San Francisco Travel Demand Forecasting Model Development

Model Validation

Final Report

prepared for
San Francisco County Transportation Authority

prepared by
Cambridge Systematics, Inc.

Updated by:
San Francisco County Transportation Authority

October 1, 2002

Table of Contents

Introduction

The San Francisco County Travel Demand Forecasting Model (San Francisco Model) was developed for the San Francisco County Transportation Authority (SFCTA) to provide detailed forecasts of travel demand for various planning applications. These applications included developing countywide plans, providing input to microsimulation modeling for corridor and project-level evaluations, transit planning, and neighborhood planning. The objective was to accurately represent the complexity of the destination, temporal and modal options and provide detailed information on travelers making discrete choices. These objectives led to the development of an activity-based model that uses synthesized population as the basis for decision-making rather than zonal-level aggregate data sources. In its current form, the activity-based model has eight primary components. A ninth model component (to perform peak spreading) is currently under development.

The model components were estimated using household survey data collected by the Metropolitan Transportation Commission (MTC) for San Francisco residents only. Each model component was calibrated using various observed data sources, then the full model was validated using traffic count and transit ridership data for each of five time periods. The model is applied as a focused model, which combines trip making from the entire Bay Area (derived from the MTC's BAYCAST trip tables) with the travel demand from San Francisco residents produced by the activity-based model.

This validation report includes a discussion of the validation tests that were completed for travel behavior and trip assignment components of the model. In addition, a summary of the overall indication of the results is presented.

Trip Behavior Validation

Trip behavior can be validated by comparing trip data in a household travel survey to related trip data in a travel demand-forecasting model. For the validation of the current 1998 SFCTA regional travel demand-forecasting model, we compared the trip data in the 1990 Census, the 1990 MTC household survey data with the same data in the model. These results are presented by model component in the following sections.

The model components were calibrated individually using various observed data sources. This effort involved calibrating each model separately, then reviewing highway and transit assignment results for each of the five time periods to make additional adjustments in the model components. The adjustments were all made to constants within the models, there were no adjustments to model coefficients[1]. The results of the calibration are summarized below for each model component.

Vehicle Availability

The vehicle availability model was calibrated primarily on two key variables, number of workers per household and MTC super-district[2], using the 1990 Census as the primary source of observed data. Table 1 presents a summary of the households by vehicle availability categories that were estimated in each super-district by comparing the 1998 San Francisco model and the 1990 Census. Figure 1 presents a summary of the validation of vehicle availability for number of workers in a household; these results were considered to be very reliable.

A second validation test was used to evaluate the total number of vehicles estimated by the vehicle availability model compared to Department of Motor Vehicle (DMV) estimates of auto registrations. These data were provided by zip code, which was not directly compatible with our traffic analysis zones, so it was determined to use these data on a countywide basis. The DMV estimates of auto registrations in 1998 were 353,717 vehicles compared to the San Francisco model, which estimated 338,076 vehicles in 1998. This represents a difference of 5 percent. The calculation of vehicles from the San Francisco model assumes that there are an average of 3.3 vehicles per household for any household with 3 or more vehicles, an assumption that was derived from the 1990 MTC survey data.

[1] The exception to this is that the pedestrian environmental factor (PEF) variables' coefficients were reduced, because the mode choice models were too sensitive to changes in the variables' values.

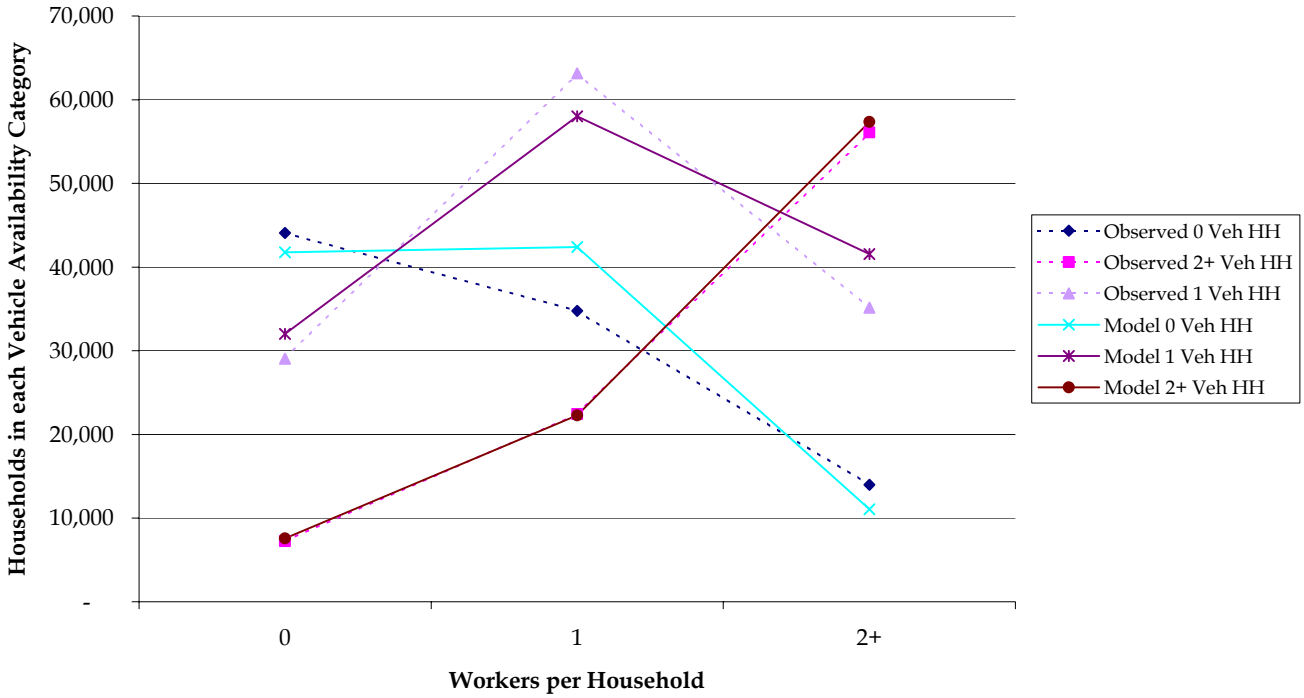
[2] MTC has defined four super-districts in San Francisco. They are numbered as followed: 1. northeastern quadrant; 2. northwestern quadrant; 3. southeastern quadrant; and 4. southwestern quadrant.

Table 1. Comparison of Households by Vehicles Available and Super-District[3]

Super-District	Number of Vehicles			
1998 SF Model	0	1	2+	Total
1	12.7%	6.4%	2.4%	21.4%
2	8.5%	14.4%	7.8%	30.6%
3	6.9%	14.5%	11.6%	33.0%
4	2.3%	6.7%	6.0%	15.0%
Total	30.3%	41.9%	27.8%	100%
1990 MTC Model				
1	11.6%	5.6%	1.7%	19.0%
2	8.7%	15.0%	7.7%	31.4%
3	7.7%	14.5%	11.9%	34.1%
4	2.4%	6.6%	6.6%	15.5%
Total	30.3%	41.6%	28.0%	100%
Differences				
1	1.0%	0.8%	0.6%	2.4%
2	-0.1%	-0.6%	0.0%	-0.7%
3	-0.8%	0.0%	-0.3%	-1.1%
4	-0.1%	0.2%	-0.6%	-0.6%
Total	0.0%	0.3%	-0.3%	0.0%

[3] See footnote two for the definition of the super-districts.

Figure 1. Comparison of Households by Vehicles Available and Workers per Household



Unfortunately, the 1990 MTC survey, which was used to estimate the model, contained different results for vehicle availability than the 1990 Census. These results are presented in Table 2. Since the 1990 Census has a much larger sample size, these data were used to calibrate the vehicle availability model. The results, therefore, have indirect effects on the market segmentation of autos and workers that were carried out in the mode split model. For instance, the MTC survey does not have as many zero-vehicle households as the 1990 Census; this can produce fewer than actual transit trips in the mode choice model.

Table 2. Comparison of 1990 Census and 1990 MTC Survey Households by Vehicles Available

	0 Vehicle Households	1 Vehicle Households	2+ Vehicle Households
1990 MTC Survey	25.5%	42.9%	31.6%
1990 Census	30.3%	41.6%	28.0%

Full-Day Pattern Tour Models

The full-day pattern tour models were calibrated by converting tours to trips and comparing these to the 1996 MTC Survey, expanded to match the 1998 population. The MTC survey trips were summarized as only those weekday trips in the survey that had an origin and destination within San Francisco County. The comparison of trips was developed from the full-day pattern tour model by reallocating the following "trips" from each "tour" for comparison purposes, as presented in Table 3.

Table 3. Identification of Trips by Tour Purpose

Trips	Home-based Work Tours	Home-based School Tours	Home-based Other Tours	Work-based Tours
Home-Work and Work-Home	✓			
Home-School and School-Home		✓		
Home-Other and Other –Home	✓	✓	✓	
Other-Work	✓			
Other-School and School-Other		✓		
Work-Other				✓
Other-Other	✓	✓	✓	✓

The 1996 MTC Survey was used because the number of trips within San Francisco County was very low in the 1990 MTC Survey because of under-reporting of trips that occurred in this survey. A comparison of the trips by time of day from the 1990 and 1996 MTC surveys, expanded to represent 1998 population, is presented in Table 4. The under-reporting of trips is not consistent across time periods or across trip purposes, which may have influenced model estimation that was based on the 1990 MTC survey.

Table 4. Observed Trips by Time Period Made by San Francisco Residents

	1990 MTC survey	1996 MTC survey	Percent Difference
Early	15,947	32,135	102%
AM	463,432	502,516	8%
Midday	855,688	1,088,855	27%
PM	536,895	646,500	20%
Late	397,779	668,817	68%
Total	2,269,741	2,938,823	29%

The differences between trips by time period was confirmed with initial assignments by time periods using the uncalibrated San Francisco model that revealed the off-peak time periods were significantly under-estimated compared to traffic counts. This evaluation led to investigation of the MTC surveys and the recommendation that the 1996 MTC survey be used for model calibration. This led to revisions of the full-day pattern tour models to increase other tours and work-based tours during these time periods.

There were other differences between the 1990 and 1996 MTC survey by tour type that were notable. The biggest difference was in other tours, where the 1996 survey captured 53 percent more trips than the 1990 survey. This would mean that the vast majority of under-reporting of trips in the 1990 MTC survey were in other tours. Table 5 summarizes these results.

Table 5. Observed Trips by Tour Type Made by San Francisco Residents

	1990 MTC survey	1996 MTC survey	Percent Difference
Work	867,635	995,642	15%
School	176,252	187,420	6%
Other	963,686	1,473,956	53%
Work-based	262,168	281,805	7%
Total	2,269,741	2,938,823	29%

The comparison of the 1990 and 1996 MTC survey trip rates with the San Francisco model trip rates by tour type is presented in Figure 2. This figure highlights the differences between the 1990 and 1996 surveys, in terms of trip rates per household.

