

*The San Francisco Model in Practice  
Validation, Testing, and Application*

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## Overview

The San Francisco County Chained Activity Modeling Process (SF-CHAMP) was developed for the San Francisco County Transportation Authority (SFCTA) to provide detailed forecasts of travel demand for various planning applications<sup>1</sup>. 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 a tour-based model that uses synthesized population as the basis for decision-making rather than zonal-level aggregate data sources. The tour-based model has nine primary components.

Most of the model components were estimated using household survey data for San Francisco residents only, collected by the Metropolitan Transportation Commission (MTC). Each model component was calibrated using various observed data sources, and 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 tour-based model.

## Original Approach and Limitations

### *Modeling Process*

The main feature of the “full day pattern” approach is that it simultaneously predicts the main components of all of a person’s travel across the day. This includes the frequency of five types of tours:

- Home-based work primary tours
- Home-based education primary tours
- Home-based other primary tours
- Home-based secondary tours
- Work-based sub-tours

A home-based tour includes the entire chain of trips made between leaving home and arriving back at home. The “primary” home-based tour is defined as the main home-based tour made during the day. If a worker makes a work tour or a student makes an education tour, then that is always the primary tour. If there are no work or education tours, the primary tour is the tour with the highest priority activity at the destination (shopping/personal business, followed by social/recreation, followed by serve passenger). If there are two or more tours with the same activity priority, then the one with the longest duration of stay at the destination is the primary

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<sup>1</sup> Cambridge Systematics, Inc., *San Francisco Travel Model Development Executive Summary* developed for the San Francisco County Transportation Authority, June 30, 2001.

tour. All other home-based tours are designated as “secondary” tours. A special type of tour is a work-based “sub-tour”, defined as the entire chain of trips made between leaving the primary workplace and returning back to that workplace in the same day. By using tours as a key unit of travel, we capture the interdependence of different activities in a trip chain. This provides a better understanding of non-home-based trips, especially in the case of the work-based sub-tours that represent a significant proportion of non-home-based travel.

The study area for the model is the 9-county San Francisco Bay Area, which is represented by the Metropolitan Transportation Commission (MTC) regional travel demand forecasting model (BAYCAST). The study area is divided into two parts, so the SF tour-based model can be used to predict travel by San Francisco County residents, while the BAYCAST model can be used to predict travel by residents from the other eight counties.

