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Regional Travel Demand Model and Land Use Model Documentation

Introduction

The Association of Monterey Bay Area Governments (AMBAG) is the federally designated Metropolitan Planning Organization (MPO) for the tri-county Monterey Bay Area. To carry out Metropolitan Transportation Planning activities, AMBAG works closely with the Santa Cruz County Regional Transportation Commission (SCCRTC), the Transportation Agency for Monterey County (TAMC), the Council of San Benito County Governments (SBtCOG), the Monterey Bay Unified Air Pollution Control District (MBUAPCD), Monterey-Salinas Transit (MST), the Santa Cruz Metropolitan Transit District (METRO), Caltrans, Federal Highway Administration (FHWA), Federal Transit Administration (FTA) and all local jurisdictions (18 cities and 3 counties) within the tri-county Monterey Bay Area.

The Monterey Bay Area constitutes California's North Central Coast Air Basin. Situated between the San Francisco Bay Area to the north and San Luis Obispo County to the south, it spans a total of 6,000 square miles. However, urbanized areas constitute less than 150 square miles.

Developing the 2040 Metropolitan Transportation Plan (MTP) and Sustainable Communities Strategy (SCS)

The Metropolitan Transportation Plan (MTP) has a horizon year of 2040 and is scheduled for adoption by the AMBAG Board of Directors in June 2018. One of the first steps in the development of the 2040 MTP/SCS was to evaluate and update the stated goals and objectives from the 2010 MTP. The AMBAG Board of Directors approved updated goals and policies as well as accepted updated performance measures at its June 2016 meeting. The performance measures were used to evaluate alternative transportation/land use scenarios and relate to each of the goal areas which are as follows:

- Access and Mobility – Provide convenient, accessible, and reliable travel options while maximizing productivity for all people and goods in the region.
- Economic Vitality – Raise the region's standard of living by enhancing the performance of the transportation system.
- Environment – Promote environmental sustainability and protect the natural environment.
- Healthy Communities – Protect the health of our residents; foster efficient development patterns that optimize travel, housing and employment choices and encourage active transportation.

- Social Equity – Provide an equitable level of transportation services to all segments of the population.
- System Preservation and Safety – Preserve and ensure a sustainable and safe regional transportation system.

AMBAG, in coordination with the Regional Transportation Planning Agencies (RTPAs), developed revenue projections and project costs.

The MTP is supplemented by the three county level Regional Transportation Plans (RTPs) prepared by SBtCOG, SCCRTC and TAMC. Therefore, the updates to all four plans, including goals and objectives, transportation project evaluation criteria, revenue projections, etc. were prepared to be consistent with each other.

The Sustainable Communities Strategy (SCS) is a new element of the MTP, as required by Senate Bill 375 and shows how regional greenhouse gas (GHG) targets will be achieved through efficient development patterns, infrastructure investments, transportation measures, and policies that are determined to be feasible. The regional GHG targets are measured from a 2005 baseline and for the AMBAG region are a zero percent per capita increase by 2020 and a five percent per capita reduction by 2035. If the SCS had not met regional GHG targets, an Alternative Planning Strategy (APS) could have been developed to demonstrate what alternative scenario and additional measures would be needed in order for the region to meet its GHG target.

Development and Evaluation of Planning Scenarios and Draft MTP

In order to evaluate various combinations of transportation and land use strategies that could lead to achieving the GHG targets adopted by the California Air Resources Board (CARB) for the tri-county region, AMBAG worked with the three county RTPAs, local governments, transit agencies and the public to develop and evaluate a set of SCS transportation and land use scenarios, using its upgraded transportation and land use modeling capabilities. These scenarios were evaluated based on how each performs in relation to the GHG targets and other performance measures. This comparison of scenarios allowed the AMBAG Board of Directors to select a preferred scenario that formed the basis for the Draft 2040 MTP/SCS. Please see Chapter 4 and Appendix E for more information on the SCS scenario planning process.

Public Participation Plan and Interagency Coordination

Another requirement of SB 375 is that each MPO adopt a public participation plan for development of the SCS and Alternative Planning Strategy (APS), if one is required. Some of the key requirements of SB 375 related to public participation are:

- Outreach efforts to encourage the active participation of a broad range of stakeholder groups in the planning process, consistent with the agency's adopted Federal Public Participation Plan, including, but not limited to, affordable housing advocates, transportation advocates, neighborhood and community groups, environmental advocates, home builder representatives, broad based business organizations, landowners, commercial property interests and homeowner associations.
- Consultation with congestion management agencies, transportation agencies and transportation commissions as applicable.
- Workshops throughout the region to provide the public with the information and tools necessary to provide a clear understanding of the issues and policy choices. Each workshop, to the extent practicable, shall include urban simulation computer modeling to create visual representations of the SCS and the APS, if one is prepared.
- Preparation and circulation of a draft SCS and APS, if one is prepared, not less than 55 days before adoption of the final MTP.

- At least three public hearings on the draft SCS. To the maximum extent feasible, the hearings shall be in different parts of the region to maximize the opportunity for participation by members of the public throughout the region.
- A process for enabling members of the public to provide a single request to receive notices, information and updates.

For more information on public participation and outreach refer to Appendix D.

Coordination of Modeling Activities with Partner Agencies

AMBAG, as a federally designated MPO, is required to develop and maintain a tri-county Regional Travel Demand Model (RTDM) to meet federal and state requirements. The GHG target set by CARB applies to the tri-county Monterey Bay region. In this context AMBAG and the RTPA staff have established two levels of working committees that regularly met and worked together to develop the region's MTP and RTPs as well as to conduct scenario planning and modeling analysis. While the RTPAs do not maintain or run the RTDM, they were engaged in the consideration of the results of scenario model runs and in the process of refining the alternative scenarios. As the MTP was being developed, AMBAG worked with all of its partners (RTPAs, transit operators and local jurisdictions) as well as the appropriate federal and state agencies to ensure its MTP conforms to all applicable state and federal regulations.

2018 Regional Growth Forecast

In 2015, AMBAG began the process of developing a new forecast benchmarked to 2015 with a horizon year of 2040. The regional forecast is based on an analysis of forecasted state and national industry growth compared to the region's historical share of each industry.

