CHAPTER 10

TRAVEL DEMAND MODEL AND UNIFORM DATABASE

Key Topics:

- Legislative Requirements
- Legislative Intent and Application to San Francisco
- Technical Approach
- Work Programs Items

1. Legislative Requirements

California Government Code section 65089 (c), requires that each Congestion Management Agency, in consultation with the regional transportation planning agency (MTC in the Bay Area), the county, and local jurisdictions, develop a uniform database on traffic impacts for use in a countywide transportation computer model. The CMA must approve computer models used for county subareas, including models used by local jurisdictions for land use impact analysis. All models must be consistent with the modeling methodology and databases used by the regional transportation planning agency.

2. Legislative Intent and Application to San Francisco

Congestion management legislation was enacted in part to help transportation planning agencies identify the source of the transportation impacts of land use decisions. All Bay Area counties except San Francisco include multiple local jurisdictions each of which has authority over land use within its boundaries. The transportation impacts of decisions made in one local jurisdiction are felt across local jurisdictional boundaries. The travel demand model is intended as a technical tool to analyze land use impacts across local jurisdictions from a uniform technical basis.

As a unified City and County, San Francisco is spared the need to estimate transportation impacts across city boundaries, although inter-county impacts must still be considered. San Francisco's travel demand forecasting challenge is primarily the accurate forecasting of travel by modes other than the private automobile, (e.g. transit and pedestrian trips).

The Authority's travel demand forecasting model was operationally complete in the spring of 2001. The Authority continues to use its Geographic Information System (GIS) database as a supplemental travel analysis tool for appropriate CMP purposes.

The model is integrated with the Authority's GIS database. The GIS is ideally suited for the graphic display of model outputs and more detailed spatial analysis. Together, GIS and the San Francisco Travel Demand Forecasting Model can be very effective both for sketch planning and the policy-level travel demand and performance forecasting exercises associated with long-range planning. The Authority's integrated model and GIS allow us to display data using graphics and maps.

The following section provides an overview of the San Francisco Travel Demand Forecasting Model (San Francisco Model) and the GIS database.

3. Technical Approach

3.1 The San Francisco Travel Demand Forecasting Model

The San Francisco Travel Demand Forecasting Model (San Francisco Model), known as SF-CHAMP is a computer-based tool used to assess the impacts of land use, socioeconomic, and transportation system changes on the performance of the transportation system. The San Francisco Model was developed to reflect San Francisco's unique transportation, socioeconomic, and land use characteristics. The Model uses San Francisco residents' observed travel patterns, detailed representations of San Francisco's transportation system, population and employment characteristics, and transit line boardings during specific time periods, roadway volumes, and the number of vehicles available to San Francisco households to measure performance. Future year transportation, land use, and socioeconomic inputs are used to forecast future travel demand.

ACTIVITY-BASED MICRO-SIMULATION

The San Francisco Model incorporates a state of the art approach to forecasting travel demand. This activity-based micro simulation model is sensitive to a broader array of conditions that influence travelers' choices.

One of the fundamental differences between the San Francisco Model and traditional models is that it is *tour*-based not *trip*-based. A tour is a sequence of trips made by an individual that begins and ends at home without any intermediate stops at home whereas a trip is a single movement from an origin to a destination. Furthermore, the Authority's model predicts tours for each individual household member over five years old in San Francisco, rather than trips for each household, as in most traditional travel demand models. Tour-based models do not require data beyond what is needed to develop a four-step travel model system. However, the tour-based methodology allows the model to:

- deal more realistically and precisely with trip chaining and interrelationships between individual trips made over the entire day;
- predict travel for individuals instead of households;
- separate travel into mandatory and discretionary tours; and
- provide a more precise estimate of volumes that can support microsimulation models.

Importantly, the tour-based methodology allows decision-makers to understand not just the changes in the magnitude and direction of trip making associated with a transportation or land use change, but also which San Francisco residents are most directly affected by that change. This equity analysis is a key advancement over traditional four-step models. Tour-based models also account more reliably for the complexities involved in multi-mode trip making. The San Francisco Model addresses the tradeoffs between modes for the full tour, as well as the tradeoffs between modal options of trips within a tour.