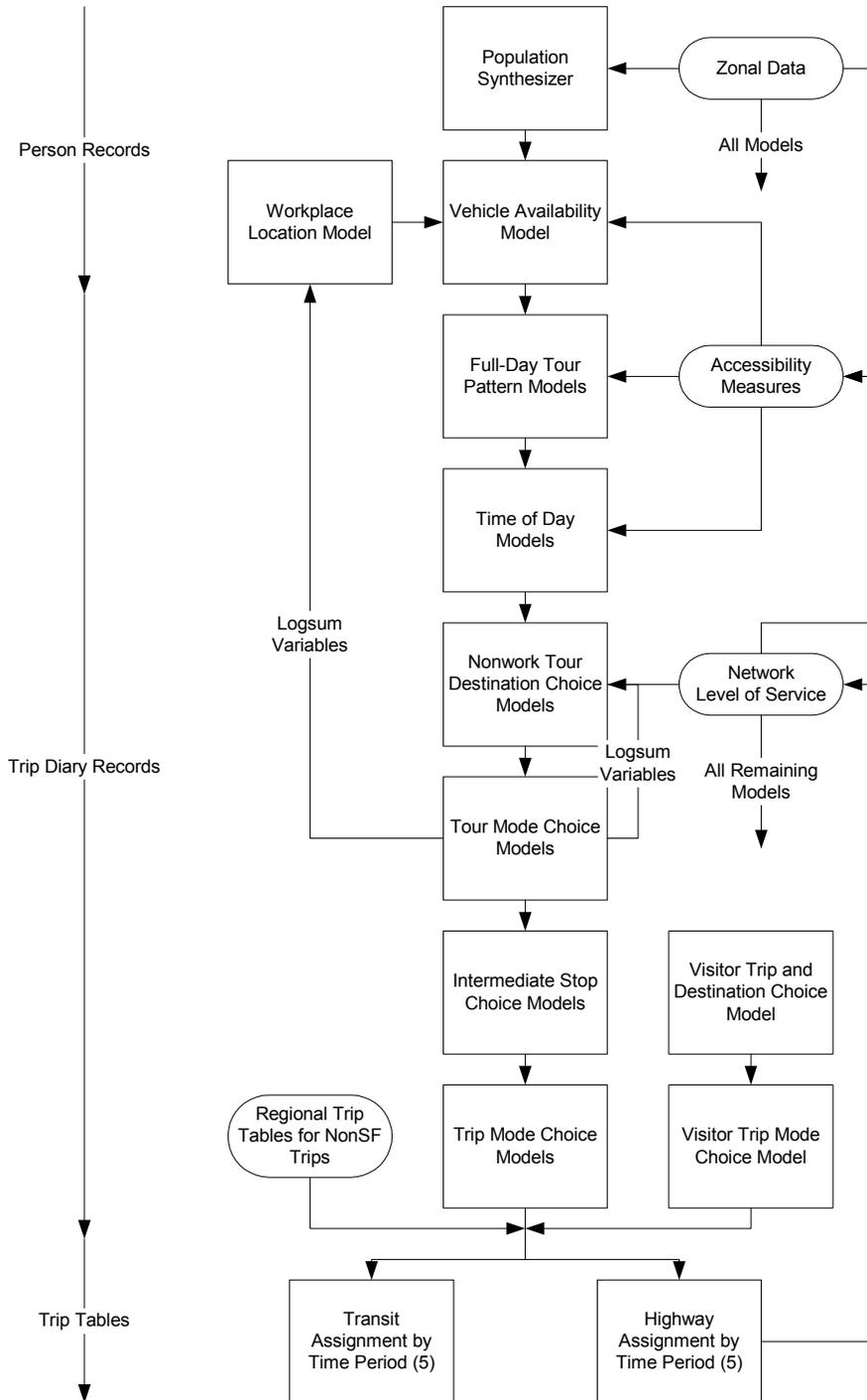
Figure 2.1 presents a schematic diagram of SF-CHAMP. This diagram includes the model components and data inputs for these components. A synthesized population of San Francisco residents is input to each model component to estimate choices for work location, vehicle availability, and tours and trips by time-of-day, destination, and mode of travel. The synthesized tours and trips aggregated to represent flows between traffic analysis zones before traffic assignment. A separate model of visitor travel is estimated to incorporate trips made by tourists and business travelers visiting San Francisco County. The model system also incorporates trips made by non-San Francisco residents by merging regional trip tables into the process for assignment.

### *Limitations of the Approach*

There were a few limitations of this approach that were a result of the available time and resources of the project:

- Initially, there was **no onboard survey** data available for validation of the mode choice model. There was a discrepancy between the Census Journey to Work data and the observed transit boarding data which could not be resolved without this additional onboard survey data. This onboard survey data was collected in the spring of 2006 and is being used to update the mode choice model now.
- The resources for the **peak spreading model** were very limited in the original project and as a result, a peak spreading model was transferred from the MTC rather than estimated for San Francisco. This transfer did not produce reliable results and was not used in any planning applications. Subsequently, the FHWA funded a research project on time of day models, which included a case study of a new time of day model (including peak spreading) for SF-CHAMP. This new time of day model is planned to be incorporated into the model.
- The approach to **trip assignment** included a traditional aggregate assignment because there were not enough resources in the project to implement a microsimulation assignment methodology. This approach has been used in all other tour-based model applications in the U.S. to date (except Transims). Nonetheless, it introduces aggregation bias and fails to take advantage of the disaggregate information on each traveler during route choice.

Figure 2.1 Model Components



- SF-CHAMP **combines trip tables** from the MTC regional trip-based model with trips generated from the San Francisco tour-based model. As a result, only the San Francisco residents are represented by the tour-based model and its advantages.