The disaggregation of the forecast at jurisdiction level uses shift-share methods for population and employment. These methods essentially calculate future years population and employment based on previous trends. The forecast disaggregation also takes into consideration local land use policies and was developed using a collaborative approach whereby AMBAG incorporated the input of local planners, elected officials and the public. The final forecast is scheduled for adoption in June 2018 along with the 2040 MTP/SCS. The 2020, 2035 and 2040 scenarios for the SCS were developed using this population and employment forecast as a control total in consultation and collaboration with region's local and regional agencies. The technical documentation for the Regional Growth Forecast is included in Appendix A.

Other Key 2040 MTP/SCS Tasks

Other key major tasks include updates to the plan performance measures, environmental justice analysis, new revenue projections, revised cost estimates for projects, programs and services and integration of system and demand management measures into the scenarios. Additionally, the 2040 MTP/SCS incorporates recommendations from recently completed or underway transportation studies, such as the U.S. 101 Freight Study, the Electric Vehicle Infrastructure for the Monterey Bay Area Study, the SCS Implementation Project and the Rural Transit Initiative. Other studies that are relevant to the development of the new AMBAG model include the Monterey Bay Origin and Destination Study, the Santa Cruz METRO On-Board Survey, and the California Household Travel Survey (CHTS).

Modeling Methodology

Development of the Regional Travel Demand Model

The primary transportation model that AMBAG employs is a trip-based, four-step RTDM run in TransCAD Version 7.0 platform and includes Monterey, San Benito and Santa Cruz Counties. AMBAG developed a very comprehensive Model Improvement Plan (MIP) which addressed recommended improvements provided by the peer review panel selected under the Federal Highway Administration sponsored Travel Model

Improvement Program (TMIP). AMBAG hired a team of professional consultants led by Caliper Corporation that included Fehr & Peers and Parsons Brinckerhoff. The model includes detailed transportation and transit networks, as well as a geographically based Traffic Analysis Zone (TAZ) layer containing socioeconomic data for the base year 2015 and forecast years 2020, 2035 and 2040.

The AMBAG RTDM is an entirely new travel demand model estimated and calibrated using data from the 2011-12 California Household Travel Survey (CHTS). The model utilizes innovative techniques to capture travel behavior at a more individual-based level and incorporates disaggregate level data into some of the modeling stages. The primary reasons for introducing more disaggregate level data into the model was to assist in addressing elements of SB 375, and to pave the way for a possible transition to a tour-based or activity-based modeling approach in the future. This updated model is a traditional four-step trip based approach, and as such includes models for Trip Generation, Trip Distribution, Mode Choice, and Trip Assignments. Specific differences compared with traditional approaches, and described in more detail later in this document, include a population synthesis to drive the trip generation socioeconomic variables, calculation of D factors - household density, employment density, intersection density, and diversity - variables using GIS techniques to support inputs to various model stages, the use of person-based trip rates, destination choice model for the trip distribution and a mode choice component designed and estimated entirely from the 2011-12 CHTS data. The model also employs a highly convergent traffic assignment algorithm. The model is calibrated to 2015 conditions, and utilizes the Census and employment data from that same year. The model is comprised of four primary time periods, an A.M. Peak Period defined as 6:00 AM to 9:00 A.M., a P.M. Peak Period from 4:00 PM to 7:00 P.M., a Mid-day period from 9:00 A.M. - 4:00 P.M. and an Night Time 7:00 P.M. to 6:00 A.M. The model is calibrated Average Annual Daily Traffic (AADT). The AADT calibration is based on summing the assigned flows for the four periods and comparing them against the AADTs from Caltrans, PeMs, HPMS, and local jurisdictional count sources. The Percent Root Mean Square Error (%RMSE) for the 2015 base year is 29.17% system wide, which is within an acceptable range (<40%). As per the Federal Highway Administration (FHWA) guideline, the AMBAG's 2015 base year model calibration is appropriate and has taken care not to over fit the base year model to observed conditions while maintaining appropriate levels of sensitivity and forecasting ability. Further details on model calibration can be found in the AMBAG RTDM Technical Documentation Report.

Travel behavior in the AMBAG region is especially difficult to model for a number of reasons. First, the region has high variability in residential density and has a very large rural component, particularly in the eastern and southern sections of the area. The region also has high income variability, which further complicates the process of linking the residential and employment zones necessary to explaining travel behavior in the region. Heavy commuter travel and interregional travel to the San Francisco Bay Area and a high number of people telecommuting complicate matters further. In addition, the region has a rich collection of tourist activities and special events occurring on weekends and during different seasons. There also are significant agriculture activities from farm workers making seasonal transient (field-to-field) trips and goods movements by freight modes, mainly by truck. The region experiences a wide variation in rural and urban characteristics with significantly longer trip lengths in rural areas, resulting in higher VMT and peak period spreads. We believe we have successfully addressed these challenges though the deployment of a destination choice model for many of the home-based trip purposes.

Following is a summary of the key modeling components and brief description of the methodology/approach proposed for this model improvement project.

Data, Surveys, and Studies Used in Model Development

Data from the recent Census, the AMBAG 2018

Regional Growth Forecast, the 2011-12 CHTS, the 2012 External Origin-Destination (OD) Study conducted by Fehr & Peers and Air Sage, the SCCRTC Onboard Transit Survey for the Santa Cruz METRO transit system, the City of Watsonville Transit Study, County and Caltrans traffic count data were used for the development, calibration, and validation of the model. In addition, reliable output data from the neighboring MPOs (interregional commute components) and data from the agriculture vanpool program were utilized for the model development.

Update to the Highway, Transit and Bicycle Networks for the 2015 Base Year, 2020, 2035 and 2040 Future Years

The consultant completed a comprehensive review and update to the highway, transit, and bicycle networks for the model update. AMBAG also employed a web-based tool to engage local jurisdictions to review and ground truth key transportation network attributes such as speed, number of lane, traffic counts. The latest data sets have exceptional geographic accuracy. The updated files include bicycle facilities and other geographic considerations pertinent to transit accessibility. For the 2020, 2035 and 2040 networks, the consultant worked with AMBAG, the RTPAs and Caltrans staff to determine which infrastructure improvements to include in each scenario.