Figure 2. Comparison of Observed and Estimated Trip Rates by Source and Tour Type

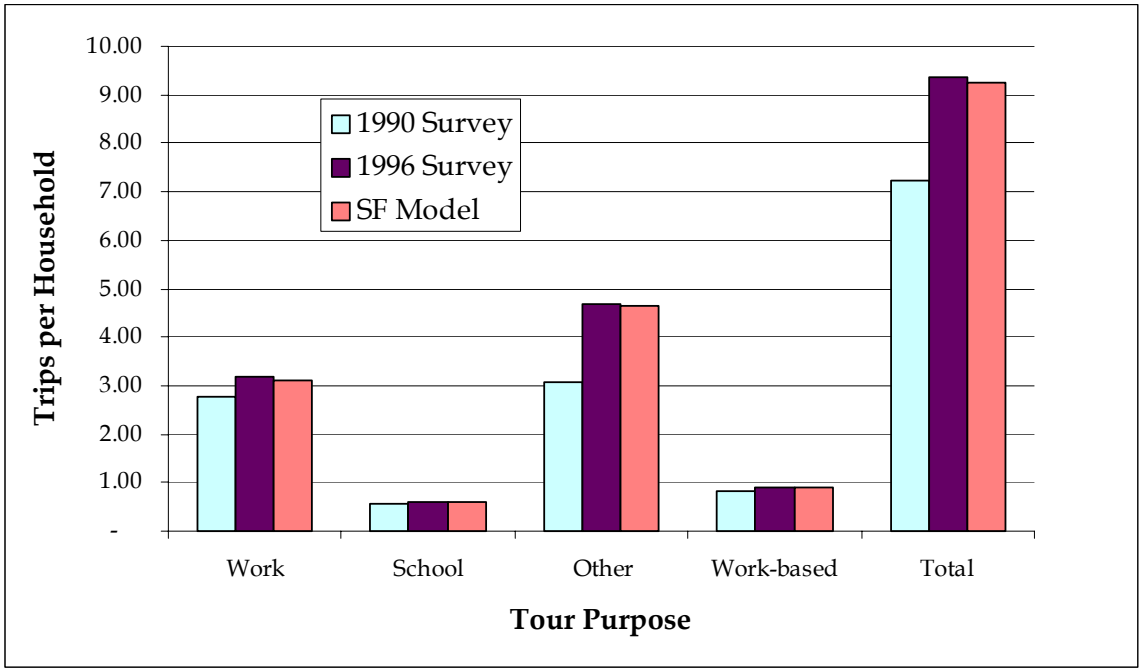


Table 6 presents a comparison of the calibrated San Francisco model trips to the 1996 MTC survey by tour type and time of day. The table shows that all trips by tour type and by time of day are within +/- 10 percent compared to the 1996 MTC survey. The most notable differences in this comparison are the home-based other trips made by non-workers in the midday, which are over-estimated in the San Francisco model, and the work and other trips made by workers in the evening time period, which are under-estimated in the San Francisco model. (Again, these differences are probably a result of the under-reporting errors (or other differences) in the 1990 MTC survey used for model estimation.)

Table 6. Comparison of Observed and Estimated Internal San Francisco Trips by Tour Type and Time of Day

Person type	Tour type	Early	AM peak	Midday	PM peak	Late	Total trips
MTC Weekday Trips from 1996 Household Survey (Expanded to 1998 population)							
Worker	HBWork	25,804	271,795	224,231	279,366	194,446	995,642
Worker	HBOther	1,589	65,930	162,559	124,763	264,685	619,526
Worker	WkBased	-	5,372	230,630	32,883	12,920	281,805
Student	HBEduc	1,464	76,155	78,813	27,557	3,431	187,420
Student	HBOther	446	11,448	62,516	45,189	49,875	169,474
Other	HBOther	2,832	71,816	330,106	136,742	143,460	684,956
Total	Total	32,135	502,516	1,088,855	646,500	668,817	2,938,823
Calibrated SF Model Trips							
Worker	HBWork	27,917	290,860	212,751	290,499	155,271	977,298
Worker	HBOther	706	46,004	151,387	130,711	232,410	561,218
Worker	WkBased	91	6,696	238,201	24,210	10,239	279,437
Student	HBEduc	87	74,527	80,605	25,844	4,954	186,017
Student	HBOther	62	18,073	43,796	47,275	48,498	157,704
Other	HBOther	823	67,594	399,030	125,255	144,809	737,511
Total	Total	29,686	503,754	1,125,770	643,794	596,181	2,899,185
Difference between observed and estimated trips							
Worker	HBWork	8.2%	7.0%	-5.1%	4.0%	-20.1%	-1.8%
Worker	HBOther	-55.6%	-30.2%	-6.9%	4.8%	-12.2%	-9.4%
Worker	WkBased		24.6%	3.3%	-26.4%	-20.8%	-0.8%
Student	HBEduc	-94.1%	-2.1%	2.3%	-6.2%	44.4%	-0.7%
Student	HBOther	-86.1%	57.9%	-29.9%	4.6%	-2.8%	-6.9%
Other	HBOther	-70.9%	-5.9%	20.9%	-8.4%	0.9%	7.7%
Total	Total	-7.6%	0.2%	3.4%	-0.4%	-10.9%	-1.3%

Trip rates per household were compared by trip purpose and time of day and are presented in Table 7, with expected results. This table reports the comparison of trips internal to San Francisco County only, because the model derives external trips from the regional model. Trip rates overall are similar, but the trips per household by trip purpose are quite different. For example, the model under-estimates work and school trips compared to the MTC survey, but this can be attributed to the definition of a trip to work or home in the survey containing all trips to and from work or school. The San Francisco model differentiates between trips to work or school with an intermediate stop from those without an intermediate stop and thus has fewer trips identified as work or school trips and many more trips identified as non-home-based. The comparison of trip rates across time period is reasonable, except that early AM and evening time periods are somewhat under-estimated compared to the MTC survey. This is most likely a result of the model estimation process, which was based on the 1990 MTC survey that showed significantly fewer trips in these time periods.

Table 7. Comparison of Observed and Estimated Internal San Francisco Trip Rates by Purpose and Time of Day

	Trips		Trips per HH		Percent
Trip Purpose	**Observed (MTC)**	**Estimated (SFCTA)**	**Observed (MTC)**	**Estimated (SFCTA)**	**Difference**
Work	995,642	353,360	3.17	1.13	-65%
School	187,420	123,127	0.60	0.39	-34%
Other	1,473,956	1,367,285	4.69	4.35	-7%
Non-home-based	281,805	1,055,413	0.90	3.36	275%
Total	2,938,823	2,899,185	9.36	9.23	-1%
Time Period					
Early AM	32,135	29,686	0.10	0.09	-8%
AM Peak	502,516	503,754	1.60	1.60	0%
Midday	1,088,855	1,125,770	3.47	3.59	3%
PM Peak	646,500	643,794	2.06	2.05	0%
Evening	668,817	596,181	2.13	1.90	-11%
Total	2,938,823	2,899,185	9.36	9.23	-1%

Destination (Primary and Intermediate Stop) Choice Models

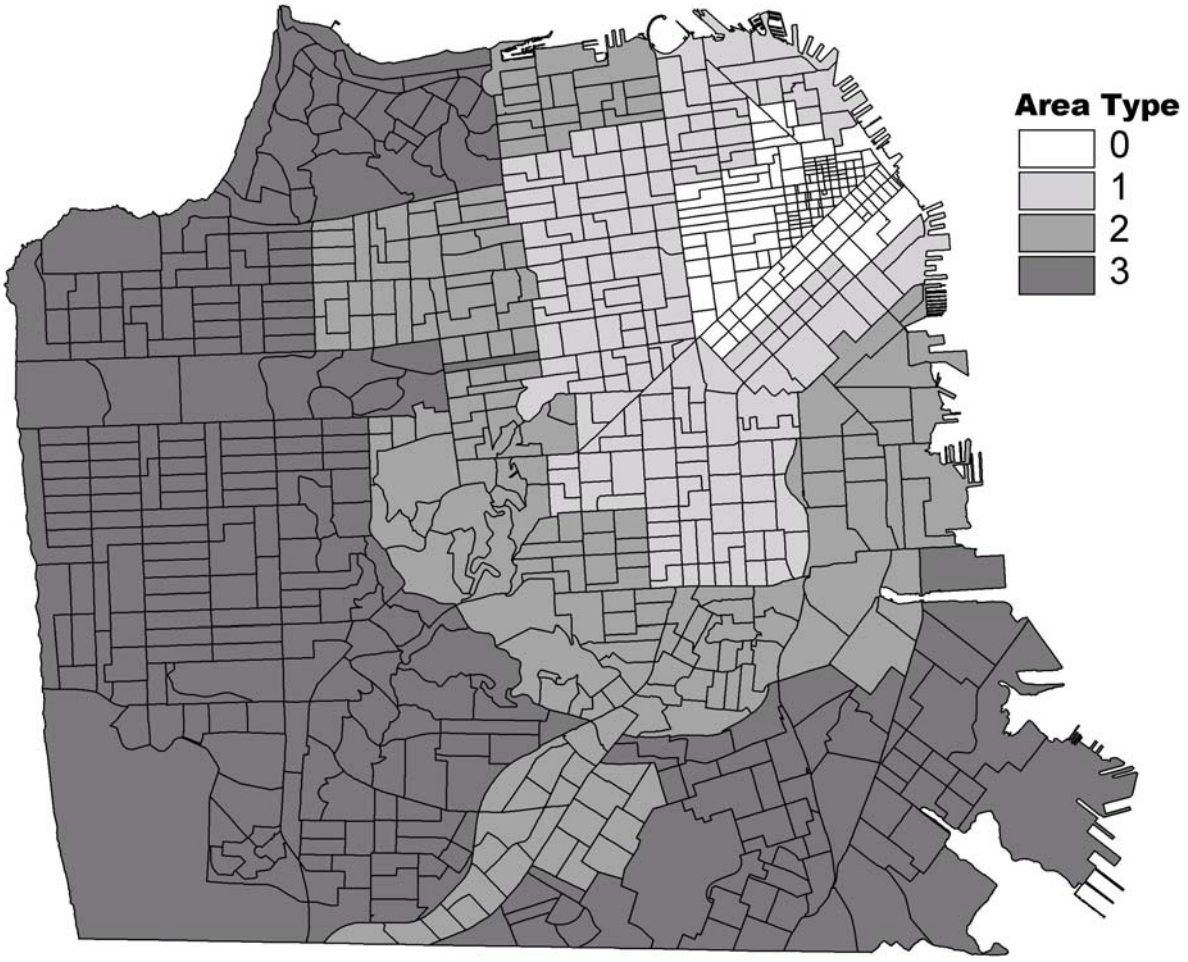
The destination choice models were calibrated against the 1990 MTC survey data for primary destinations by purpose and trip length frequency distributions. Table 8 presents the comparisons of destinations by location, defined by the four area types in San Francisco County and those destinations that reside outside the County. The area types are presented in Figure 3. These results reflect very reasonable allocation of destinations among these four areas of the City and those destinations located outside the City. The other and work-based sub-tours overestimate primary destinations outside of San Francisco County. It is possible, perhaps even likely, that this over-estimation is caused by discrepancies in the accuracy and level of detail for destinations within San Francisco and those located in other parts of the Bay Area. It is also possible that some of the differences arise from the under-reporting of trips in the 1990 MTC survey identified in the preceding section.