MODEL APPLICATIONS

The Authority used the San Francisco Model to provide detailed forecasts supporting a number of specific planning applications, including the Doyle Drive Environmental & Design Study, the Countywide Transportation Plan, the Authority's Strategic Analysis Reports (SARs), policy analyses, mobility assessments, Muni's transit service planning, and environmental analyses. Current model applications include the New Central Subway FTA New Starts analysis, Northeast Waterfront SAR, Folsom St SAR, 16th St SAR, and the Geary and Van Ness Bus Rapid Transit (BRT) studies.

The Authority also applied the model to assess Proposition K Expenditure Plan performance and impacts, as well as the full Countywide Transportation Plan package.

MODEL DEVELOPMENT INPUTS

The key inputs required to develop and apply a travel demand forecasting model include information on household and individual travel behavior (obtained in a household travel survey), representations of the pedestrian, transit, and roadway networks, and spatial representations of employment and residential characteristics. In the San Francisco Model, most of the model components were estimated (the process of establishing the relationship between various relevant inputs) using household travel data collected by the Metropolitan Transportation Commission (MTC) for San Francisco residents only. In addition to the household travel survey, a "stated preference" survey collected preference data on transit reliability, crowding, personal security, and auto parking availability and cost.

The model is applied as a windowed 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. The San Francisco Model provides the inputs to develop a detailed window of San Francisco's residents and visitors' trip making behavior within the MTC network and model structure. All trips made by San Francisco residents within San Francisco are estimated from the activity-based models. Trips that do not begin and end in San Francisco are taken from the MTC model and are applied to the San Francisco Model networks, which include the entire Bay Area.

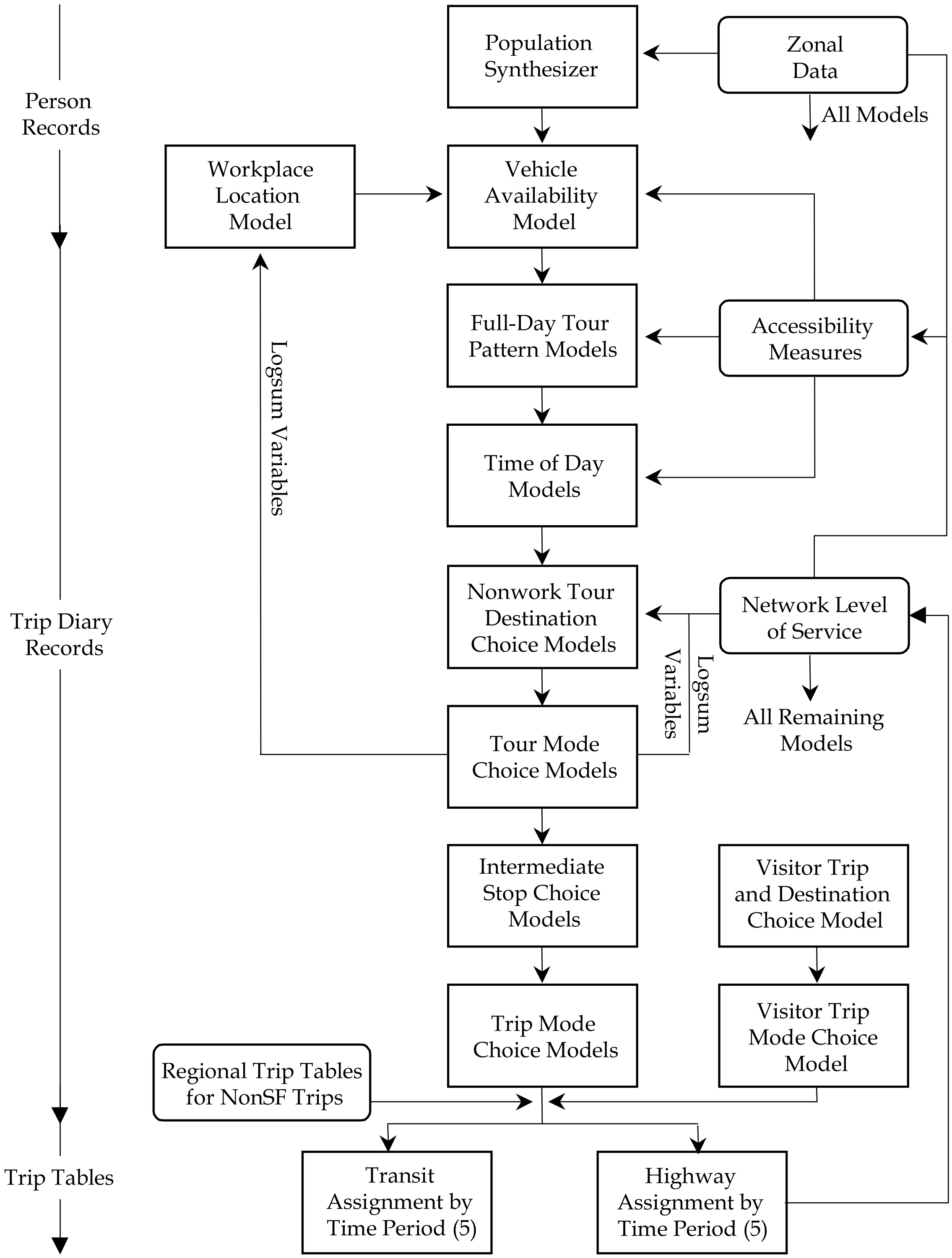
Note that while the model system is referred to as the "San Francisco Model," it is, in fact, a series of component models that operate in a coordinated fashion, each with its own unique purpose. The following paragraphs provide brief overviews of the model inputs and components. Figure 1 illustrates how the model components are structured to produce travel demand forecasts.