Update to the 2015 base year, 2020, 2035 and 2040 Future Years TAZ Data Layers

Utilizing current estimates and projections for future year socioeconomic characteristics pertinent to the model at various geographic scopes, the consultant generated attributes using GIS tools for the model TAZ layer. The TAZ geography used in the updated model is an aggregation of 2010 Census Block boundaries. The geography is very similar to that submitted to the Census by AMBAG as part of the TAZ delineation process. The zone structure is comprised of 1,710 zones including 37 external zones that serve as the primary gateways to the study area. This consistency ensures a reliable calculation and transfer of important demographic data from the Census data files. Although the TAZ boundaries will remain the same for the horizon years of the model, the socioeconomic characteristics may change significantly by county and region. AMBAG and its stakeholders provided this information for the future years.

Trip Generation Model

In developing the trip generation model, AMBAG with the consultant's assistance evaluated increasing the number of explanatory variables. In addition to auto availability, age, and household size, other geographic variables such as lifestyle considerations, presence of young children in the household, and the availability of recreational opportunities were explored for inclusion in the model. A final list of variables included is shown below.

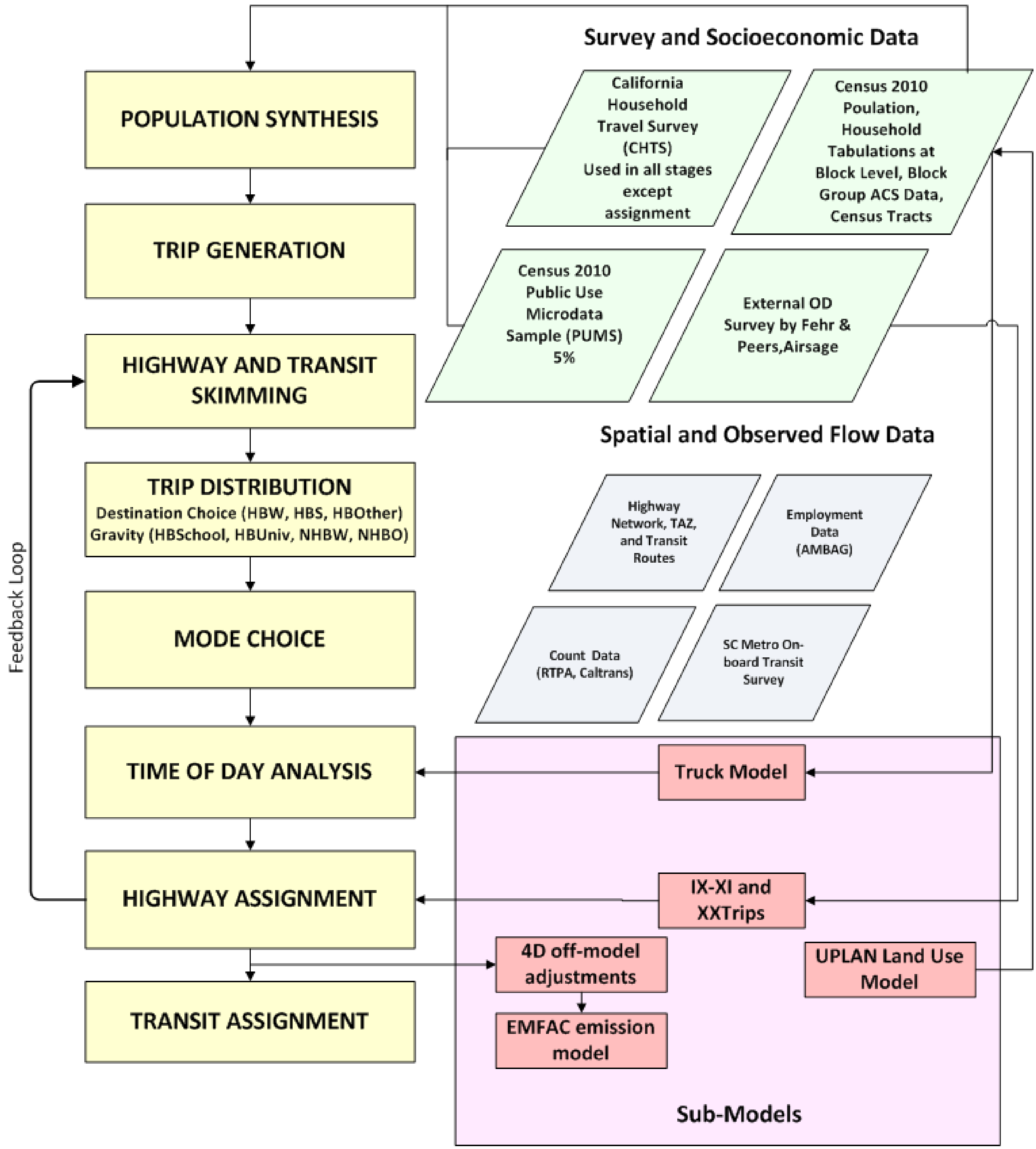
The AMBAG region is a large and diverse area. To better handle such diversity, the AMBAG model estimates a person based trip rate model instead of a household based model. This includes the creation of a synthetic population for the AMBAG region detailing a discrete record of persons and their characteristics to which the trip generation model is applied. Applying person based trip generation models has several advantages. It increases the sample size of data used to estimate the models and better explains the variations in travel behavior. It also provides a better platform on which to quantify the D factors and prepares the foundation for a possible transition to activity based modeling.

The following attributes are output at the person and household levels and matched against the appropriate census aggregation (block or block group) and are used as inputs into the trip generation model:

For Households:

- Household Size
- Vehicles in Household
- Income Category
- Tenure (own or rent)

Figure F-1: Model Stream for Regional Travel Demand Model



- Number of Children under 18 in Household
- Number of persons above 65 years of age in household

For Persons:

- Age
- Employment Status
- Sex
- Enrolled in School
- Education Level Attained
- Race
- Worker Status

The trip generation model forecasts trip productions and trip attractions at the zonal level for seven primary trip purposes: Home based Work (HBW), Home based Shopping (HBShop), Home based School (HBSchool), Home based University (HBUniv), Home based Other (HBOther), Non home based-work (NHBW), and Non home based other (NHBO), and Visitors (to shopping and tourism sites). NHBW refers to trips that are non-home-based but have one trip end at a work location. NHBO trips are similar except that neither end of the trip is a work location. The visitor model is split into two market segments: Visitors to Shopping sites (Visitor_Shop) and Visitor to Tourism sites (Visitor_Tourist). The visitor purposes are the only models not fully supported by the travel survey. They are based on previous AMBAG modeling efforts with some modification.