Table 8. Comparison of Observed and Estimated Primary Destinations by Location

Destinations[4] (by Area Type)	Observed	Estimated	Difference
Work Tours			
to the Core (0)	31%	33%	2%
to the CBD (1)	23%	23%	0%
to the UBD (2)	15%	17%	2%
to Urban Areas (3)	12%	9%	-3%
External to SF	19%	19%	0%
School Tours			
to the Core (0)	8%	12%	4%
to the CBD (1)	17%	20%	3%
to the UBD (2)	23%	22%	-1%
to Urban Areas (3)	46%	40%	-6%
External to SF	7%	7%	-1%
Other Tours			
to the Core (0)	15%	12%	-2%
to the CBD (1)	23%	24%	1%
to the UBD (2)	21%	17%	-4%
to Urban Areas (3)	32%	24%	-8%
External to SF	9%	23%	14%
Work-based Sub-Tours			
to the Core (0)	40%	38%	-2%
to the CBD (1)	29%	24%	-4%
to the UBD (2)	13%	15%	2%
to Urban Areas (3)	13%	10%	-4%
External to SF	5%	13%	9%

[4] Refer to Figure 3 for the locations of the zones with these area types.

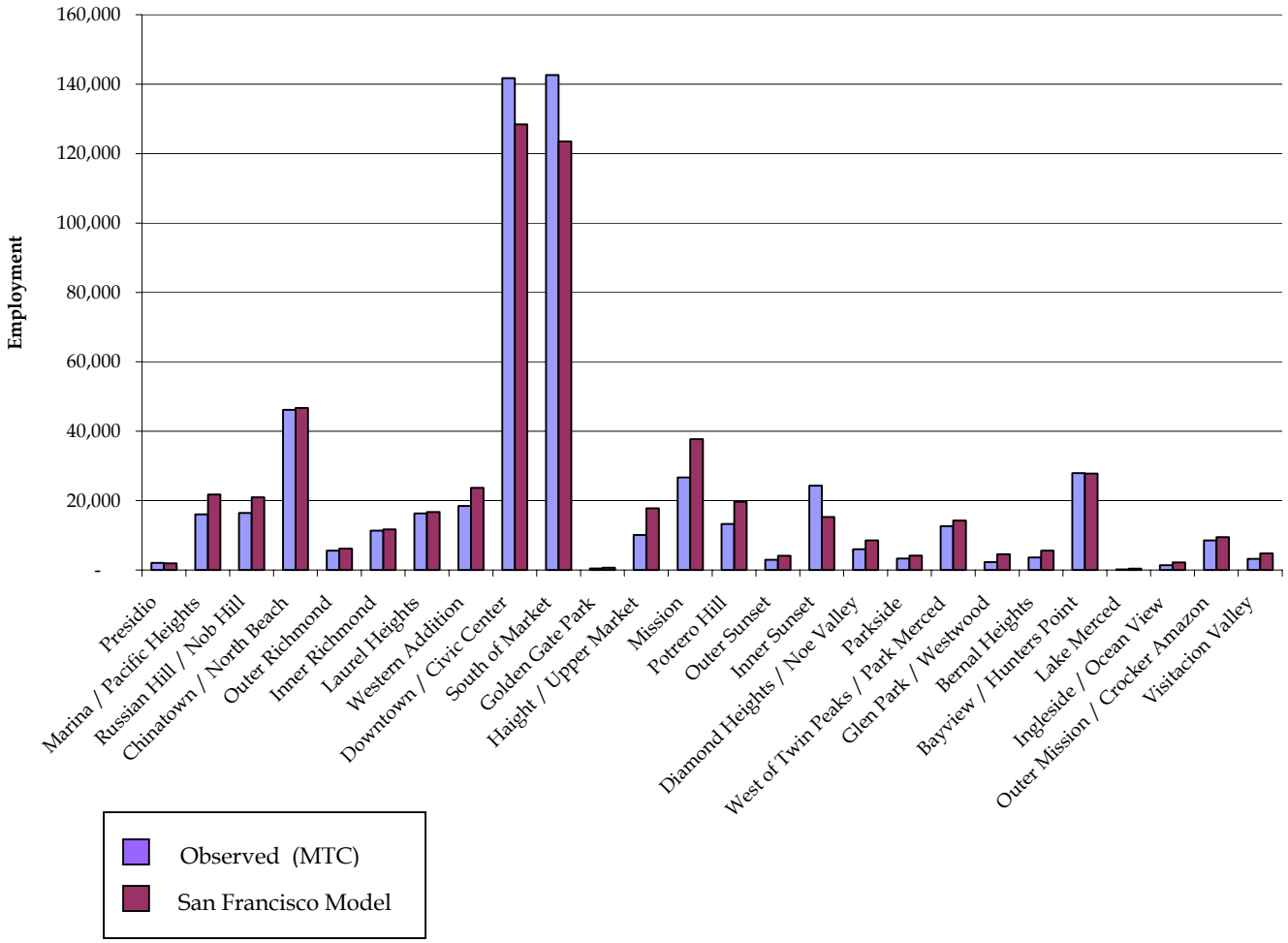
Figure 3. Area Types for San Francisco



Area Type	Description
0	Regional Core
1	Central Business District
2	Urban Business
3	Urban

Figure 4 presents another evaluation of work locations, which is the estimate of employment that results from the work location model compared to actual employment by neighborhood. This comparison required estimates of employment that included non-residents who work in the City, so estimated values of employment include the San Francisco Model estimates of work location plus the MTC model estimates of work locations for non-San Francisco residents who work in San Francisco. Because some of these data were not actually observed, these results were considered reasonable when compared to estimated values by neighborhood. The biggest differences were the two neighborhoods in the core business district, which were underestimating employment, but the previous calibration results in Table 2 show that the destinations in the core are within three percent for each tour type and are actually overestimated in these results. This comparison highlights the differences resulting in using data from sources other than actual observed data in model calibration (i.e., model estimates of work locations for non-residents) but it was still considered to be a valuable test.

Figure 4. Estimate and observed work locations by neighborhood



The destination choice model was also calibrated by comparing trip length and duration frequency distributions. Summaries of the average travel time, distance and average speed are provided in Table 9 to reflect these comparisons for each tour purpose. The results of average travel time by tour purpose are also summarized in Figure 5. The observed trip lengths are derived from the 1990 MTC survey and reported as the average time and distance to/from the primary destination. These results show reasonable average trip lengths for all tour types.

Trip duration frequency distributions were evaluated to determine reasonableness by tour purpose. Observed and estimated values of trip duration by travel time increment are presented in Figures 6 through 9 and reflect reasonable comparisons.

Table 9. Comparison of Average Travel Time, Distance and Speed to/from Primary Destinations

	Observed	Estimated	Difference
Work Tours			
Average Travel Time (minutes)	12.27	13.16	7%
Average Distance (miles)	3.30	3.59	9%
Average Speed (mph)	16.14	16.38	2%
School Tours			
Average Travel Time (minutes)	9.87	9.47	-4%
Average Distance (miles)	2.90	2.75	-5%
Average Speed (mph)	17.63	17.40	-1%
Other Tours			
Average Travel Time (minutes)	7.55	7.67	2%
Average Distance (miles)	2.35	2.32	-1%
Average Speed (mph)	18.68	18.16	-3%
Work-based Subtours			
Average Travel Time (minutes)	5.06	5.44	7%
Average Distance (miles)	1.37	1.45	6%
Average Speed (mph)	16.25	15.99	-2%