These limitations were known at the outset and accepted as lesser priorities than the core objective to build a tour-based model. In some cases, these limitations are already undergoing change in the update of the SF-CHAMP model.

There was one additional innovative aspect of the mode choice model, the inclusion of reliability and crowding as explicit variables in the transit utility functions, which was tested and then not included in the final models. These variables were included in a stated-preference telephone survey of 407 transit users in San Francisco. Logit analysis was used to estimate tradeoffs between in-vehicle time, frequency of service, reliability (defined as the percent of days that the vehicle arrives five or more minutes late), and crowding (“low” = plenty of seats available, “medium” = few seats available, but plenty of room to stand, “high” = no seats available, standing room is crowded). It was estimated that improving the percent of vehicles arriving on time by 10 percent (e.g., once every two weeks) is equivalent to reducing the typical wait time (half the headway) by four minutes for commuters, or three minutes for non-commuters. It was also estimated that improving the level of crowding from “high” to “low” is equivalent to reducing the typical wait time by five minutes for commuters and nine minutes for non-commuters. Thus, relative to commuters, non-commuters are less sensitive to delay but more sensitive to crowding, on average. For application, the reliability and crowding was coded in the transit network using observed system data collected by SFCTA. The tradeoffs estimated between these variables and wait time were applied in performing transit assignment and found to be not coincident with the observed boardings. As a result, these variables were not used in model application.

## Model Validation

Travel behavior was validated by comparing travel data in a household travel survey to related travel data in the 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 and the 1990 MTC household survey data with the same data in the model<sup>2</sup>.

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. Highlights of 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 super-district, using the 1990 Census as the primary source of observed data. A second validation test was used to evaluate the total

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<sup>2</sup> Cambridge Systematics, Inc., *San Francisco Travel Model Development Report on Validation of 1998 Models*, developed for the San Francisco County Transportation Authority, May 7, 2001.

number of vehicles estimated by the vehicle availability model compared to Department of Motor Vehicle (DMV) estimates of auto registrations. These data were different by 5 percent. Unfortunately, the 1990 MTC survey, which was used to estimate the model, contained different results for vehicle availability than the 1990 Census. 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.

- **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 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. 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. The differences between trips by time period was confirmed with initial assignments by time periods using the un-calibrated SF model that revealed the off-peak time periods were significantly under-estimated compared to traffic counts. The vast majority of under-reporting of trips in the 1990 MTC survey were in other tours.
- **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. The results reflect very reasonable allocation of destinations among four areas of the City and those destinations located outside the City. The estimate of employment that results from the work location model compared to actual employment by neighborhood showed that results were 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 calibration results also show that the destinations in the core are within three percent for each tour type and are actually overestimated in these results. The destination choice model was also calibrated by comparing trip length and duration frequency distributions. These results show reasonable average trip lengths and durations for all tour types. 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 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.
- **Mode Choice (Tour and Trip) Models** - The tour and trip mode choice models were calibrated by tour purpose. The calibration results for tour and trip modes show a very close match between estimated and adjusted observed tours and trips by mode and purpose. Initially, estimated transit boardings were discovered to be much higher than observed boardings, particularly for local bus and MUNI Metro transit modes and 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.

- **Trip Assignment** - There are two primary modes for assignment validation: highway and transit. These were validated separately using observed volumes of vehicles and passengers on the highway and transit systems, respectively. Assignment validation at the county level was 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. The highway assignment results were compared for five individual time periods and the average daily results. All highway assignment validation targets were met except for 2 screenlines and one neighborhood. For transit assignment, all modes are within 5% of observed transit boardings. However, there are some distinct differences by time of day, with estimated bus boardings significantly greater than observed boardings in the a.m. peak period. Matching the number of a.m. 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 a.m. period local bus trips.

## Comparisons to a Trip-based Model

The comparisons of the SF tour-based model with the MTC regional trip-based model showed expected differences in the base year model and some interesting differences in the forecast year model. Since the base year models are both validated to observed datasets, we do not see as many differences as in the future, where the impacts of various forecasts show different impacts in the modeling systems.

