is Destination Zone Dummy	1.4436	0.2729	5.29
Origin Zone & Stop Zone are in an Urban area - Dummy	0.6929	0.2149	3.22
Stop Zone & Destination Zone are in Core - Dummy	0.5372	0.3137	1.71
Stop Zone & Destination Zone are in CBD - Dummy	0.8464	0.2900	2.92
Stop Zone & Destination Zone are in a Suburban area - Dummy	1.0880	0.9322	1.17
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)			
Stop Zone is Origin Zone Dummy	1.3179	0.2875	4.58
Stop Zone is Destination Zone Dummy	1.0416	0.4360	2.39
Origin Zone & Stop Zone are in Core - Dummy	0.9237	0.3239	2.85
Origin Zone & Stop Zone are in CBD - Dummy	0.6657	0.2716	2.45
Origin Zone & Stop Zone are in UBD - Dummy	0.5865	0.2587	2.27
Origin Zone & Stop Zone are in an Urban area - Dummy	0.9939	0.3388	2.93
Stop Zone & Destination Zone are in UBD - Dummy	0.3868	0.2853	1.36
Stop Zone & Destination Zone are in an Urban area - Dummy	0.4639	0.2647	1.75
Origin-Destination Level of Service			
Auto Travel Time	-0.0323	0.0080	-4.02
Summary Statistics			
Number of Observations	643		
Initial Log-Likelihood	-2762.6		
Log-Likelihood at Convergence	2494.7		
Rho-squared at Convergence	0.097		
Adjusted Rho-squared at Convergence	0.089		

Table 26. Intermediate Stop Location Choice Model Estimation Results for Work Subtours

Attribute	Coefficient	Standard Error	t-statistic
Destination Size Attributes			
Logarithm of MIPS Employment (All Zones)	0.5040	0.0841	5.99
Logarithm of Retail Employment (All Zones)	0.0812	0.0991	0.82
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)			
Stop Zone is Home Zone Dummy	5.5918	1.0822	5.17
Stop Zone is Destination Zone Dummy	1.3947	0.5293	2.63
Origin Zone & Stop Zone are in UBD - Dummy	1.2938	0.8882	1.46
Origin Zone & Stop Zone are in an Urban area – Dummy	-1.0079	0.7321	-1.38
Stop Zone & Destination Zone are in Core - Dummy	2.5050	1.0496	2.39
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)			
Stop Zone is Home Zone Dummy	6.3368	0.6377	9.94
Stop Zone is Origin Zone Dummy	1.6583	0.4413	3.76
Stop Zone is Destination Zone Dummy	0.5626	0.5992	0.94
Origin Zone & Stop Zone are in Core - Dummy	1.2850	0.5371	2.39
Stop Zone & Destination Zone are in CBD - Dummy	1.5085	0.6734	2.24
Origin Zone & Stop Zone are in UBD - Dummy	1.9386	0.5951	3.26
Stop Zone & Destination Zone are in UBD - Dummy	-1.6978	0.8859	-1.92
Origin-Destination Level of Service			
Auto Travel Time - To Stop Zones in SF County	-0.0285	0.0229	-1.25
Auto Travel Time - To Stop Zones outside SF County	-0.1336	0.0307	-4.35
Summary Statistics			
Number of Observations	120		
Initial Log-Likelihood	-542.1		
Log-Likelihood at Convergence	-373.8		
Rho-squared at Convergence	0.311		
Adjusted Rho-squared at Convergence	0.281		

Model Application

All of the models in this chapter were incorporated into two C++ programs:

- SFTOURMC.EXE, which is the combined tour destination choice/mode choice program
- SFISTOP.EXE, which is the intermediate stop choice program (also known as trip destination choice)

There are two modes for the destination choice/tour mode choice program.

- Mode 1 is used to generate workplace locations for workers in the sample file.
- Mode 2 is used to determine the primary destination and choice of mode for all tours in the sample file.

The combined tour destination choice/mode choice program is called 'SFTOURMC.EXE'. To run the program, type:

SFTOURMC *n*

at a DOS prompt, where *n* is 1 for workplace location mode, and 2 is mode/destination choice mode.