Interregional Trip Estimates and the Assumptions

AMBAG recently conducted an Origin Destination (OD) study using two different methodologies as well as weeklong classified traffic counts. The OD survey results using license plate video survey were used to account for External-External (X-X), External-Internal (X-I), and Internal-External (I-X) and was validated with traffic counts. AMBAG also consulted with Metropolitan Transportation Commission/Valley Transportation Authority, San Luis Obispo Council of Governments and Merced County Association of Governments modeling staff for the verification of the future year traffic forecast for respective external gateway locations.

Trip Distribution (Destination Choice Model)

The AMBAG RTDM deployed two primary models, a destination choice model and a gravity model for this model component. Traditionally, distribution models have primarily utilized a formulation of a gravity model. Unfortunately, the gravity model's aggregate nature limits its ability to capture the range of individual destination choice behaviors manifested by the population. A destination choice modeling approach has the potential to introduce more behavioral realism and hence generate trip tables that are closer to reality and more sensitive to smart growth land use policies.

A destination choice model also can include variables not typically present in a traditional gravity model. For instance, the home-based-work trip purpose gravity model can be replaced with a work location choice model for workers that predicts their work zone. Another clear advantage of the destination choice model is that accessibility measures can be directly input as variables to the choice models. Finally, destination choice models will eliminate the need for ad-hoc adjustments such as the use of K-factors in the gravity model.

Time of Day Analysis

A major upgrade to the model is the deployment of time period and trip purpose specific parameters. This includes the utilization of separate peak and off peak period skims, and model parameters. This approach provides a superior explanation of peak and off peak travel patterns throughout the region

AMBAG worked closely with Caltrans, and other relevant local and county agencies to determine the most appropriate day and time periods for modeling. The model uses the following time periods:

- A.M. Peak hour and period (6:00-9:00

A.M.)

- P.M. Peak hour and period (4:00-7:00 P.M.)
- Mid-day (9:00 A.M.-4:00 P.M.)
- Night (7:00 P.M.-6:00 A.M.)

Using the available count data, the AMBAG RTDM was calibrated for each of the time periods shown above.

Mode Choice Model

The mode choice model was evaluated to explore avenues for enhancing its structure, utility specifications, and coefficients. Model parameters were compared against Federal Transit Administration (FTA) guidelines to document any instances of values that fall outside of the ranges suggested by the guidelines. Nevertheless, it should be noted that the most appropriate model parameters for the AMBAG region were obtained by re-estimating the model from the latest CHTS and Census data. The non-uniform travel characteristics, demographics, and population densities of the region meant that additional improvements for optimizing the mode choice component of the travel demand model had to be incorporated. These include:

- Re-estimating the existing models with the latest surveys and model skims.
- Moving from the current daily skims to a time-of-day approach that might better match peak and off peak skims to those perceived and experienced by surveyed travelers.
- Implementing additional nesting structures to better fit the new data.
- Utilizing regional heterogeneity so that the mode choice model nested structure varies by trip purpose.

Weighted nested and multinomial logit model estimations were conducted using the Nested Logit Estimation procedure in TransCAD 7.0. One objective was to estimate separate mode choice models for the peak and off-peak periods. However, no significant difference was observed for any of the purposes. A combined model was therefore estimated for each of the purposes.

The estimated models are a series of logit models (multinomial or nested) that vary by trip purpose and by peak/off-peak periods. For most purposes, the following travel modes are estimated (for further technical details on the mode choice model by each trip purpose please refer to the AMBAG RTDM Technical Documentation Report):

- Auto drive alone
- Auto shared ride (carpool)
- Walk
- Bike
- Transit

Highway and Transit Assignment

For highway assignment the AMBAG RTDM utilized a state of the practice and highly convergent traffic assignment methodology known as Origin-based User Equilibrium. This method improves significantly on previous highway assignment methods by providing a more stable solution to the highway assignment problem. This provided AMBAG RTDM with the ability to more accurately quantify project benefits and explain the highway assignment results in a clearer context.

In the highway assignment step, trips from the origin destination matrix are assigned to the highway network to determine flows on links and route choices between any origin and destination. In the AMBAG model, four assignments are performed: A.M. peak period trips (6:00-9:00 A.M.), P.M. Peak period trips (4:00-7:00 P.M.), Mid-day (9:00 A.M.-4:00 P.M.), and Evening/Night (4:00 P.M. - 6:00 A.M.).

Transit assignment was performed using TransCAD's Pathfinder methodology. This methodology is a generalization and significant improvement of the highly-regarded Optimal Strategies approach and far superior to typical Urban Transportation

Planning System (UTPS) methodologies. The transit assignment includes walk and bike access, along with park and ride functionality for both access (A.M.) and egress (P.M.). The Pathfinder methodology has been deployed successfully across the United States, and has gained wide acceptance from the FTA. For the transit assignments peak and off-peak transit trips are assigned separately and then aggregated for time of the day assignments into a total transit flow table.

Sensitivity Testing Results

Fehr and Peers independently conducted a model sensitivity test for modified land use changes (density and diversity), added highway capacity and additional bus rapid transit (BRT)/light rail transit (LRT) transit services using the 2010 and 2035 RTDM.

The conclusions of these tests demonstrate the model's sensitivity to land use and transportation changes. For changes where the model is not sensitive, a discussion of potential enhancements or post-processing methods is summarized below with additional technical details to be found in the 2014 AMBAG RTDM Technical Documentation Report.

Added Roadway Capacity

The model is appropriately sensitive during traffic assignment for roadway widening projects in terms of route selection. The influence of roadway capacity on trip generation, distribution, mode choice, and GHG emission were not evaluated.

Modified Land Use

The changes in land use and the formulation of the mode choice model were not significant enough to cause a change in mode. As a result, the implication of the land use change on VMT is determined by the location and magnitude of the land use rather than the density, diversity and other D factors. Post-processing for active transportation, Transportation Demand Management, and density were recommended and applied for 2040 MTP/SCS.