### *Base Year - 1998*

SF-CHAMP predicts tours by type rather than trips, so a direct comparison of the home-based work trips is difficult<sup>3</sup>. The 1996 MTC Survey was used for calibration because the number of trips within San Francisco County was very low in the 1990 MTC Survey (used to calibrate the MTC trip-based model) due to under-reporting of trips that occurred in this survey. 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. Off-peak time periods and other and work-based tours were all under-estimated as a result.

Trip rates per household were compared by trip purpose and show that 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 SF 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.

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<sup>3</sup> Cambridge Systematics, Inc., *San Francisco Travel Model Development Report on MTC Consistency*, developed for the San Francisco County Transportation Authority, May 15, 2001.

A relative comparison for trip distribution is the summary of employment attracted to each zone as part of the work tour primary destination choice model. This comparison required the estimation of non-San Francisco residents who work in San Francisco by zone, which may have biased the comparison results to some degree. Another comparison is the district-to-district level trip table for intra-county trips, which shows a strong correlation in percentage distribution of trips by district between the SF and MTC models, but a difference in total trips due to the under-estimation of trips discussed in trip generation.

Trips by mode and super-district show a strong similarity between the results of the mode shares by super-district, resulting from the fact that both mode choice models were developed from the same 1990 MTC travel survey data. A comparison of the vehicle trips shows there is quite a bit of difference between the trip-based and the tour-based auto mode shares. Drive alone trips are slightly over-estimated in SF-CHAMP and carpool trips are under-estimated, compared to the MTC model. A comparison with the Census Transportation Planning Package (CTPP) for trips within San Francisco shows that drive alone trips are 89 percent of total vehicle trips and shared ride trips are 11 percent of total vehicle trips, which bears a strong correlation with the SF model results.

### ***Forecast Year - 2030***

MTC produces year 2030 forecasts for its Regional Transportation Plan. The SF-CHAMP model uses the same land use projections, road improvements, and regional transit improvements as the MTC model. This allows for convenient comparison of results from the mode choice steps of each model.

The overall trip rates per household remain very similar in the 2030 forecasts for both models: about 9.2 trips per household. As in the base case, the distribution across the various trip purposes is very different for the two models, due again to the impact of intermediate stops; the MTC model predicts more home-based trips, particularly work trips, and fewer non-home-based trips than the SF model. This “accounting” issue is well understood.

Examining the geographic distribution of trips reveals more differences. In the base year, the SF and MTC models predict very similar overall levels of trip-making among the four quadrants (defined by MTC as “super-districts”) of San Francisco; comparing the MTC and SF model trip distribution patterns shows that all movements between all super-districts vary by less than three percent on relative terms. Again, the absolute trip-making rates are different due to trip generation issues described above).

When the 2030 distributions of the two models are compared, larger differences emerge. Compared to its base year forecast, SF-CHAMP shows a very small reduction in intra-district movements for all quadrants except the Sunset, the lowest-density and most suburban car-oriented part of the city. The Sunset District is the only quadrant which increases its share of trip-making to and from all other quadrants, by up to four percentage points. No district-to-district movement changes by more than four percentage points, comparing the base to the 2030 forecast with SF-CHAMP.

The MTC model shows larger swings in trip distribution, in a somewhat similar pattern. Again the Sunset district shows growth, but the MTC model also predicts a relative increase in trips to downtown, and an increase in intra-downtown trips. This is in contradiction to SF-CHAMP's two percent reduction in trips to downtown trips. This finding echoes other studies which have found the gravity model used in trip-based distribution models to be quite sensitive to changes in travel time.

From the perspective of mode split, the two models behave in very similar manners in the base and future years. In both base and 2030, the SF-CHAMP model predicts more walk trips than MTC, fewer transit trips than MTC, and more drive trips than MTC. The relative amount and direction of these differences is about the same in both base and future, except for walk trips.