Zonal System and Networks

The model uses a zone system much like the United States Census Bureau's block groups to maintain land use and socioeconomic inputs. There are 766 travel analysis zones (TAZ) within San Francisco County, ranging in size from a single block or smaller in the dense urban core, to groups of six to ten blocks in less densely developed residential area on the City's west side.

Model networks were based on centerline shape files provided by the San Francisco Department of Public Works during the initial model development. The model networks are ground-truthed and updated on a project-specific basis. Left-turn restrictions and traffic lanes are verified prior to calibrating the road and transit volumes for a base year model run.

FIGURE 1 San Francisco model components.



MODEL INPUT AND COMPONENTS

The Authority is working with the San Francisco Planning Department to develop updated detailed population and employment inputs that are consistent with the county-wide control totals from the latest Association of Bay Area Government (ABAG) land use projections. Base year and future year forecasts will pivot off of a parcel-level residential and employment database, inventories of new development projects under construction, approved, and under review, and information on development potential for major area plans. A model consistency report will be prepared in the Spring of 2006 based on Projections 2003 land-use inputs used by MTC in the current RTP. This report will be referenced in a Spring 2006 CMP addendum, issued concurrently with the 2005 LOS Monitoring results.

The San Francisco Planning Department prepared detailed land-use allocations for Projections 2000 and 2002. We have used the 2002 planning department's land use inputs for all city-wide model applications; these are consistent with the ABAG 2002 totals. For the 2005 FTA New Starts application for Muni's New Central Subway, projections 2003 land use forecasts were used for consistency with the 2005 RTP.

The San Francisco 766 Traffic Analysis Zone (TAZ) system is used within the City and County of San Francisco. Outside of the City, the San Francisco Model zone system is the same as the MTC Model 1099 zone system. Overall the model has approximately 1740 zones. The model zone system is currently being updated to reflect MTC's new 1454-zone system. This update will be reflecting in the upcoming Model Consistency Report and the Spring 2006 CMP addendum.

Additional zone-level model inputs were developed to help refine the model to reflect San Francisco conditions. One key set of inputs developed by the Authority to support the model is a set of Pedestrian Environment Factors. These factors provide a qualitative assessment of the pedestrian-friendliness of different areas of the City. In addition, estimates of on-street and off-street parking supplies and costs were developed to help understand how this factor affects San Francisco residents' decision-making

The San Francisco Model transportation networks are very detailed. Within San Francisco, the network is the City base map developed by the San Francisco Department of Public Works. It is highly spatially accurate and it includes every street segment within the City. For external counties, the San Francisco Model's roadway network is the MTC regional model highway network. All local and regional transit route alignments and all stop locations are coded in the San Francisco Model's transit networks. Outside San Francisco, the MTC regional model transit network is used to represent the pertinent transit services. Finally, all City streets are part of the model's pedestrian network.