Added Transit Service

The model is not sensitive to changes in transit. The mode choice model estimation based on survey data resulted in a fairly static mode split model. As such, the change to transit shifted trips from local bus to BRT, but overall mode shares remained constant. The 2040 MTP/SCS includes 69 projects totaling over $2.9 billion, or 30.5 percent of available revenue over the next 22 years. In order to capture the benefit of such transit investments, AMBAG applied off-model adjustments using the California Air Pollution Control Officers Association (CAPCOA) recommended approach. [3]

Transportation Demand Management (TDM), Transportation Systems Management (TSM), and Active Transportation

TDM, TSM and Active Transportation (bicycle facilities, pedestrian facilities, and complete streets projects) were not evaluated in the AMBAG RTDM since there are no variables or sub-models for their implementation. The 2040 MTP/SCS includes almost 300 projects totaling nearly $709 million, or 7.1 percent of available revenue over the next 22 years. In order to capture the benefit of these investments, AMBAG applied off-model adjustments using CAPCOA recommended approach. [3]

Considering the complexity in the application of such improvements, off-model adjustments were applied at a system level rather than a project by project basis using methodologies from CAPCOA, the Sacramento Association of Governments (SACOG), and other recommended off-model adjustment methodologies.

Off-Model Adjustments

Where the impacts of certain policy scenarios cannot be measured in the AMBAG RTDM, AMBAG relied on "off-model" techniques based on academic literature reviews, collaboration with other MPOs and consultation with CARB's Policies and Practices Guidelines.

Off-model adjustments were made for five programs or bundles of projects that are included in the 2035 MTP/SCS: Transit Service Enhancements, TSM, Active Transportation, TDM and other travel demand reduction programs such as vanpools for agriculture workers, car sharing, Electric Vehicle

Infrastructure for the Monterey Bay Area plan (August 2013), as well as the increasing prevalence of telecommuting. The need for these adjustments was recognized in the Regional Targets Advisory Committee Final Report to the California Air Resources Board.

Several references were used for estimating the potential GHG off-model adjustments for Active Transportation projects, TSM, ITS, TDM and Transit Enhancement initiatives combined with density and neighborhood design:

1. The Urban Land Institute publication "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emission."[1]
2. The series of "policy briefs" authored by Marlon Boarnet[2] and Susan Handy[3] under a grant provided by the California Air Resources Board, and published on the CARB website.[4]
3. The CAPCOA "Quantifying Greenhouse Gas Mitigation Measures."[5]
4. SACOG Model Technical Report, APPENDIX C-4: Final Environmental Impact Report For The Metropolitan Transportation Plan/ Sustainable Communities Strategy For 2035, SACOG, February 2012.[6]
5. Bay Area Plan, Strategy for a Sustainable Region, Metropolitan Transportation Commission (MTC) and Association of Bay Area Governments (ABAG), July 2013.[7]
6. INDEX 4D: A Quick-Response Method of Estimating Travel Impacts from Land Use Changes, Criterion Planners and Fehr & Peers, 2001. [9]

These references were used for several reasons. Each reference synthesized current research and program effectiveness results from many other sources, with high standards for data quality applied to the synthesis. Each reference focused analysis of transportation-generated GHG, particularly "Moving Cooler", including GHG not directly tied to changes in VMT. The reports itemize specific project types, as well as "bundling" the projects in ways that make them very useful for transportation analysis. More importantly, the document provided estimates of the cumulative effects of implementation of the bundles, which accounted for the synergistic effects of the bundled policies. The reports include descriptive information defining the project deployment levels needed to achieve GHG reductions. The table below summarizes the total reductions of the GHG emission for the tri-county AMBAG region with implementation of the 2040 MTP/SCS.

EMFAC Model

AMBAG used the 2014 EMission FACtors model (EMFAC) to calculate GHG (CO2) emissions for the SCS as required by California Government Code 65080. EMFAC is a California specific computer model that calculates daily emissions of air pollutants from all on-road motor vehicles including passenger cars, trucks and buses for calendar years 1970 to 2040. In the EMFAC model, the emission rates from each of the motor vehicle types are multiplied by the vehicle activity data to calculate vehicle emissions. The GHG emissions analysis for passenger vehicles, (LDA, LDT1, LDT2 and MDV vehicle types), uses the automobile VMT by speed class from the AMBAG RTDM model run for each scenario.

Table F-1: GHG Calculations

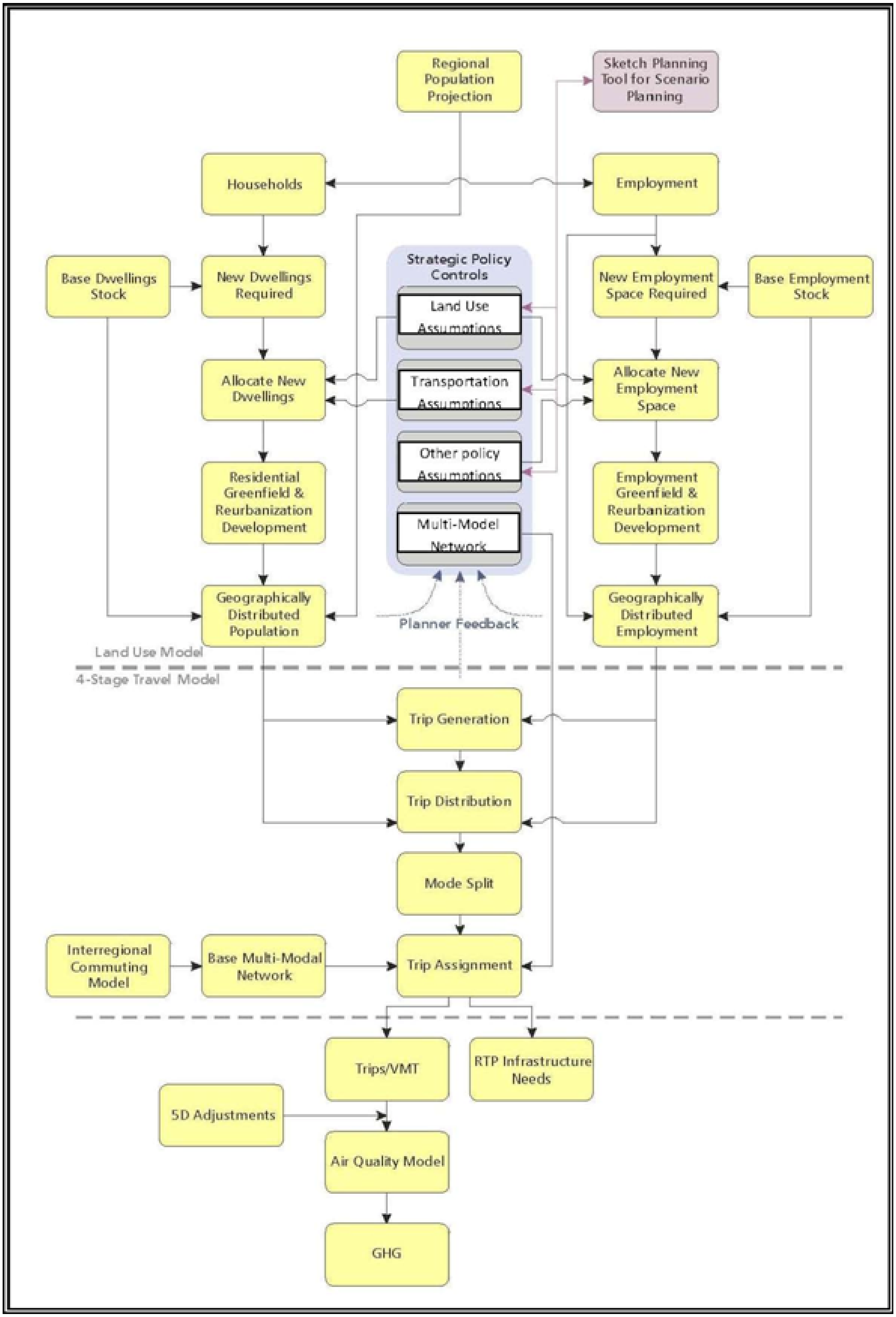
GHG Calculations for Passenger Vehicles	2005	2020	2035
Modeled Per Capita CO2 Emissions	15.39	14.3	14.29
Modeled Reduction from 2005		-7.08%	-7.14%
EMFAC 2011 - EMFAC 2014 Adjustments		-2.80%	-5.50%
Adjusted PER Capita GHG Reduction from 2005		-4.30%	-1.60%
Transportation System Management Strategies		N/A	-0.90%
Transportation Demand Management		N/A	-0.50%
Increased Work at Home Workers		N/A	-0.50%
Active Transportation		N/A	-1.60%
Transit System Enhancement Strategies		N/A	-0.50%
Zero Emission Vehicles and Electric Charging Infrastructure Development		N/A	-1.00%
Total Percent Reduction from 2005		-4.30%	-6.60%