Figure 5. Average Trip Lengths to and from Primary Destinations

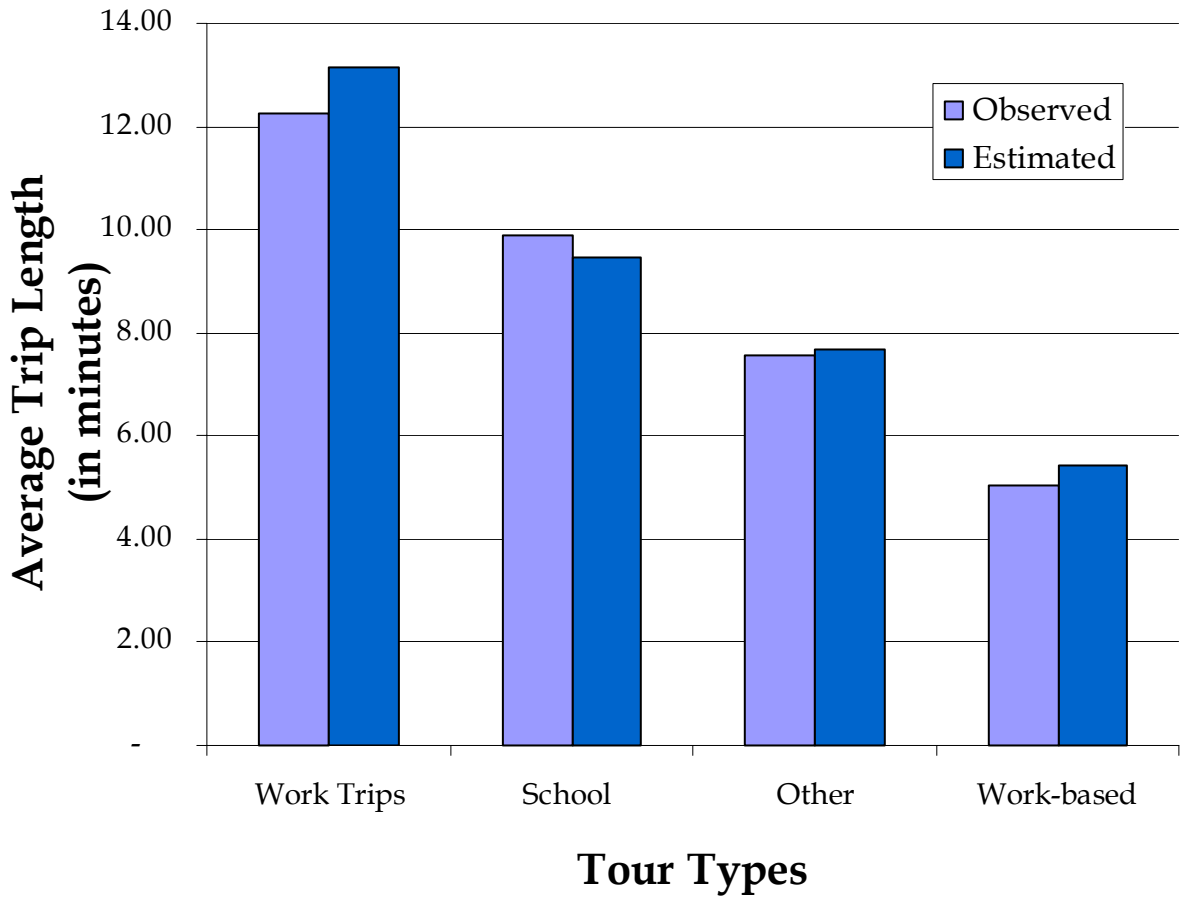


Figure 6. Travel Time Frequency Distribution for Work Tours

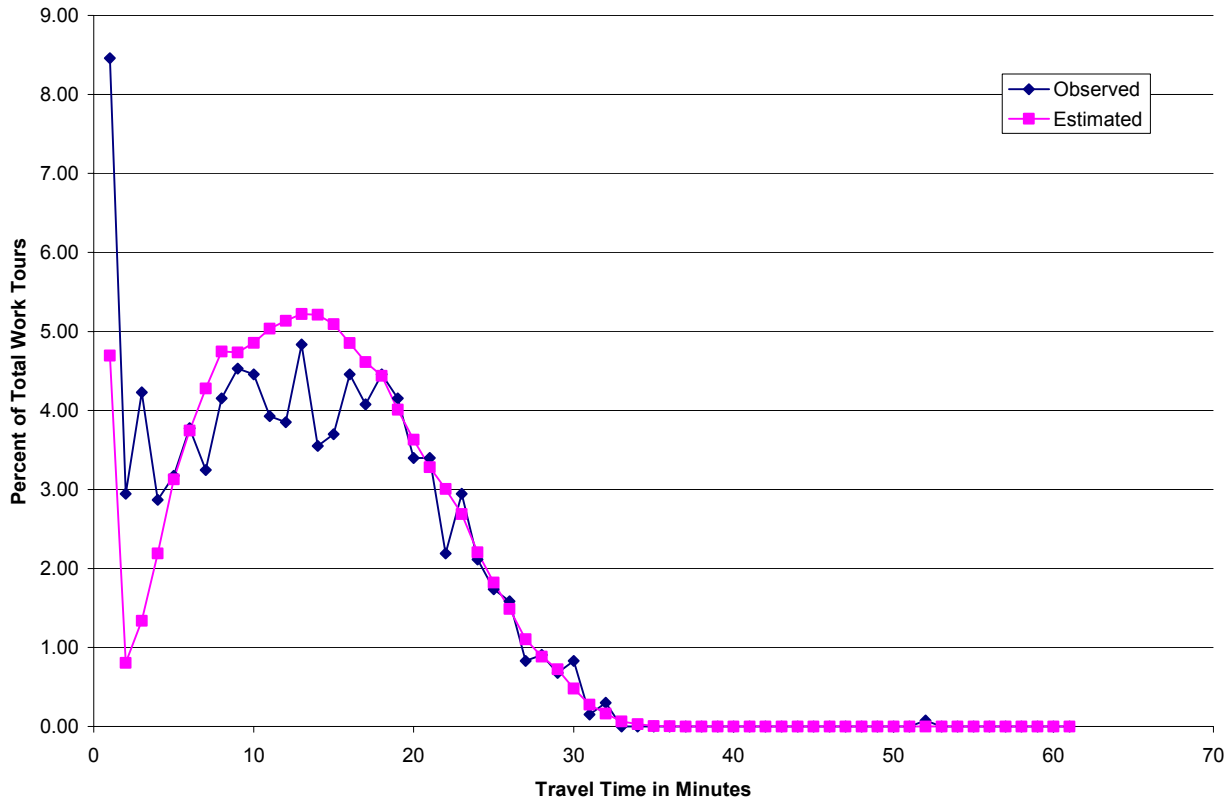


Figure 7. Travel Time Frequency Distribution for School Tours

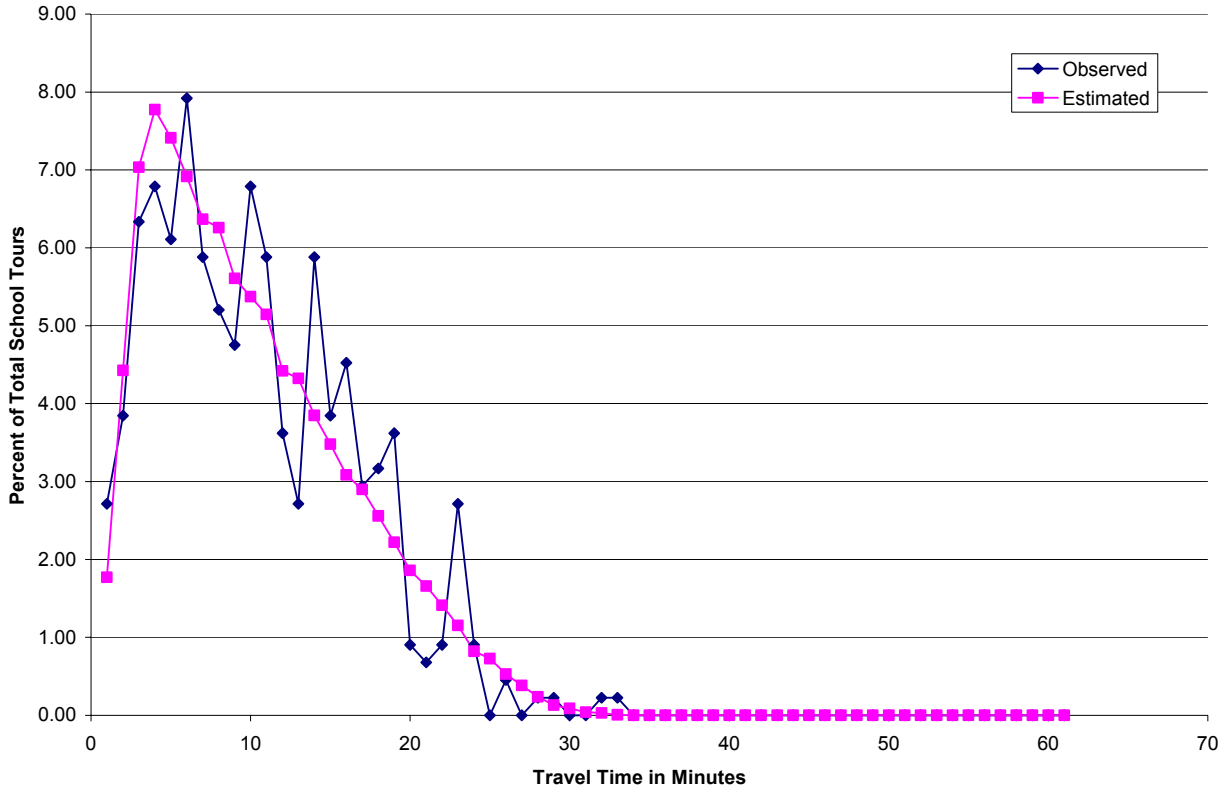


Figure 8. Travel Time Frequency Distribution for Other Tours

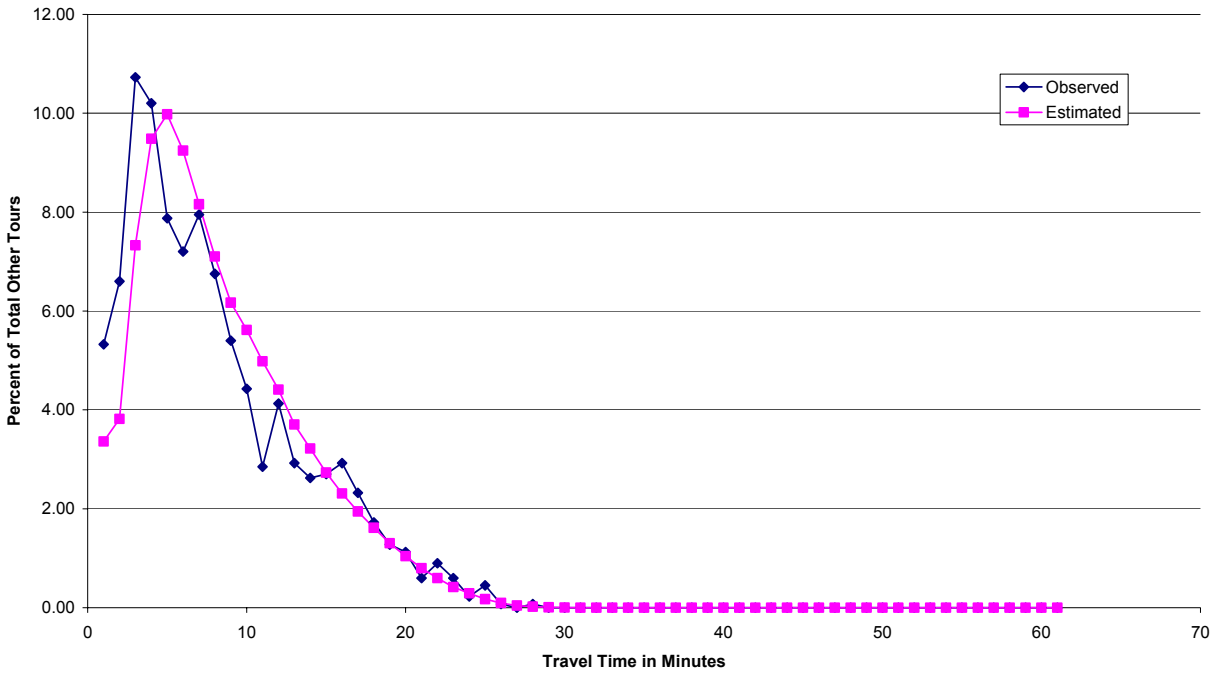
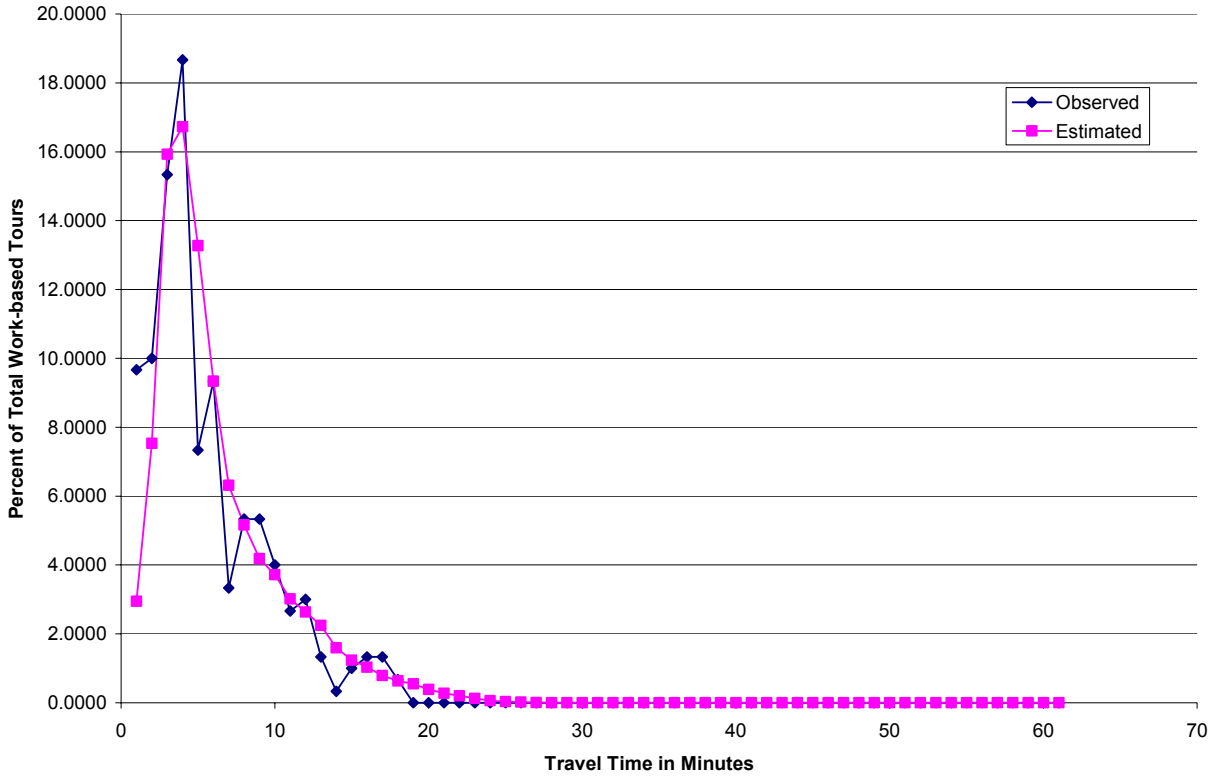
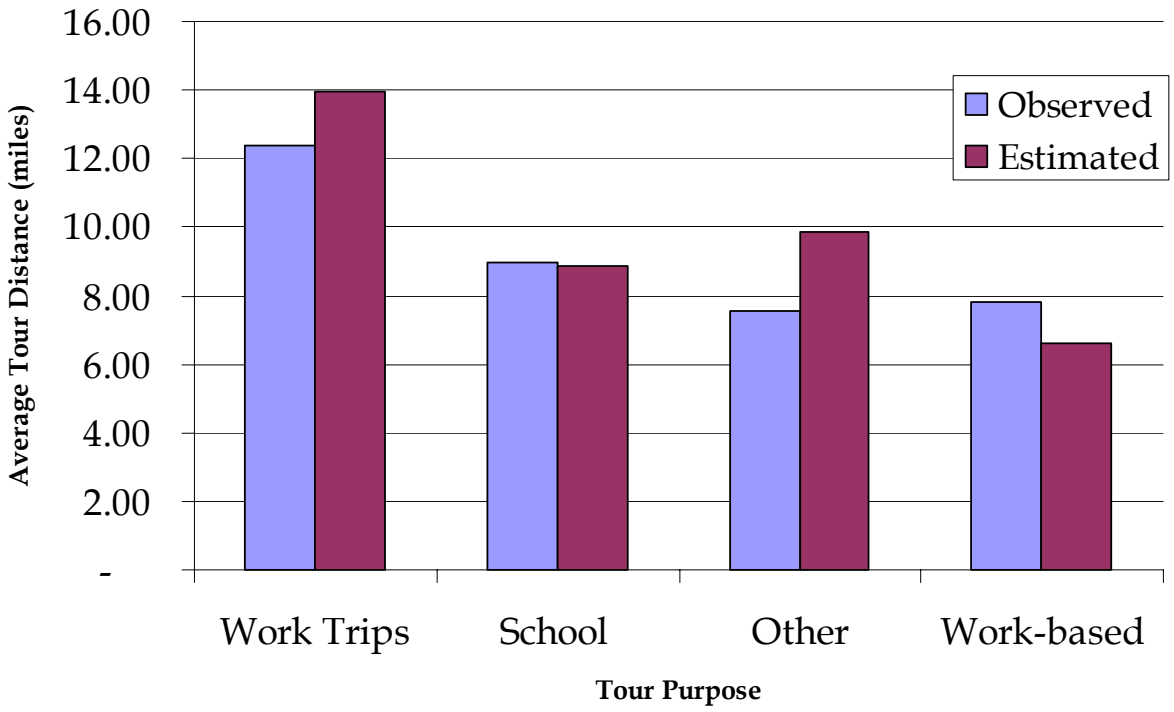