APPENDIX A. Work Tour Destination Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Size Specification	
Log-Sum-Multiplier	0.6534
Total Employment (All Zones)	1.0000
SF CIE Employment (Zones in SF County)*	2.7037
SF MIPS Employment (Zones in SF County)*	1.4717
SF PDR Employment (Zones in SF County)*	1.9357
SF Retail Employment (Zones in SF County)*	2.5079
MTC Other Employment (Zones outside SF County)*	0.9736
Destination Characteristics	
Average Household Income in Thousands of Dollars	0.0020
Destination is in Core or CBD	2.0000
Destination is in UBD	1.9000
Destination is in an Urban or Suburban area	1.1000
Destination Zone is in SF County	1.4758
Destination Zone is in Silicon Valley (Santa Clara)	2.1118
Destination Zone is in Oakland (Alameda)	0.9627
Southern Destinations (San Mateo)	1.9281
Northern Destinations (Marin + Sonoma + Napa)	0.9500
Origin-Destination Characteristics	
Destination Zone is Home Zone Dummy	4.4950
Origin & Dest are in Core Dummy	0.5000
Origin & Dest are in CBD Dummy	0.4000
Origin & Dest are in UBD Dummy	0.3352
Origin & Dest are in an Urban area Dummy	1.1000
Origin-Destination Level of Service	
Piecewise linear distance 0-3 miles	-0.4735
Piecewise linear distance 3Plus miles	-0.0551
Mode Choice Logsum	0.0921
Missing Mode Choice Logsum	-1.6603
Summary Statistics	
Number of Observations	1627
Log-Likelihood with Zero Coefficients	-6001.8
Initial Log-Likelihood	-6726.9
Log-Likelihood at Convergence	-5010.9
Rho-squared at Convergence	0.255
Adjusted Rho-squared at Convergence	0.252
Rho-squared w.r.t. Zero at Convergence	0.165
Adjusted Rho-squared w.r.t. Zero at Convergence	0.161

APPENDIX B. School Tour Primary Destination Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
School Area in Thousands of Square Feet (Zones in SF County)	4.14E-04
High School Enrolment (in Thousands)	8.53E-01
Full-time College Enrolment (in Thousands)	4.12E-02
Part-time College Enrolment (in Thousands)	7.64E-02
Logarithm of Number of Households	8.57E-02
Service Employment (Zones outside SF County)	2.56E-04
Destination Characteristics	
School Zone Dummy (Zones in SF County)	0.5675
College Zone Dummy	1.6334
Number of School Buildings (Zones in SF County)	0.2779
Origin-Destination Level of Service	
Piecewise linear distance 0-1 miles	-0.6807
Piecewise linear distance 1-2 miles	-0.5675
Piecewise linear distance 2-5 miles	-0.1760
Piecewise linear distance 5Plus miles	-0.1099
Mode Choice Logsum (Zones in SF County)*	0.5358
Mode Choice Logsum (Zones outside SF County)*	0.3436
Missing Mode Choice Logsum	0.1861
Summary Statistics	
Number of Observations	477
Initial Log-Likelihood	-2115.5
Log-Likelihood at Convergence	-1393.5
Rho-squared at Convergence	0.341
Adjusted Rho-squared at Convergence	0.334

APPENDIX C. Other Tour Primary Destination Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of Retail Employment (Zones in SF County)	0.3018
Logarithm of Service Employment (Zones in SF County)	0.1870
Logarithm of Retail Employment (Zones outside SF County)	0.5177
Total Area in Thousands of Acres	3.33E-02
Destination Characteristics	
Average Household Income in Thousands of Dollars	4.29E-03
Destination Zone is Home Zone Dummy	1.2381
Eastern Destinations (Solano + Contra Costa + Alameda)	-1.2836
Origin-Destination Characteristics	
Origin & Dest are in CBD Dummy	0.2756
Origin is in CBD & Dest is in UBD Dummy	0.3686
Origin is in CBD & Dest is in an Urban/Suburban/Rural area Dummy	0.5075
Origin is in an Urban area & Dest is in Core Dummy	0.3444
Origin & Dest are in an Urban area Dummy	0.9000
Origin-Destination Level of Service	
Piecewise linear distance 0-1 miles	-0.4822
Piecewise linear distance 1-2 miles	-0.8468
Piecewise linear distance 2-5 miles	-0.2481
Piecewise linear distance 5Plus miles	-0.1156
Mode Choice Logsum (Zones in SF County)	0.6755
Mode Choice Logsum (Zones outside SF County)	0.2634
Missing Mode Choice Logsum	0.9614
Summary Statistics	
Number of Observations	1465
Initial Log-Likelihood	-6280.4
Log-Likelihood at Convergence	-4236.5
Rho-squared at Convergence	0.325
Adjusted Rho-squared at Convergence	0.322