Source: Computed using 2040 MTP/SCS AMBAG-RTDM data

Using UPlan for the MTP

AMBAG is mandated to develop various scenarios

Figure F-2: Model Improvement Plan



to evaluate alternative land use and transportation growth patterns for the SCS in the MTP. In order to evaluate land use alternatives AMBAG selected the modeling program UPlan to build land use scenarios based on input from a wide variety of audiences. Each land use scenario resulted in data that was then fed into the regional travel demand model for evaluation of the combined effect of land use and transportation changes on vehicle miles traveled and other Board selected performance measures.

UPlan was originally developed by University of California at Davis for the Merced County Association of Governments (MCAG). The UPlan application is a raster based extension used in conjunction with ESRI ArcGIS software and was developed as an analytical tool that allows users to envision future lands use growth patterns.

The UPlan Model is based on the following assumptions:

- The population growth can be converted into demand for land use by applying conversion factors to employment and households.
- The new urban expansion will conform to city and county general plans.
- Cells have different attractions weights because of accessibility to transportation and infrastructure.
- Some grid cells, such as lakes and streams, will not be developed while other cells, such as environmentally sensitive habitats and flood plains, may "discourage" new development.

The inputs into UPlan consists of GIS files converted to 50 ft raster grid cells. Multiple grids are created that represent land use development, transportation facilities, political jurisdictions and other inputs. UPlan allocates growth based on residential and employment parameters and converts growth into acres needed for employment and housing by overlaying "attractors," "discouragers" and masks that have been given various buffers and weights.

For residential, the conversion looks at factors of persons per household and the density of a grid cell based on land use categories. For employment, the factors are determined based on employees per square foot and floor area ratios in commercial or industrial categories.

UPlan consists of three models types: Cluster, County, and Sub-Regional. For AMBAG, the Cluster model was utilized. The Cluster model is designed to model several counties together on the basis that they have strong transportation and land use ties in order to test the impacts of the regional transportation infrastructure and land use policies. The UPlan model consists of model specifics, demographics (residential and employment), general plan land use, slope, attractors, discouragers, and masks to allocate future growth.

Model Specifics

The specific input determines the model parameters such as extent, cell size, display units and TAZ raster. The model specific parameters used for AMBAG were as follows:

- Extent: County Boundary Raster consisting of all three counties
- Cell size: 50 ft
- Display Units: Acres
- TAZ: raster of TAZ boundaries

Demographics (Population and Employment)

Demographics in UPlan consist of population and employment for both the base year and the future year. The 2010 base year utilized Census data for population and Employment Development Department (EDD) for employment. The EDD data was compared against InfoUSA data for the work conducted for the 2018 Regional Growth Forecast. The future years of 2020, 2035 and 2040 use the 2018 AMBAG Regional Growth Forecast data.

General Plan Land Use

The term general plan is used by UPlan to refer to the land use categories used as a basis for allocating either residential or commercial growth. In the AMBAG region there are 21 jurisdictions each with their own general plan. The terminology and density or intensity categories used in any given general plan varies across the region. In order to maintain consistency when analyzing land use, AMBAG worked with local jurisdictions to develop a land use typology system that is descriptive of all potential types of land use and their associated densities in the region. This typology system was then applied to all the general plans in the region in order to provide a consistent definition of land use types across jurisdictional boundaries.

The typology system created consists of twenty-two land use categories, which substantially delayed processing time within UPlan. In order to get the model to run within a couple of hours AMBAG "crosswalked" the twenty-two categories to the seven standard UPlan land use categories. See Table F-2.

These seven (7) categories are ranked and given a strict hierarchical order based on bid price potential in the land use allocation. This ranking simply prioritizes the order in which UPlan allocates the type of growth. As shown in the Table F-3, UPlan first allocated Industrial employment growth then high density commercial growth and so forth.

The model produces a table of acres demanded for each land use category from which the model operates its allocation routing. At the end of the model run a report is generated and notice is given if the total available acres are smaller than the total acres needed for the projection year.