Figure 9. Travel Time Frequency Distribution for Work-based Tours



The validation of the intermediate stop choice model was challenging because similar models of destination choice have not included separate validation of the intermediate stop choice component for comparison. The validation test was to review the total tour length by tour purpose compared to the observed values, as presented in Figure 8. Distance was selected as the primary validation test for this model to isolate the location of the destination from the congestion effects during a particular time period. The results of this validation test are that both work and other tours are over-estimated slightly by the model, while work-based tours are under-estimated. Additional calibration adjustments to try and reconcile these differences were not pursued because further adjustments would have negatively impacted the results of the highway assignments by time period.

Figure 8. Trip Distance for Total Tour Length by Tour Purpose



■ Mode Choice (Tour and Trip) Models

The tour and trip mode choice models were calibrated by tour purpose. Alternative-specific constants for each mode were adjusted to match observed modal shares from the 1990 MTC Household Survey. The structure of the tour-based models require that tour models are calibrated first to match tours by mode and market segment, then trip models are calibrated to match trips by trip mode and tour mode. The trips resulting from applying the calibrated alternative-specific constants were then assigned to highway and transit networks and compared to observed traffic counts and transit boardings by mode.

Initially, estimated transit boardings were discovered to be much higher than observed boardings, particularly for local bus and MUNI Metro transit modes. There are four possible reasons for the transit over-estimation: there may be too many trips generated by the pattern models (too many trips going in to mode choice); the transfer rate may be too high; the calibration targets observed in the 1990 MTC survey may be incorrect; or the observed transit boardings may be too low.

A comparison of estimated versus observed traffic volumes on the highway network confirmed that the number of trips generated by the pattern models was reasonable when compared to independent estimates of travel. An analysis of the estimated transfer rates also confirms that the number of estimated transfers for San Francisco residents is reasonable. Therefore, it was concluded that either the transit calibration target values generated from the household survey were too high or the observed transit boardings are low. Because the transit boardings are calculated annually by MUNI, they were held constant and both the observed and estimated transit shares were adjusted to better match boardings.

The calibration results for tour modes are shown by trip purpose are shown in Tables 10 through 13. Calibration results for trip modes are shown in Tables 14 through 17. The tables show a very close match between estimated and adjusted observed tours and trips by mode and purpose.

Table 10: Estimated and Adjusted Observed Work Tours by Mode Share

	Autos=0		Autos<Workers		Autos>=Workers		Total	
	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Mode								
Driver	0%	0%	48%	48%	68%	68%	50%	50%
Passenger	14%	14%	8%	8%	4%	5%	7%	7%
Walk	22%	22%	2%	2%	3%	3%	6%	6%
Bicycle	3%	3%	1%	1%	1%	1%	1%	1%
Walk-Transit	61%	61%	37%	37%	23%	23%	34%	34%
Drive-Transit	0%	0%	4%	4%	1%	1%	2%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 11: Estimated and Adjusted Observed School Tours by Mode Share

	Autos=0		Autos<Workers		Autos>=Workers		Total	
	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Mode								
Driver	0%	0%	0%	0%	0%	0%	0%	0%
Passenger	4%	4%	34%	34%	0%	0%	23%	23%
Walk	28%	28%	19%	18%	0%	0%	22%	22%
Bicycle	1%	1%	1%	1%	0%	0%	1%	1%
Walk-Transit	67%	67%	47%	47%	0%	0%	54%	54%
Drive-Transit	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	0%	0%	100%	100%

Table 12: Estimated and Adjusted Observed Other Tours by Mode Share

	Autos=0		Autos<Workers		Autos>=Workers		Total	
	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Mode								
Driver	0%	0%	48%	48%	65%	65%	49%	49%
Passenger	21%	22%	10%	11%	13%	13%	14%	15%
Walk	35%	34%	32%	31%	17%	17%	23%	23%
Bicycle	2%	2%	1%	1%	0%	0%	1%	1%
Walk-Transit	43%	43%	8%	8%	4%	4%	13%	13%
Drive-Transit	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 13: Estimated and Adjusted Observed Work-Based Tours by Mode Share

	Autos=0		Autos<Workers		Autos>=Workers		Total	
	Estimated	**Observed**	**Estimated**	**Observed**	**Estimated**	**Observed**	**Estimated**	**Observed**
Mode								
Driver	0%	0%	21%	22%	46%	47%	35%	36%
Passenger	10%	12%	6%	7%	3%	3%	4%	5%
Walk	62%	60%	61%	59%	44%	43%	50%	49%
Bicycle	14%	14%	1%	1%	1%	1%	2%	2%
Walk-Transit	14%	14%	11%	11%	7%	7%	9%	9%
Drive-Transit	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 14: Estimated and Adjusted Observed Work Trip Mode Share by Tour Mode

	Driver		Passenger		Walk		Bike		Walk-Transit		Drive-Transit		Total	
TRIP MODE	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Drive Alone	73%	73%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	37%	38%
Shared Ride 2	18%	18%	76%	76%	0%	0%	0%	0%	7%	6%	9%	8%	17%	18%
Shared Ride 3+	6%	6%	14%	14%	0%	0%	0%	0%	2%	2%	2%	2%	5%	5%
Walk	3%	3%	11%	11%	100%	100%	0%	0%	11%	11%	27%	29%	12%	11%
Bicycle	0%	0%	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	1%	1%
Walk-Local	0%	0%	0%	0%	0%	0%	0%	0%	57%	57%	13%	12%	20%	19%
Walk-MUNI	0%	0%	0%	0%	0%	0%	0%	0%	15%	15%	4%	3%	5%	4%
Walk-Premium	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walk-BART	0%	0%	0%	0%	0%	0%	0%	0%	9%	9%	9%	10%	3%	3%
Drive-BART	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	36%	37%	0%	1%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 15: Estimated and Adjusted Observed School Trip Mode Share by Tour Mode

	Driver		Passenger		Walk		Bike		Walk-Transit		Total	
TRIP MODE	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Drive Alone	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shared Ride 2	0%	0%	42%	49%	0%	0%	0%	0%	21%	20%	21%	23%
Shared Ride 3+	0%	0%	45%	38%	0%	0%	0%	0%	7%	8%	14%	13%
Walk	0%	0%	13%	13%	100%	100%	3%	3%	12%	12%	30%	30%
Bicycle	0%	0%	0%	0%	0%	0%	97%	97%	0%	0%	1%	1%
Walk-Local	0%	0%	0%	0%	0%	0%	0%	0%	43%	43%	24%	24%
Walk-MUNI	0%	0%	0%	0%	0%	0%	0%	0%	15%	15%	8%	8%
Walk-Premium	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walk-BART	0%	0%	0%	0%	0%	0%	0%	0%	2%	3%	1%	1%
Total	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 16: Estimated and Adjusted Observed Other Trip Mode Share by Tour Mode