Population Synthesis

Prior to running the remainder of the San Francisco Model, it is necessary to create a synthesized population of San Francisco residents. As described earlier, the San Francisco Model is an activity-based micro simulation model. This means that the model works at the level of the individual decision-maker – each San Francisco resident. It is therefore necessary to create a representation of each decision-maker for the other models to work with. TAZ-level totals of households, population, and employed residents, as well as census-based distributions of household configuration, age, and income-level serve as inputs to the population synthesis model.

The model samples the Census Public Use Microdata Sample (PUMS) (i.e. long form respondents) household records, and then assigns these to the TAZ, based on the control totals and marginal distributions. The result is a file with one record for each decision-maker. It matches all control totals and distributions when aggregated to the TAZ-level.

Vehicle Availability

The vehicle availability model predicts the vehicles available in each household for each San Francisco resident. The model estimates the probabilities of having zero, one, two, or three or more vehicles available. The San Francisco Model can account for tradeoffs for auto ownership based on the employment location of the primary worker in the household. This is a significant factor for auto ownership in a transit-rich environment such as San Francisco. According to the most recent Census, San Francisco has the second highest percentage of transit usage in the U.S. and the third highest percentage of other non-single occupancy vehicle modes for travel to and from work.

The vehicle availability model was validated primarily on two key variables, number of workers per household and super district[1], using the 1990 Census as the primary source of observed data. 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 in San Francisco.

Full Day Pattern Model

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. Predicting tours (a sequence of trips made by an individual that begin and end at home without any intermediate stops at home) rather than trips is a significant improvement over traditional trip generation procedures because of the relationships between trips on any tour. Figure 2 illustrates the difference between trips (as estimated in the traditional four-step process) and tours.

Several models are used to predict the full day pattern. The **Primary Tour Generation Models** predict whether each individual will make either no tour on a typical weekday or will make a primary tour for one of the following purposes: work, school or other. The individual's primary tour is defined as the longest tour in elapsed time made with a stop at work, school or for other purposes. All of these tours are home-based. Work-based tours and secondary home-based tours are also predicted. The models also predict whether there are intermediate stops on each primary tour: none, one or more on the outbound portion only, one or more on the inbound portion only, or one or more on both portions. Subsequent models predict the exact number of intermediate stops on each tour leg.

[1] Superdistrict is a geographic area defined by MTC. San Francisco is divided into four superdistricts.

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 full-day pattern tour models were validated 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.

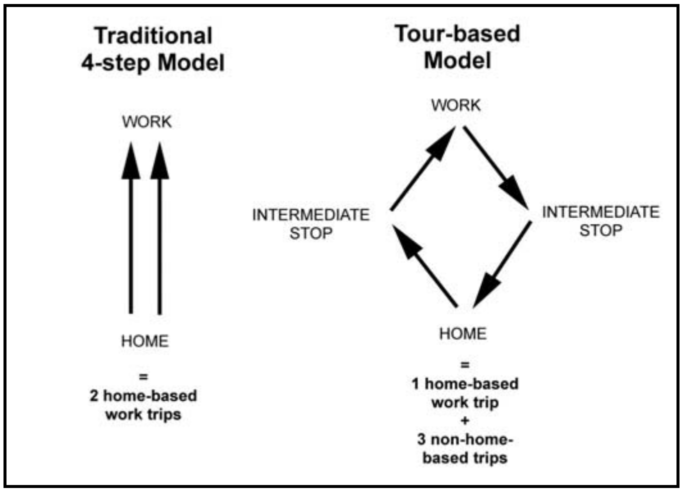
Time Of Day Models

The time-of-day model predicts the period when the traveler leaves home to begin the primary tour simultaneously with the period when the traveler leaves the primary destination to return home. It also predicts the time period of any intermediate stops. The periods used in the San Francisco Model are defined as:

- Early (3:00 AM to 5:59 AM)
- AM peak (6:00 AM to 8:59 AM)
- Midday (9:00 AM to 3:29 PM)
- PM peak (3:30 PM to 6:29 PM)
- Late (6:30 PM to 2:59 AM)

Activity-based models can account for tradeoffs between trip chaining and time of day by evaluating time of day decisions at the tour level rather than the trip level. Pricing policies (such as parking or toll policies) can be tested more accurately by including these tradeoffs between the need to travel for purposes that are time-dependent (such as day care or work) and the desire to avoid peak period pricing. Activity-based models can also account more reliably for the complexities involved in multi-mode trip making.