Slope

UPlan has a setting for the maximum slope that each land use category can be is assigned. The units for this can be in either percent or degrees, however historically percent slope has been used. A 30 percent slope was utilized on all land use types for this project.

Attractors, Discouragers and Masks

It is assumed that development occurs in areas that are attractive due to their proximity to existing urban areas and transportation facilities. Conversely, it is assumed that development is discouraged in areas that are unattractive such as flood plains, environmentally sensitive habitats, or earthquake faults. Additionally, there are some geographic areas where development cannot occur such as open space and water bodies. These areas types are called masks.

Attractors and discouragers can be buffered at user-specified intervals. Weights are given to each attractor and discourager and if they have buffers each buffer is given a weight. Each attractor and discourager is assigned to any given land use category separately, such that one land use category can have different attractors or discourages with different weights than another. The same is true of the buffers assigned to the attractors and discourages. For attractors these buffers and weights represent the strength of attraction. For discouragers buffers and weights represent the cost to which development will be discouraged.

Allocation of Land Use in UPlan

Using the general plans of all the jurisdictions in the region AMBAG developed a typology system that classified land use into twenty-two categories. The typology system acted as a crosswalk between all the various general plan definitions of land use types. For example, one jurisdiction may call sixteen dwelling units per acre "High Density Residential," whereas another may classify this kind of density as Medium Density Residential. Therefore, it was necessary to create consistency among all the

Table F-2: Conversion of Land Use Types

General Plan Land Use Type	Uplan Land Use Type
Urban Single-Family	Medium Density Residential
Urban Multi-Family Residential	High Density Residential
Urban Commercial	Low Density Commercial
Urban Mixed Use	High Density Residential
Urban Mixed Use	High Density Commercial
Single-Family Residential	Low Density Residential
Multi-Family Residential	High Density Residential
Neighborhood Commercial	Low Density Commercial
Regional Commercial	High Density Commercial
Employment Center	High Density Commercial
Neighborhood Mixed Use	Medium Density Residential
Neighborhood Mixed Use	Low Density Commercial
Town Single-Family Residential	Medium Density Residential
Town Multi-Family Residential	High Density Residential
Town Commercial	Low Density Commercial
Town Mixed Use	High Density Commercial
Agriculture	Very Low Density Residential
Rural-Town Commercial	Low Density Commercial
Rural-Town Residential	Low Density Residential
Exurban and Rural Residential	Very Low Density Residential
Institutional	High Density Commercial
Airport	Mask
Industrial and Manufacturing	Industry
Open Space/Recreation	Mask

Table F-3: UPlan Land Use Rankings

Allocation Rank	UPlan Land Use
1	Industry
2	High Density Commercial
3	High Density Residential
4	Low Density Commercial
5	Medium Density Residential
6	Low Density Residential
7	Very Low Density Residential

different plans.

General Plan

To utilize UPlan and to develop the allocation rules AMBAG associated the typology land uses to UPlan land use categories. For categories that are mixed-use AMBAG assigned multiple UPlan land use types (see Table F-2). UPlan terminology identifies land use parameters as "general plan." For that reason this text will refer to the "general plan" settings, however the land use used as the general plan layers consists of the aforementioned typology and actually represents 21 jurisdictions' general plans.

The UPlan model allocates the population growth and employment growth within the county to the land use types that are designated in the general plan. Areas with higher attractiveness values and large amounts of available land will have a higher proportion of population growth and employment growth.

UPlan land use allocations assume that:

- Future growth will have no effect on land use categories general plan and
- No redevelopment, abandonment or shift of land use from one type to another will take place unless specifically included as redevelopment areas

For future growth UPlan allocates starting with the highest valued (most attractive) cells. As the higher valued cells are consumed, the model looks for incrementally lower valued cells until all acres of projected land consumption are allocated. The model does this for each of the land use categories. Projected land consumption is based on the land area required to satisfy the employment and residential projections. The UPlan model starts with industry, then proceeds to high density commercial, high-density residential, low-density commercial, medium-density residential, low-density residential and very low density residential (Table F-3). This order is chosen to represent the way in which the land market typically operates - higher valued land uses are more competitive in acquiring the most desired properties thereby outbidding the less valuable uses. The allocation sequence matters when mixed use types are designated in the general plan as they encompass different types of land use.

The allocation routine converts future acres consumed to the number of cells needed. It then determines how many cells are available in the highest valued category and if this is less than what is needed, simply converts all those cells to the designation of the land use it is allocating at that time. It then subtracts the number of cells it just allocated and moves on to the next highest cell value and again determines how many cells are available. Allocation only occurs in the land use categories that are designated in the general plan crosswalk Table F-2. The general plan typically specifies the average number of units per acre. In terms of the general ranges of gross density allowable in an area, UPlan has settings to specify the average size of a lot (in acres) for each of the density classes. The current existing developed land per the general plan is masked. The results from UPlan model are households and employment distributed by TAZ.

UPlan Scenarios

Parameters for Each Scenario

The UPlan parameter structure is made up of specific data parameters, buffers, weights and masks. There is a separate set of parameters for each land use type. There are two categories of parameters: (a) generalized attractions and discouragements that apply everywhere in the region and (b) specific parameters that applied in the set-up and are the base for each scenario

The generalized parameters reflect proximity to, and service levels provided by, transportation system elements such as freeway ramps, transit and the non-freeway road network. They also indicate proximity to existing land use clusters that attract new growth. The general plan designations are used to control where development can occur.

For each scenario, AMBAG ran each county separately to take into account the specific attractions, weights, and buffers for growth patterns. The output information was merged to create an overall picture for growth.

Calibration of Scenarios

UPlan was calibrated with trial-and-error techniques, which do not guarantee unbiased parameter estimates. No assessment of the degree of linear calibration bias was made. A typical calibration UPlan model run is setup as follows via the "UPlan 2 Model" button in ArcGIS 10.

The calibration of each scenario was performed incrementally. For each scenario, the GIS variables for the attractiveness grid for each land use category were selected and the associated buffer distances and weights were set. The initial selection and settings of the buffers and weights were taken from previous UPlan applications in California.

UPlan was calibrated to produce allocations at the city level by comparing the model outputs with land use change. UPlan outputs are limited to new growth, i.e. incremental growth for population, employment, and housing units.