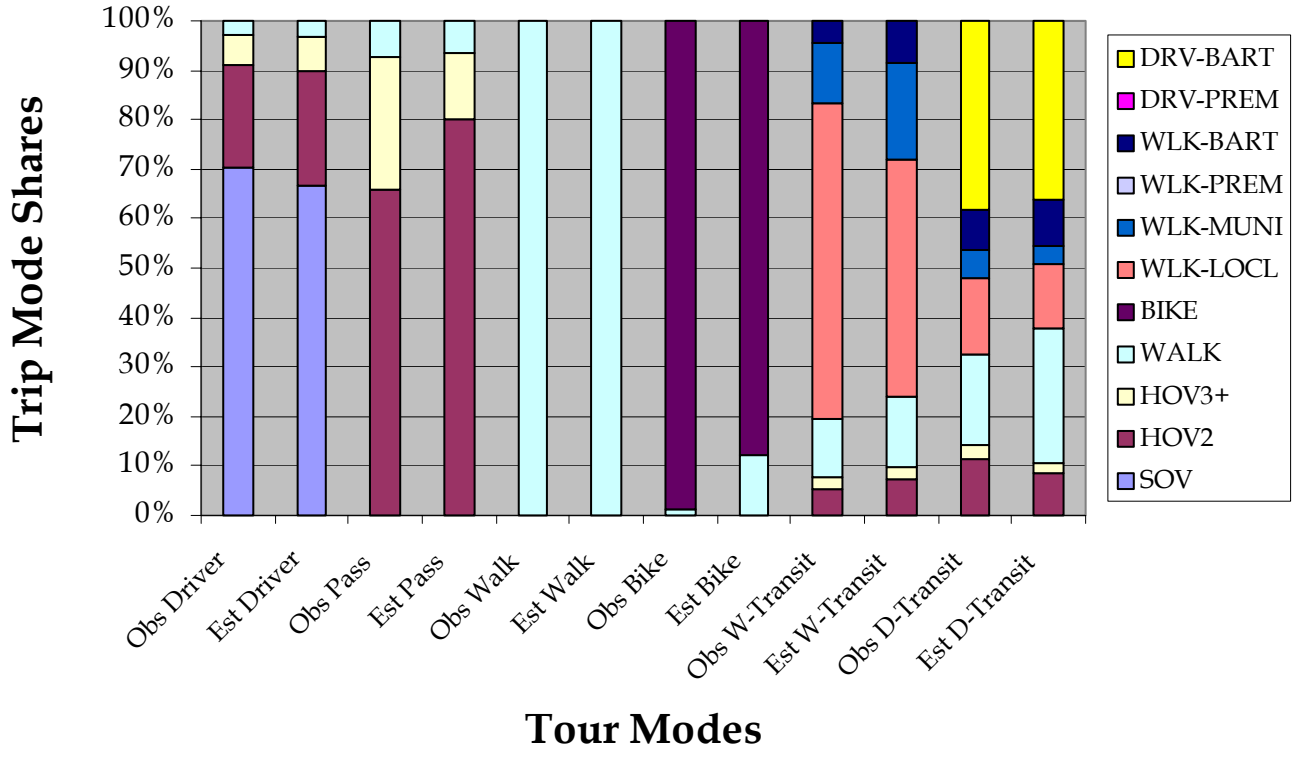
	Driver		Passenger		Walk		Bike		Walk-Transit		Total	
TRIP MODE	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Drive Alone	61%	61%	0%	0%	0%	0%	0%	0%	0%	0%	30%	29%
Shared Ride 2	28%	28%	90%	64%	0%	0%	0%	0%	2%	2%	27%	22%
Shared Ride 3+	8%	8%	7%	32%	0%	0%	0%	0%	1%	1%	5%	8%
Walk	3%	3%	4%	4%	100%	100%	1%	1%	20%	20%	26%	28%
Bicycle	0%	0%	0%	0%	0%	0%	99%	99%	0%	0%	1%	1%
Walk-Local	0%	0%	0%	0%	0%	0%	0%	0%	36%	36%	5%	6%
Walk-MUNI	0%	0%	0%	0%	0%	0%	0%	0%	29%	29%	4%	4%
Walk-Premium	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walk-BART	0%	0%	0%	0%	0%	0%	0%	0%	11%	11%	2%	2%
Drive-Premium	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Drive-BART	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 17: Estimated and Adjusted Observed Work-Based Trip Mode Share by Tour Mode

	Driver		Passenger		Walk		Bike		Walk-Transit		Total	
TRIP MODE	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed	Estimated	Observed
Drive Alone	81%	79%	0%	0%	0%	0%	0%	0%	0%	0%	28%	27%
Shared Ride 2	15%	17%	71%	67%	0%	0%	0%	0%	2%	2%	8%	8%
Shared Ride 3+	1%	2%	17%	21%	0%	0%	0%	0%	1%	1%	1%	1%
Walk	3%	2%	11%	12%	100%	100%	70%	4%	21%	18%	56%	55%
Bicycle	0%	0%	0%	0%	0%	0%	30%	96%	0%	0%	1%	2%
Walk-Local	0%	0%	0%	0%	0%	0%	0%	0%	47%	48%	4%	5%
Walk-MUNI	0%	0%	0%	0%	0%	0%	0%	0%	19%	20%	2%	1%
Walk-Premium	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walk-BART	0%	0%	0%	0%	0%	0%	0%	0%	10%	11%	1%	1%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure 10 presents the above results of trip mode shares by tour mode in a graphical format for comparison. This comparison is for all tour types combined, demonstrating that the total trip mode and tour mode choice models compare reasonably well with observed values.

Figure 10. Trip Mode Shares by Tour Mode



Assignment Validation

There are two primary modes for assignment validation: highway and transit. These are validated separately using observed volumes of vehicles and passengers on the highway and transit systems, respectively. Assignment validation at the county level is completed using aggregated volumes by corridor (identified by screenlines), type of service (facility type, mode or operator), size (volume group), and time period. Speeds and travel times are also used in highway and transit validations to ensure that these are accurately represented in the models.

Highway Assignment

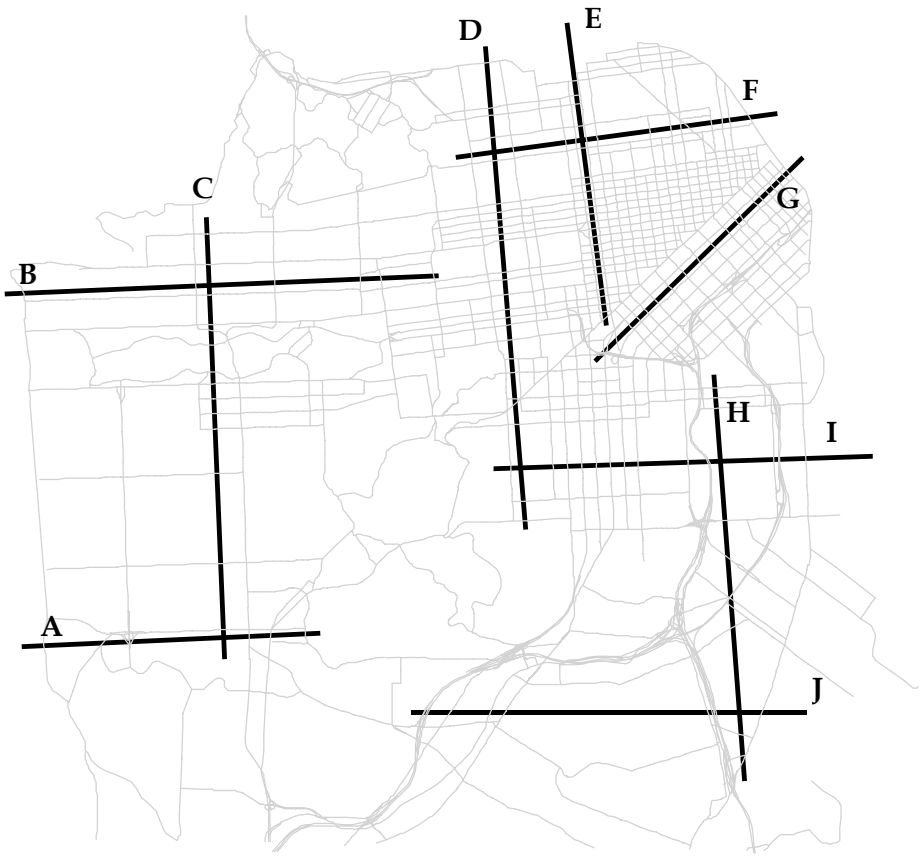
Highway assignments are validated using traffic volumes and speeds, aggregated from individual links to categories in the following areas:

- volumes by corridor using screenlines,
- volumes by facility type, volume group and area type, and
- volumes by time period, gateway and neighborhood.

Volumes by Corridor

Highway corridors are validated using screenlines, which cross a number of roadways in a given corridor. The screenlines were developed during the course of this validation effort and are presented in Figure 11. Table 23 presents a summary of the 1998 model and 1998 traffic count volumes by screenline for San Francisco County. This table shows that the target error for every screenline was +/-10 percent. Eight of ten screenlines met this criterion.

Figure 11. Screenlines for San Francisco County



The National Cooperative Highway Research Program established guidelines for screenline volumes in 1982 that have been used extensively in validating demand-forecasting models.[5] These guidelines have also been cited as validation targets in the Federal Highway Administration work[6] and the Travel Model Improvement Program efforts[7]. Figure 12 presents a comparison of the San Francisco County screenlines with the maximum desirable deviation for screenline volumes established by these guidelines. This comparison shows that the majority of screenlines meet the target values. Only Screenline H, East of Highway 101 does not meet this particular criterion. Investigation into possible causes for the under-estimation of this screenline revealed a number of centroid loading, parallel street loading and traffic count location problems that could be contributing to this problem.

Table 23. Estimated and Observed Screenline Volumes

	Screenlines	Links	Observed Count	Estimated Volume	Relative Error	Target Error	%RMSE [8]
A	South of Sloat	10	144,289	143,325	-0.7%	+/- 10 %	32%
B	North of Balboa	9	129,322	118,102	-8.7%	+/- 10 %	45%
C	East of 25th Street	26	182,582	213,732	17.1%	+/- 10 %	44%
D	East of Divisadero	38	223,247	218,085	-2.3%	+/- 10 %	67%
E	West of Van Ness	31	363,960	340,661	-6.4%	+/- 10 %	52%
F	North of Broadway	20	172,876	180,069	4.2%	+/- 10 %	64%
G	South of Mission	26	487,167	524,935	7.8%	+/- 10 %	50%
H	East of Highway 101	18	102,667	70,090	-31.7%	+/- 10 %	50%
I	South of 21st Street	18	384,453	389,853	1.4%	+/- 10 %	26%
J	South of Silver	12	100,993	106,406	5.4%	+/- 10 %	48%
	Total	208	2,291,556	2,305,258	0.6%	+/- 5 %	49%

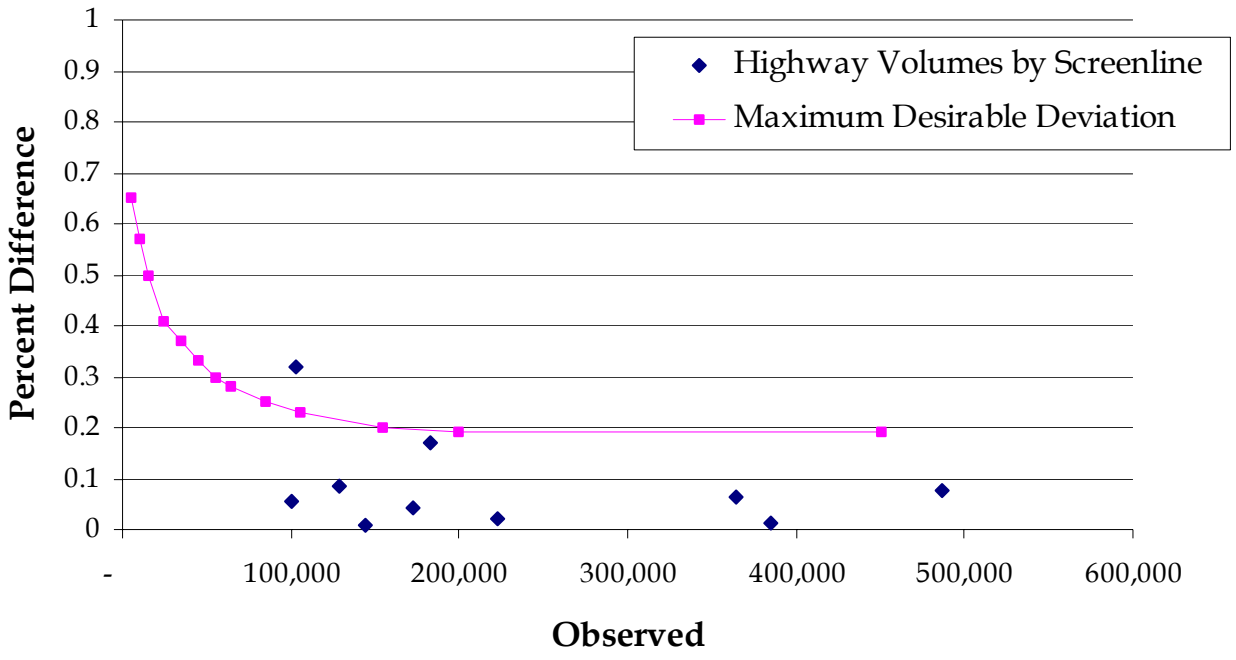
[5] National Cooperative Highway Research Program (NCHRP) *Report 255 Highway Traffic Data for Urbanized Area Project Planning and Design,* prepared by JHK & Associates for the Transportation Research Board, December, 1982, page 41.