Figure 2. Trip Definitions: 4-step model vs. tour-based model



Destination Choice Models

Given that the full day activity model has predicted that a traveler makes a tour with a primary destination as well as potentially some number of intermediate stops, the destination choice models select the likely destinations for these trips. The San Francisco Model includes two types of destination choice models.

The **Primary Tour Destination Models** predict the destination of tours such as the workplace or school. The **Intermediate Stop Location Models** predict the location of intermediate stops for tours with stops on the way to and/or from the primary destination, where those stops are conditional on where the primary destination is located.

The Destination Choice Models were validated against the 1990 MTC survey data for primary destinations by purpose and trip length frequency distributions

Mode Choice Models

After the Full Day Pattern Models and the Destination Choice Models have predicted the number, timing, and destination of trips, the Mode Choice Models predict the mode used by the traveler to reach their destination. Mode refers to the type of transportation, such as walking, bicycling, riding transit (such as light rail or bus), driving alone, or sharing a ride. The San Francisco mode choice models differ from traditional trip-based mode choice models in that there are two distinct sets of mode choice models. The Tour Mode Choice Model determines the primary mode for the tour, while the Trip Mode Choice Models determine the mode for each individual trip made on that tour, based on the mode chosen for the tour.

An analysis of trips by mode revealed the significant percentage of transit trips and non-motorized (walk and bike) trips made by San Francisco residents. It also showed that a number of transit trips are made by using several transit modes; i.e., local bus access to BART. San Francisco can be considered a transit-rich environment, where most residents can walk to transit, and a limited supply of parking is available with a high cost. Based on this analysis, a detailed representation of available modes was developed, including:

- Muni Metro
- Muni local bus
- Regional "premium" transit (Golden Gate Transit, AC Transit, SamTrans, Caltrain)
- BART
- Walk
- Bike
- Drive Alone
- Shared Ride 2
- Shared Ride 3+

The mode choice models were validated against the MTC household travel surveys and existing modal count information.

The 2004 Multimodal Onboard Survey accomplished a major goal of ongoing model development and improvement efforts. The key product from this survey is a robust data set for calibration of the San Francisco mode choice and transit assignment submodels. Rich data on MUNI passenger origins, destinations, and demographics were not available when the model was originally developed. The survey covered all MUNI transit lines at all times of day, and provided transit passenger demographics, origin/destination patterns, transfer rates, fare payment types, access/egress modes, and other transit travel demand characteristics. In addition, the survey collected information on tour characteristics such as tour purpose, which will be critical for tour submodel calibration efforts.

The data from this survey will be used to recalibrate the San Francisco Model in the spring of 2006.

Visitor Models

Given San Francisco's popularity as a tourist destination, trips made by visitors from beyond the San Francisco Bay Area had to be accounted for in the San Francisco Model. A series of models were estimated to predict the visitor trips by mode for San Francisco tourist destinations. These models were not based on MTC's household travel survey of Bay Area residents, but rather were estimated using San Francisco Visitor & Convention Bureau data, and coefficients derived from the Honolulu model visitor development effort.

The visitor models are significantly less complex than the San Francisco resident models. They estimate the number of visitors to 29 key visitor destinations for each of three modes. The destinations include among others, Alcatraz, Golden Gate Park, North Beach, Union Square, and a cable car ride.

Assignment

Once the detailed activity patterns of San Francisco residents and visitors is estimated (including the type and timing of trips, destinations, and modes of travel), this travel demand is integrated with MTC's forecasts of travel demand by regional travelers, producing tables of trips by mode of travel from zone to zone by time of day. For example, a matrix may contain the number of transit trips during the AM peak, while another may contain a matrix of drive alone trips in the evening time period. This time period-specific demand is then assigned to the regional roadway and transit networks.