APPENDIX D. Work Subtour Primary Destination Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of Health Services Employment (Zones in SF County)	0.1047
Logarithm of MIPS Employment (Zones in SF County)	0.1110
Logarithm of Retail Employment (Zones in SF County)	0.2741
Logarithm of Retail Employment (Zones outside SF County)	0.1724
Logarithm of Service Employment (Zones outside SF County)	0.0996
Logarithm of Other Employment (Zones outside SF County)	0.1722
Logarithm of Agricultural Employment (Zones outside SF County)	0.0989
Logarithm of Manufacturing Employment (Zones outside SF County)	0.1303
Logarithm of Trade Employment (Zones outside SF County)	-0.1607
Households per Acre	-0.0092
Destination Characteristics	
Average Household Income in Thousands of Dollars	4.65E-03
Destination Zone is Home Zone Dummy	4.8357
Destination Zone is Work Zone Dummy	0.5167
Origin-Destination Characteristics	
Origin & Dest are in CBD Dummy	0.80021
Origin & Dest are in UBD Dummy	0.30000
Origin is in UBD or Urban & Dest is in UBD or Urban	0.5095
Origin & Destination are outside SF County	0.8755
Origin-Destination Level of Service	
Piecewise linear distance 0-1 miles	-0.7913
Piecewise linear distance 1-2 miles	-0.9591
Piecewise linear distance 2-5 miles	-0.3555
Piecewise linear distance 5Plus miles	-0.1745
Mode Choice Logsum (Zones in SF County)	0.5136
Mode Choice Logsum (Zones outside SF County)	0.1620
Missing Mode Choice Logsum	0.4324
Summary Statistics	
Number of Observations	391
Initial Log-Likelihood	-1809.7
Log-Likelihood at Convergence	-1114.4
Rho-squared at Convergence	0.384
Adjusted Rho-squared at Convergence	0.374

APPENDIX E. Work Tour Intermediate Stop Location Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of Health Services Employment (Zones in SF County)	0.1434
Logarithm of MIPS Employment (Zones in SF County)	0.1088
Logarithm of Retail Employment (Zones in SF County)	0.2333
Logarithm of Service Employment (Zones in SF County)	0.0625
Logarithm of Retail Employment (Zones outside SF County)	0.4149
Logarithm of Service Employment (Zones outside SF County)	0.2360
Destination Characteristics	
Destination Zone is in SF County	2.0915
O-D Characteristics for First Half-tour	
(From Origin/Home to Primary Destination)	
Stop Zone is Origin Zone Dummy	1.1558
Stop Zone is Destination Zone Dummy	0.9733
Origin Zone & Stop Zone are in CBD - Dummy	0.3926
Origin Zone & Stop Zone are in UBD - Dummy	0.3497
Origin Zone & Stop Zone are in an Urban area - Dummy	0.4848
Stop Zone & Destination Zone are in Core - Dummy	0.9558
Stop Zone & Destination Zone are in UBD - Dummy	0.5144
Stop Zone & Destination Zone are in an Urban area - Dummy	-0.8718
O-D Characteristics for Latter Half-Tour	
(From Primary Destination to Home)	
Stop Zone is Origin Zone Dummy	0.6492
Stop Zone is Destination Zone Dummy	1.2026
Origin Zone & Stop Zone are in Core – Dummy	0.2400
Stop Zone & Destination Zone are in Core – Dummy	-0.7299
Origin Zone & Stop Zone are in CBD – Dummy	0.3493
Stop Zone & Destination Zone are in an Urban area – Dummy	0.3224
Origin-Destination Level of Service	
Auto Travel Time	-0.0287
Summary Statistics	
Number of Observations	976
Initial Log-Likelihood	-4068.5
Log-Likelihood at Convergence	-3721.5
Rho-squared at Convergence	0.085
Adjusted Rho-squared at Convergence	0.080

APPENDIX F. School Tour Intermediate Stop Location Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of CIE Employment (Zones in SF County)	0.1737
Logarithm of Health Services Emp (Zones in SF County)	0.1920
Logarithm of MIPS Employment (Zones in SF County)	0.1033
Logarithm of PDR Employment (Zones in SF County)	-0.1995
Logarithm of Retail Employment (Zones in SF County)	0.1480
Logarithm of Retail Emp (Zones outside SF County)	1.2781
Logarithm of Agricultural Emp (Zones outside SF County)	-0.6833
Logarithm of Trade Emp (Zones outside SF County)	0.2440
Destination Characteristics	
School Zone Dummy (Zones in SF County)	0.5993
Destination Zone is in SF County	4.4671
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)	
Stop Zone is Origin Zone Dummy	2.6048
Stop Zone is Destination Zone Dummy	0.9099
Origin Zone & Stop Zone are in CBD - Dummy	4.0550
Origin Zone & Stop Zone are in UBD - Dummy	1.0910
Origin Zone & Stop Zone are in an Urban area - Dummy	0.4233
Stop Zone & Destination Zone are in UBD - Dummy	-1.8220
Stop Zone & Destination Zone are in an Urban area – Dummy	1.4271
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)	
Stop Zone is Origin Zone Dummy	1.8116
Stop Zone is Destination Zone Dummy	2.0854
Origin Zone & Stop Zone are in Core - Dummy	2.2140
Stop Zone & Destination Zone are in Core - Dummy	2.8957
Origin Zone & Stop Zone are in UBD - Dummy	-1.0409
Stop Zone & Destination Zone are in an Urban area – Dummy	0.9340
Origin-Destination Level of Service	
Auto Travel Time	-0.0740
Summary Statistics	
Number of Observations	178
Initial Log-Likelihood	-761.1
Log-Likelihood at Convergence	-575.6
Rho-squared at Convergence	0.244
Adjusted Rho-squared at Convergence	0.212