[6] U.S. Department of Transportation, Federal Highway Administration, *Calibration and Adjustment of System Planning Models*, Publication No. FHWA-ED-90-015, December 1990.

[7] U.S. Department of Transportation, Travel Model Improvement Program, *Model Validation and Reasonableness Checking Manual,* prepared by Barton Aschman Associates and Cambridge Systematics for the Federal Highway Administration, February 1997, page 99.

[8] %RMSE means root mean square error.

Figure 12. Maximum Desirable Deviation in Screenline Volumes



Volumes by Facility Type, Volume Group and Area Type

It is useful to validate traffic volumes by facility type, volume group and area type to determine if there are any biases in the system that could be corrected for using model adjustments. Table 24 presents a comparison of observed and estimated traffic volumes by facility type. The validation targets are derived from the most recent guidelines from the Federal Highway Administration[9], which are the same as those cited in previous Federal Highway guidance[10]. This comparison shows model volumes that are close to acceptable guidelines. The local and collector streets are under-estimated and we believe this is a result of the greater level of detail on the street system than is contained in most travel models, which would require specific network loading and review of attributes on the local level to correct. This level of detail is appropriate for subarea studies where the model is applied and can be updated at that time.

Table 24. Average Daily Observed and Estimated Volumes by Facility Type

Codes	Facility Type	Observed Count	Estimated Volume	Relative Error	Target Error	%RMSE	Target RMSE
2,3	Freeway	1,808,829	1,966,129	8.7%	+/-7%	15%	15%
7	Major Arterial	5,913,055	6,276,740	6.2%	+/-10%	47%	30%
12	Minor Arterial	2,005,434	1,674,998	-16.5%	+/-15%	55%	45%
4	Collector	1,051,807	679,245	-35.4%	+/-25%	72%	100%
11	Local	695,952	377,825	-45.7%	+/-50%	113%	N/A

Table 25 presents a comparison of observed and estimated traffic volumes by volume group. These validation targets are derived from those presented in the aforementioned Federal Highway guidance[11]. The volume groups used in this study were slightly different than those presented in the guidance, so the tighter validation target was used in every case where the volume groups were different than those in the guidance. Again, this comparison shows that all volume groups are well within the validation targets, except for the lowest volume group where one expects the higher-level errors to occur.

[9] U.S. Department of Transportation, Travel Model Improvement Program, *Model Validation and Reasonableness Checking Manual,* prepared by Barton Aschman Associates and Cambridge Systematics for the Federal Highway Administration, February 1997, page 107.

[10] U.S. Department of Transportation, Federal Highway Administration, *Calibration and Adjustment of System Planning Models*, Publication No. FHWA-ED-90-015, December 1990.

[11] U.S. Department of Transportation, Travel Model Improvement Program, *Model Validation and Reasonableness Checking Manual,* prepared by Barton Aschman Associates and Cambridge Systematics for the Federal Highway Administration, February 1997, page 108.

Again, we believe that the high level of error on these lower volume facilities is greater in the San Francisco Model than it would be in other models because of the inclusion of all streets in the network, which may contribute to loading problems at the local level. In addition, the overall root mean square error is high compared to other models because of the inclusion of local streets.

Table 25. Average Daily Observed and Estimated Volumes by Volume Group

Volume Group	Code	Observed Count	Estimated Volume	Relative Error	Target Error	%RMSE	Target RMSE
0-5,000	1	1,055,524	1,149,689	9%	+/-40%	107%	100%
5,000-10,000	2	2,235,492	2,277,262	2%	+/-35%	67%	75%
10,000-15,000	3	2,054,627	1,960,754	-5%	+/-30%	54%	60%
15,000-20,000	4	1,592,436	1,541,830	-3%	+/-25%	49%	50%
20,000-25,000	5	1,707,333	1,564,612	-8%	+/-20%	37%	40%
25,000-50,000	6	2,277,456	2,019,815	-11%	+/-15%	29%	30%
>50,000	7	1,535,244	1,636,762	7%	+/-10%	12%	15%
Total		12,458,112	12,150,724	-2.5%	+/- 5 %	52%	35%

Table 26 presents the average daily observed and estimated volumes by area type. This table shows that all the area types are well within the target tolerance. There is no target root mean square error set by area type because there are no available standards to refer to.

Table 26. Average Daily Observed and Estimated Volumes by Area Type

Code	Area Type	Observed Count	Estimated Volume	Relative Error	Target Error	%RMSE
0	Regional Core	1,521,591	1,488,235	-2.2%	+/-10%	64%
1	Central Business District	3,382,361	3,302,109	-2.4%	+/-10%	47%
2	Urban Business	3,062,123	3,109,182	1.5%	+/-10%	47%
3	Urban	4,492,037	4,251,199	-5.4%	+/-10%	54%

Volumes by Time Period

Table 27 presents the volumes by time period. The validation targets by time period were originally set by facility type, area type, screenline and neighborhood group, but the results did not vary significantly by time period. The validation summary by time period is therefore presented as total volume by time period. Only the evening time period is outside the 10 percent target range and this under-estimation was recognized during model calibration and significantly improved from initial estimates. It is further described in the section on Day Pattern Models.

Table 27. Observed and Estimated Volumes by Time Period

Time period	Observed Count	Estimated Volume	Relative Error	Target Error
Early AM	300,284	322,416	7.4%	+/-10%
AM Peak	2,049,858	2,057,558	0.4%	+/-10%
Midday	4,581,381	4,599,263	0.4%	+/-10%
PM Peak	2,646,911	2,623,814	-0.9%	+/-10%
Evening	2,879,678	2,547,673	-11.5%	+/-10%
Daily	13,435,925	13,173,188	-2.0%	+/-5%

Volumes by Gateway

Table 28 presents the volumes by gateway. This was a critical part of the model calibration effort since the gateway volumes had significant impact on the volumes within San Francisco County. The gateway volumes were originally derived directly from MTC trip tables, stratified by time period, mode and purpose, but these did not produce volumes by time period at each gateway that were accurate enough for local planning purposes. We believe this is because the MTC assignments are daily assignments and the San Francisco model produces daily assignments by summing the five time period assignments. This can lead to very different results, as we discovered. As a result, the MTC trip tables were adjusted to match traffic counts by time period at each gateway crossing.

Table 28. Observed and Estimated Volumes by Gateway and Time Period

Gateway	Time period	Observed Count	Estimated Volume	Relative Error	Target Error
Golden Gate					
	Early AM	4,841	5,019	3.7%	+/-10 %
	AM Peak	24,408	23,984	-1.7%	+/-10 %
	Midday	42,414	45,148	6.4%	+/-10 %
	PM Peak	26,275	26,081	-0.7%	+/-10 %
	Evening	22,383	22,854	2.1%	+/-10 %
	Total Daily	120,321	123,086	2.3%	+/-10 %
Bay Bridge					
	Early AM	21,588	20,191	-6.5%	+/-10 %
	AM Peak	47,125	51,260	8.8%	+/-10 %
	Midday	92,886	97,370	4.8%	+/-10 %
	PM Peak	53,921	57,284	6.2%	+/-10 %
	Evening	61,163	59,375	-2.9%	+/-10 %
	Total Daily	276,683	285,481	3.2%	+/-10 %
County Boundary					
	Early AM	15,265	15,951	4.5%	+/-10 %
	AM Peak	101,355	104,837	3.4%	+/-10 %
	Midday	187,585	203,882	8.7%	+/-10 %
	PM Peak	119,332	126,451	6.0%	+/-10 %
	Evening	131517	122,283	-7.0%	+/-10 %
	Total Daily	555,054	573,404	3.3%	+/-10 %

Volumes by Neighborhood

Table 29 presents the model volumes and traffic counts summarized by neighborhood. These neighborhoods, presented in Figure 13, are used in various neighborhood-planning activities and will be directly supportive of subarea planning work. The target error for neighborhoods was set at +/- 20 percent and only one neighborhood falls outside this range: Laurel Heights. The observed and estimated highway volumes by neighborhood are also presented in Figure 14.