There are two primary components to the assignment process – transit and roadway. Transit assignment uses detailed information from the mode choice models to determine the particular route that a traveler uses. For example, the mode choice models may predict that a traveler uses a bus to get from the Inner Sunset to Civic Center, but it does not predict which bus. The Transit Assignment Model predicts the specific route chosen, and any transfers, based on walking time to the nearest stop, expected wait time, presence of other transit alternatives (such as the multiple routes that serve a significant portion of Van Ness Avenue), fares, in-vehicle travel time, and walk time to the final destination.

Roadway assignment predicts the specific route chosen by travelers based primarily on congested travel times. If a particular route between two points is faster than another, it will attract drivers until the travel time on all routes between two points is equal.

The validation of transit and highway assignments is done 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.

FURTHER INFORMATION

More detail about the San Francisco Travel Demand Forecasting Model can be found in the model development documentation.

3.2 GIS Database and ArcGIS 9.1

The Authority uses a GIS database coupled with ESRI's ArcGIS 9.1 software to complement the strategic analysis facilitated by the San Francisco Travel Demand Model. The Authority's GIS database includes a large repository of shape files corresponding to local and regional street networks, census tracts, census block groups, census blocks, TAZ, transit routes, and more.

The GIS database is continually refreshed with data obtained from our citywide and regional partner agencies, as the Authority does not currently directly maintain any GIS files in-house. Updated San Francisco GIS files are provided via the City's website.

3.3 Use of the Regional Model

As described in Section 3.1, the San Francisco Travel Demand Forecasting Model is a windowed model. It uses inputs from the regional model in a number of ways. The network and zone system outside San Francisco are taken directly from the MTC model. In addition, all trips that are not made by San Francisco residents or visitors are taken from the MTC trip tables. Finally, trips by San Francisco residents and visitors that begin and/or end outside San Francisco are also taken from the MTC trip tables.

The Authority now has the ability to run the MTC model in-house to evaluate the impacts of large projects of a regional scope. As part of the New Starts process for New Central Subway, the Authority used the MTC regional model to quantify the benefits attributed to non-San Francisco residents.

By maintaining the MTC Model in-house, the Authority now has the capability to test the effects of transportation and land use changes on *regional* travel patterns. For example, congestion pricing on bridges or changes to Caltrain service would be expected to affect the travel patterns of both San Francisco residents and non-San Francisco residents.

3.4 MTC Model Consistency

A model consistency report will be released in spring of 2006 that will describe in detail the results of several planned improvements to the San Francisco Model's zone and network structure.

The San Francisco Model is based on MTC's 1,099-zone system, which MTC has recently expanded to 1,454 zones with the introduction of the 2005 Regional Transportation Plan (RTP). As part of this year's CMP update and model consistency report, the Authority is updating its model to the new 1,454 zone standard for areas outside of San Francisco County. In addition to the zonal updates, fresh copies of the regional transit networks will be imported into the San Francisco Model as a part of this process.

Upon completion of the network and zonal updates, the Model Consistency report will be filed as an addendum to this CMP in the spring of 2006. The results of the Fall 2005 LOS Monitoring will also be submitted in this timeframe.

4. Work Program Items – Key Milestones

The Authority will continue to work collaboratively with the Planning Department, Department of Parking and Traffic, the Municipal Railway, other City agencies, regional transit operators, Caltrans, and MTC to:

- Use new travel surveys, census data, and on-board survey data in order to perform a model recalibration and refresh.
- Work with the Planning Department to develop a permanent land use growth allocation methodology.
- Continue to apply the model to determine impacts of policy and transportation service supply changes on local trip making behavior.
- Link transit speeds to highway congestion. Currently bus speeds are hard-coded and do not vary according to traffic congestion. As

traffic congestion increases in the future, bus travel times do not lengthen appropriately.

- Update the SF Model TAZ structure such that it reflects the new MTC 1454 zone system for areas outside of San Francisco. This update is required for the San Francisco model to be consistent with the regional model, while providing for easier import of the regional transit networks.

- Updates to the non-work tour components of the model. Improve balance between tours and zone size.

- Make necessary model updates to effectively model a congestion pricing cordon. Implement a peak spreading model. Use results from recent FHWA time-of-day research to implement time-of-day travel forecasting in 30-minute increments throughout a 24-hour period.