APPENDIX G. Other Tour Intermediate Stop Location Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of Health Services Employment (Zones in SF County)	0.2060
Logarithm of MIPS Employment (Zones in SF County)	0.0957
Logarithm of Retail Employment (Zones in SF County)	0.1871
Logarithm of Retail Employment (Zones outside SF County)	0.2854
Total Area in Acres	0.0006
Destination Characteristics	
Eastern Destinations (Solano + Contra Costa)	1.4305
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)	
Stop Zone is Origin Zone Dummy	3.76107
Stop Zone is Destination Zone Dummy	2.84359
Origin Zone & Stop Zone are in an Urban area - Dummy	0.6929
Stop Zone & Destination Zone are in Core - Dummy	0.5372
Stop Zone & Destination Zone are in CBD - Dummy	0.8464
Stop Zone & Destination Zone are in a Suburban area - Dummy	1.0880
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)	
Stop Zone is Origin Zone Dummy	2.61788
Stop Zone is Destination Zone Dummy	2.04156
Origin Zone & Stop Zone are in Core - Dummy	0.9237
Origin Zone & Stop Zone are in CBD - Dummy	0.6657
Origin Zone & Stop Zone are in UBD - Dummy	0.5865
Origin Zone & Stop Zone are in an Urban area - Dummy	0.9939
Stop Zone & Destination Zone are in UBD - Dummy	0.3868
Stop Zone & Destination Zone are in an Urban area - Dummy	0.4639
Origin-Destination Level of Service	
Auto Travel Time	-0.0323
Summary Statistics	
Number of Observations	643
Initial Log-Likelihood	-2762.6
Log-Likelihood at Convergence	2494.7
Rho-squared at Convergence	0.097
Adjusted Rho-squared at Convergence	0.089

APPENDIX H. Work Subtour Intermediate Stop Location Choice: final calibrated model

Attribute	Coefficient
Destination Size Attributes	
Logarithm of MIPS Employment (All Zones)	0.5040
Logarithm of Retail Employment (All Zones)	0.0812
O-D Characteristics for First Half-tour (From Origin/Home to Primary Destination)	
Stop Zone is Home Zone Dummy	5.5918
Stop Zone is Destination Zone Dummy	0.35471
Origin Zone & Stop Zone are in UBD - Dummy	1.2938
Origin Zone & Stop Zone are in an Urban area – Dummy	-1.0079
Stop Zone & Destination Zone are in Core - Dummy	2.5050
O-D Characteristics for Latter Half-Tour (From Primary Destination to Home)	
Stop Zone is Home Zone Dummy	6.3368
Stop Zone is Origin Zone Dummy	2.0583
Stop Zone is Destination Zone Dummy	0.7626
Origin Zone & Stop Zone are in Core - Dummy	1.2850
Stop Zone & Destination Zone are in CBD - Dummy	1.5085
Origin Zone & Stop Zone are in UBD - Dummy	1.9386
Stop Zone & Destination Zone are in UBD - Dummy	-1.6978
Origin-Destination Level of Service	
Auto Travel Time - To Stop Zones in SF County	-0.0285
Auto Travel Time - To Stop Zones outside SF County	-0.1336
Summary Statistics	
Number of Observations	120
Initial Log-Likelihood	-542.1
Log-Likelihood at Convergence	-373.8
Rho-squared at Convergence	0.311
Adjusted Rho-squared at Convergence	0.281

APPENDIX I. Files for Running the Destination Choice Models

HWYxx.MAT - The highway skim files by time period (EN, AM, MD, PM)

TRNyyyxx.MAT - The transit skim files by mode of access and egress (walk and auto) and time period (yyy = ATW,WTA,WTW, xx = EA, AM, MD, PM, EV)

TAZDATA.DAT - The zonal data file. 1738 records in space delimited format

SFSAMPzz.TXT – The sample file in space delimited format (zz = last two digits of year of interest)

ZONEEQUIV.DAT - The zonal equivalence file in space delimited format

NODES.TXT - The node file

SFTOURMC.CPP and SFTOURMC.EXE – the combined destination and mode choice code and executable files. It uses the output from the tour generation/time of day models plus the input files above. It creates TOURDC.OUT and TOURDC.RPT, which is a report file output.

SFISTOP.CPP and SFISTOP.EXE – the intermediate stop choice code and executable files. It uses the output from the trip mode choice model, plus the input files above to create TOURIS.OUT and TOURIS.RPT, which is a report file output.