The most direct and perhaps best way to evaluate the accuracy of UPlan is to qualitatively compare simulated with surveyed new footprint coverage by grid cell. A comparison with the clipped areas revealed that the UPlan land use allocations are not perfect, but the model produces coherent developments. At the micro-scale, developer preferences and land market factors (e.g., demand, supply, cost, availability, and zoning issues) can strongly influence the location, timing, and type, of land use development in ways not considered by the model. However, all models for the purposes of the regional plan are calibrated at a regional scale and are not intended for simulating the market to the degree of accuracy that a jurisdiction or developer might need for determining viability of development.

Specific Parameters

The 2015 household population and employment was based on the 2010 Census and the California

Department of Finance. The 2020, 2035 and 2040 populations were based on the 2018 Regional Growth Forecast. Population living in group quarters was excluded from the allocation as this population is restricted to living in specific locations such as university dormitories and prisons. This population is assumed to continue growing in the locations they are currently located in and for that reason are not reallocated.

For a similar reason agricultural employment was excluded from the UPlan allocation of new land use. Agricultural lands may be consumed, but they are not moved. In other words, it is not logical to reallocate agricultural employees and lands to new locations. Additionally, the focus of the land use modeling was to look at different scenarios for land use growth within urbanized areas. For this reason no new growth was modeled for rural or non-urbanized areas. In the County of Santa Cruz urbanized areas included areas within the Urban Service Boundary as defined by the County General Plan, which includes both incorporated areas and certain urbanized unincorporated areas. In the County of San Benito urbanized included areas were considered within the city boundaries of Hollister and San Juan Bautista. In Monterey County urbanized areas were considered to be within each jurisdiction's LAFCO-designated Sphere of Influence (SOI). For unincorporated areas subject to a Community Plan, Place Types would be applied to the Community Plan Area.

UPlan converts household population and employment growth into land consumption using 50 ft grids based on residential, commercial, and industrial development densities. In an UPlan run, grid level allocated consumption is constrained to available land. This process can be described using the following general demographic rules:

- People take up space
- People live in groups (e .g. households)
- Different households take up different amounts of space (residential densities)
- The number of households multiplied by the space needed per household equals the residential space needed
- Some portion of each household is employed
- Different forms of employment require different amounts of space
- The number of employees multiplied by the space needed per employee equals the total employment space needed

The land consumption parameters used in this model were used for each scenario and were calibrated for AMBAG.

Residential Parameters

Residential Ratio

The Residential Ratio is the proportion of households in each of the four residential density categories, where the sum of the four categories is 100 percent. This was calculated by taking the geographic area of the four residential general plan category types:

- High density residential
- Medium density residential
- Low density residential
- Very low density residential

This was weighted by the "space per household" (gross acres by type) ratios listed above to give a units per area split between the four groups.

Average Lot Size

Average Lot Size is used to specify the average size of a lot (in acres) for each of the residential density classes. Average lot sizes across the county for each density class were estimated by using the unit, size, and square feet information contained in the county parcel database as maintained by the assessor.

Employment Parameters

Employee Ratio

The Employee Ratio is the proportion of employees in each of the three employment categories, where the total of the three categories is equal to 100 percent.

Average building square footage per employee by type

Average building square footage per employee by type is assumed to be a fair representation of the square feet usage likely in each County, based on historic averages, and can be adjusted based on local feedback as necessary.

Floor Area Ratio (FAR)

FAR is calculated by dividing the total square footage of a building by the square footage of its lot. FAR is a commonly used planning measure for zoning ordinances. However, a limitation of UPlan is the inability to program a FAR of greater than one. There is a method of changing the script to force the program to use a FAR of greater than one, however changing the script caused the model to produce other errors. For this reason AMBAG was forced to use a low FAR even though some land use types should probably have a higher FAR associated with them.

Self-Employment

Most UPlan studies have not explicitly addressed self-employment, while many employment forecasts do not include the self-employed and instead enumerate "wage and salary employment." The self-employed are forecasted in the regional growth forecast and therefore are indirectly included in this analysis. However, they are not explicitly modeled as an industry. To include this type in the land use model, numbers would be required for self-employment that can logically be connected to an industry type that needs floor space (i.e. the businesses are not being run out of a house). However, a large percentage of self-employment is in the construction, finance, insurance, real estate, and other service industries. These sectors do not necessarily lend themselves to a specific work location.

Scenario Variable Selections, Weights, and Buffers

For each scenario, the buffer and weight settings are defined for each land use type. As one might expect, transportation infrastructure is attractive to all land use types (i.e. residential, commercial and industrial). Certain types of special generators also attract residential and commercial growth.

Another significant attraction variable was census blocks with net population growth between 2020 and 2040. This variable encourages homogeneous residential development patterns (clustering) by in-filling vacant/underdeveloped land in existing developed areas. Another important attractor for all land use types include the spheres of influence for each city for this same reason.

Base Case

Utilizing the general plans, TAZ and demographic data from 2015, AMBAG developed an existing conditions "base case" from which the different scenarios were compared to determine the long-term net change. For the base case AMBAG utilized the following assumptions for population density, average lot size, proportions of employment, average square footage, and FAR.

UPlan Results

UPlan is used as an intermediary step in preparing inputs for the regional travel demand model. The goal of modeling any given scenario is to test its performance on a variety of indicators as adopted by the AMBAG Board of Directors. The metrics or indicators used are mostly reliant on GIS analysis or outputs from the regional travel demand model. Both of these means of obtaining results of scenario performance rely on using UPlan to prepare the data.

The output of UPlan is relatively simple, it provides the spatial distribution of the relative location of new jobs, housing and population in the region based on the parameters identified, such as attractors and detractors. This shapefile is then used as an input into either the regional travel demand model or for a GIS analysis that results in a specific metric. For a list of the performance measures reviewed refer to Chapter 5 of the 2040 MTP/SCS document.

The calibrated UPlan model does a reasonable job of allocating the various categories of land uses to allowed growth areas. This is made possible by the geographic specificity and precision in the GIS land use and transportation system data that underlie the UPlan calculations. The generalized UPlan model is applicable in a wide variety of rural, suburban, and urban settings

It may be possible to improve the accuracy of the model by using more sophisticated calibration methods. However, there is large inherent variability in the site-level scale of the UPlan outputs. At this micro level, developers, urban designers and landowners have significant economic latitude to vary the land use mix, density and timing of specific projects. Also, one should guard against over calibration, which reflects local policies that may change over time.