## **Model Applications**

### *Equity Analysis*

SFCTA developed an application of the San Francisco tour-based model to estimate impacts on mobility and accessibility for different populations to support development of a countywide transportation plan<sup>4</sup>. Equity analyses based on traditional travel demand forecast models are compromised by aggregation biases and data availability limitations. Use of the disaggregate (individual person-level) San Francisco microsimulation model made it possible to estimate benefits and impacts to different communities of concern, based on individual characteristics such as gender, income, auto availability, and household structure.

### *Tenderloin Residents*

A recent study of the predominantly low-income Tenderloin neighborhood took advantage of disaggregate model outputs to explore the differences between travel patterns of Tenderloin residents and other trip-makers in the neighborhood. The model suggests two interesting findings. The first, modes used by anyone who makes trips to or from the Tenderloin, for any reason, choose walking, transit, and bicycling at greater rates than the average San Franciscan. Trips to and from the Tenderloin are almost half as likely to be made by car than the average San Francisco trip.

The other interesting finding is that when non-Tenderloin residents' trips are included in the totals, car use increases. This indicates that non-Tenderloin residents who make a trip to the Tenderloin – for work, social activities, or any reason – are one-third more likely to use a car than a Tenderloin resident. This suggests that about 1/3 of the cars destined for the Tenderloin are from outside the neighborhood. The greater use of cars by non-Tenderloin residents is even greater when only work trips are analyzed. Employees who work in the Tenderloin, but live

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<sup>4</sup> Castiglione, Hiatt, Chang, Charlton. "Application of a Travel Demand Microsimulation Model for Equity Analysis." TRB 2006 Annual Meeting Paper #06-2855.

elsewhere, are more likely to drive into the Tenderloin for work. The auto mode share for all San Francisco residents with origins in the Tenderloin (35.4% for work trips) is double the auto mode share of trips made only by Tenderloin residents (17.7%). This difference can be explained by a large number of Tenderloin workers who commute from outlying neighborhoods by private automobile. The specific characteristics of residents vs. non-residents making trips in the neighborhood were easy to analyze due to the disaggregate nature of the SF-CHAMP outputs, thus providing a new way of using model results to support planning project work.

### *New Starts*

SFCTA developed an application of the San Francisco model to the proposed New Central Subway project in downtown San Francisco<sup>5</sup>. This is the first application of a tour-based travel demand model in the United States to a major infrastructure project in support of a submission to the Federal Transit Administration (FTA) for project funding through the “New Starts” program. To enable the submittal of a New Starts request, software was developed to collapse the micro-simulation output of the tour and trip mode choice models into a format compatible with the FTA SUMMIT program. SUMMIT was then successfully used to summarize and analyze user benefits accruing to the project and prepare an acceptable New Starts submittal.

### *Parallel Processing*

The initial implementation of the SF-CHAMP model took 36 hours to run, which became a major impediment to further model development as well as application. The bulk of this time was not in the core microsimulation steps, but was rather in the road and transit skim-building and assignment procedures. The desire to decrease random microsimulation variation (by running multiple iterations), combined with the highly granular nature of the skimbuiding and path-building steps, made obvious the need for a parallel structure instead of the existing “top-down” model process.

SFCTA devised a job control system to allow a model job to be submitted as a transaction, which would then be processed by all available machines as quickly as possible, in parallel. The most difficult aspect of this process was analyzing the dependency tree of model steps to determine what could be parallelized and what couldn't; some steps obviously required earlier actions being fully complete. Job files were rewritten to unlink the pieces that did not depend on each other. The revised job files were passed to a new “dispatcher” utility program which could farm out each step to available computers and keep track of the model run progress.

The extraordinary time savings of this method was limited only by the amount of hardware available and the granularity of the model steps. In practice, full runs shortened from 36 hours to 9. The goal of an overnight run thus attained, staff added five additional core iterations in order to reduce error due to microsimulation variability. The model now runs in just under 12 hours.

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<sup>5</sup> Freedman, Castiglione, Charlton. “Analysis of a New Starts Project using the San Francisco Tour-Based Model.” TRB 2006 Annual Meeting Paper #06-2269.