Figure 13. Neighborhoods in San Francisco

Figure 14. Highway Volumes by Neighborhood

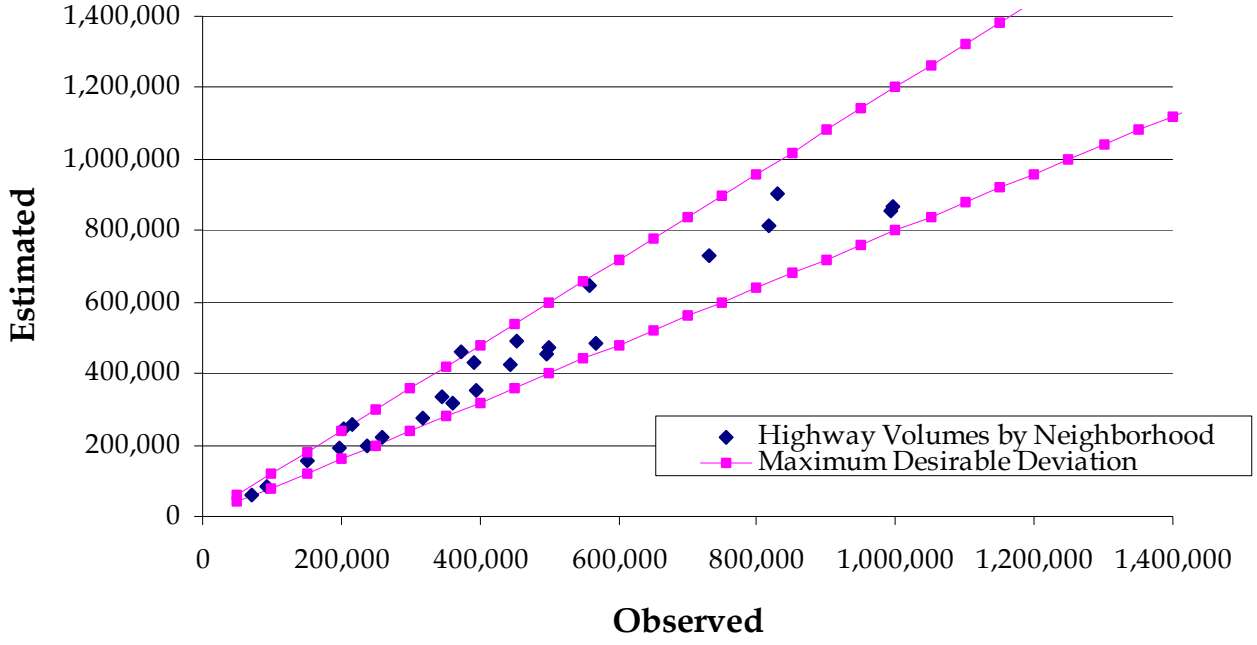


Table 29. Observed and Estimated Volumes by Neighborhood

	Neighborhoods	Links	Observed Count	Estimated Volume	Relative Error	Target Error
1	Presidio	78	817,803	816,447	-0.2%	+/- 20 %
2	Marina / Pacific Heights	70	498,940	475,014	-4.8%	+/- 20 %
3	Russian Hill / Nob Hill	28	359,713	319,314	-11.2%	+/- 20 %
4	Chinatown / North Beach	46	317,182	274,461	-13.5%	+/- 20 %
5	Outer Richmond	40	197,163	191,031	-3.1%	+/- 20 %
6	Inner Richmond	35	445,300	426,349	-4.3%	+/- 20 %
7	Laurel Heights	31	371,597	463,238	24.7%	+/- 20 %
8	Western Addition	65	828,734	902,106	8.9%	+/- 20 %
9	Downtown / Civic Center	57	729,873	731,298	0.2%	+/- 20 %
10	South of Market	81	1,466,217	1,408,955	-3.9%	+/- 20 %
11	Golden Gate Park	29	394,644	353,254	-10.5%	+/- 20 %
12	Haight / Upper Market	54	392,496	432,956	10.3%	+/- 20 %
13	Mission	69	995,995	865,568	-13.1%	+/- 20 %
14	Potrero Hill	42	495,586	456,929	-7.8%	+/- 20 %
15	Outer Sunset	27	237,682	195,471	-17.8%	+/- 20 %
16	Inner Sunset	24	258,226	221,722	-14.1%	+/- 20 %
17	Diamond Heights / Noe Valley	24	214,401	255,882	19.3%	+/- 20 %
18	Parkside	11	92,660	82,559	-10.9%	+/- 20 %
19	W. of Twin Pks / Park Merced	77	993,052	857,578	-13.6%	+/- 20 %
20	Glen Park / Westwood	22	203,766	246,440	20.9%	+/- 20 %
21	Bernal Heights	29	346,651	333,867	-3.7%	+/- 20 %
22	Bayview / Hunters Point	49	568,022	485,251	-14.6%	+/- 20 %
23	Lake Merced	8	70,175	58,910	-16.1%	+/- 20 %
24	Ingleside / Ocean View	10	152,239	154,280	1.3%	+/- 20 %
25	Outer Mission / Crocker Amazon	38	556,827	648,593	16.5%	+/- 20 %
26	Visitacion Valley	55	453,168	493,250	8.8%	+/- 20 %
	Total	1,099	12,458,112	12,150,724	-2.5%	+/- 5 %

Transit Assignment

San Francisco resident trip tables were constructed from trip mode choice model outputs and assigned to transit networks by time period and detailed mode. Non-San Francisco resident trip tables were constructed from MTC trip tables and assigned to identical transit networks by time period and MTC transit mode. Time periods include: Early AM, AM Peak, Midday, PM Peak, and Evening. The detailed modes assigned for San Francisco resident trips include:

- Walk-Local-Walk
- Walk-MUNI Metro-Walk
- Walk-BART-Walk
- Drive-BART-Walk
- Walk-BART-Drive

MTC Modes include:

- Walk-Transit-Walk
- Walk-Transit-Drive
- Drive-Transit-Walk

After the trip tables are assigned to transit networks, summary programs read transit assignment database (dbf files) files and results are batched into a spreadsheet for comparison to observed 1998 boardings by mode, route, and time period. Tables 30 through 35 show these comparisons. Note that across all modes, the San Francisco models are within 5% of observed transit boardings. However, there are some distinct differences by time of day.

The time periods utilized by MUNI to report observed 1998 MUNI transit boardings are inconsistent with those used for the SFCTA models. The MUNI boardings by time period were converted to SFCTA time periods by applying conversion factors to total daily boardings by route. The time period specific boardings are therefore computed numbers, not observed, and therefore not as reliable as actual observed data. Additionally, though certain transit routes truly only run for a few hours in the early AM period, they may be included in the early AM skims, which extend from 3:30 AM to 6:00 AM. Therefore the number of trips that are exposed to these routes may be inconsistent in many cases with the true number of trips that have the option of utilizing the routes. This inconsistency is also observed in the evening period.

Finally, it is shown that estimated bus boardings are significantly greater than observed boardings in the AM Peak period. As previously discussed in the section on Mode Choice calibration, the tour and trip transit shares were reduced in an attempt to better match bus boardings. However, matching the number of AM bus boardings within 5% would require a 30% reduction in Work transit tours compared to the observed 1990 MTC Household Survey data. An independent estimate of Census Journey-to-Work data indicates that the observed transit share of Work tours (35%) is reasonable. Therefore the observed Work Walk-Transit share was held constant, causing an over-estimation of AM period local bus trips.

Table 30. Observed Transit Boardings by Time Period and Mode

Mode	Early AM	AM Peak	Midday	PM Peak	Evening	Total
MUNI Bus	3,498	110,903	221,650	146,608	53,399	536,058
MUNI Light Rail / Cable Car	406	31,675	63,737	44,999	24,125	164,942
BART	4,411	76,309	72,385	77,829	45,879	276,813
Total	8,315	218,887	357,772	269,436	123,403	977,813

Table 31. Estimated Transit Boardings by Time Period and Mode

Mode	Early AM	AM Peak	Midday	PM Peak	Evening	Total
MUNI Bus	5,434	158,864	211,109	152,085	75,895	603,387
MUNI Light Rail / Cable Car	1,874	30,001	56,068	37,272	34,090	159,305
BART	0	87,128	67,904	81,925	22,815	259,772
Total	7,308	275,993	335,081	271,282	132,800	1,022,464

Table 32. Estimated – Observed Transit Boardings by Time Period and Mode

Mode	Early AM	AM Peak	Midday	PM Peak	Evening	Total
MUNI Bus	1,936	47,961	-10,541	5,477	22,496	67,329
MUNI Light Rail / Cable Car	1,468	-1,674	-7,669	-7,727	9,965	-5,637
BART	-4,411	10,819	-4,481	4,096	-23,064	-17,041
Total	-1,007	57,106	-22,691	1,846	9,397	44,651

Table 33. Estimated vs. Observed Percent Difference in Transit Boardings by Time Period and Mode

Mode	Early AM	AM Peak	Midday	PM Peak	Evening	Total
MUNI Bus	55%	43%	-5%	4%	42%	13%
MUNI Light Rail / Cable Car	362%	-5%	-12%	-17%	41%	-3%
BART	-100%	14%	-6%	5%	-50%	-6%
Total	-12%	26%	-6%	1%	8%	5%

Table 34 shows a comparison of estimated versus observed transit boardings by route group, ranked by daily boardings. The table shows a reasonable match between estimated and observed boardings, especially given the overall 8% over-estimate of boardings. These results are presented graphically in Figure 15, plotted against the same maximum desirable deviation target found in the highway screenlines.

Finally, Table 35 shows the estimated transfer rate for San Francisco residents by primary mode and mode of access.[12] Due to the lack of an on-board transit survey, it is not possible to compare these estimates to observed data. However, the transfer rates are reasonable; Bus mode transfer rates are lower than MUNI Metro and BART, and are typical of transfer rates for other urban areas.

Table 34: Estimated versus Observed Transit Boardings by Route Group

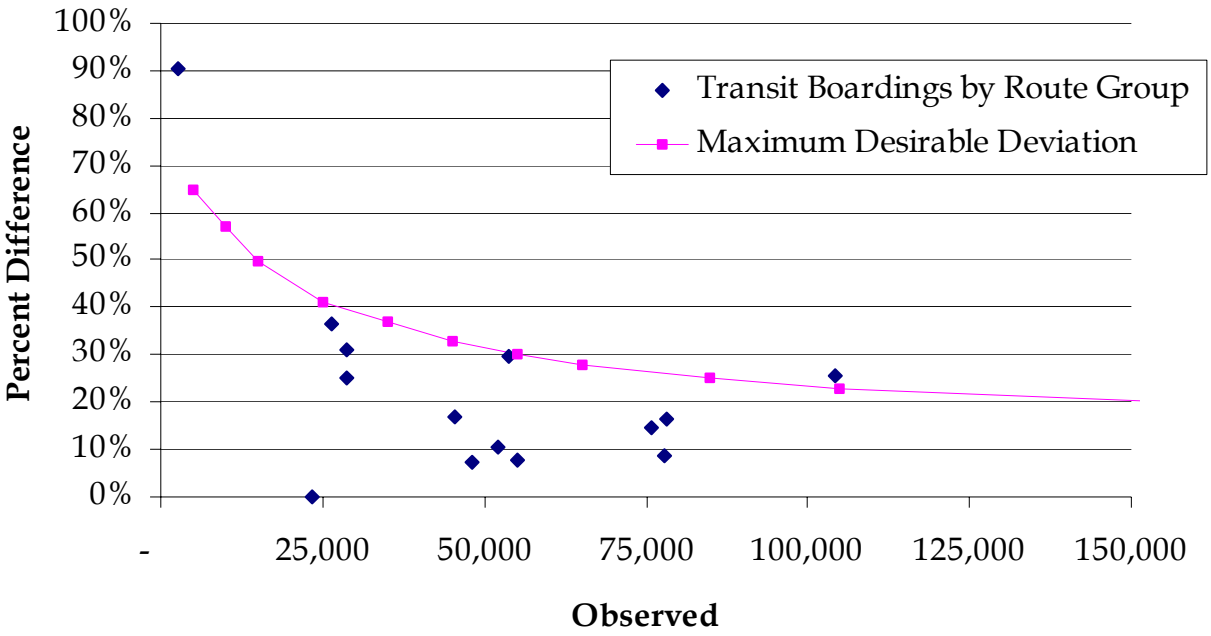
Route Group	Observed Boardings	Estimated Boardings	Ratio Est/Obs	Percent Difference
Richmond	104,350	131,112	1.26	25.65%
Sunset	52,100	57,589	1.11	10.54%
Bayshore	55,150	59,450	1.08	7.80%
Mission/Noe	77,750	71,060	0.91	-8.60%
Haight/Upper Market	23,500	23,538	1.00	0.16%
Chinatown/Marina/North Beach	47,950	51,355	1.07	7.10%
Van Ness	53,800	69,864	1.30	29.86%
West of Twin Peaks	78,300	65,534	0.84	-16.30%
Western Addition	28,650	37,506	1.31	30.91%
West Side	45,550	53,254	1.17	16.91%
Caltrain	2,550	244	0.10	-90.43%
Cable Cars	28,700	35,875	1.25	25.00%
Other-Crosstown	76,000	87,125	1.15	14.64%
Other- Community Service	26,550	16,849	0.63	-36.54%
Total	700,900	760,355	1.08	8.48%

Table 35: Estimated Transfer Rate by Transit Mode and Time Period

	Early AM	AM Peak	Midday	PM Peak	Evening	Total
Walk -Bus	1.24	1.39	1.36	1.38	1.31	1.37
Walk- MUNI	1.50	1.69	1.65	1.64	1.61	1.64
Walk- BART	0.00	1.56	1.53	1.63	1.53	1.57
Drive -BART	0.00	1.48	1.85	0.95	N/A	1.41
Average	1.33	1.47	1.46	1.47	1.44	1.46

[12] The transfer rate is generally defined as the total number of boardings divided by the total number of predicted trips by mode. Note: The transfer rate for Drive-BART evening is unavailable at this time.

Figure 15. Transit Boardings by Route Group



Q:\Model\Documentation--Final\validation_report_final revised.doc