ABSTRACT

TITLE: 2030 Regional Growth Forecast Update: Process and Model Documentation

AUTHOR: San Diego Association of Governments

DATE: April 2008

SOURCE OF COPIES: San Diego Association of Governments
401 B Street, Suite 800
San Diego, CA 92101
(619) 699-1900

NUMBER OF PAGES: 118

ABSTRACT: The SANDAG forecasts comprise a complex set of discussions, assumptions, input data, computations, and model interactions. This report presents a basic description of the SANDAG forecast models used in the 2030 Regional Growth Forecast Update, including a general flow of information and some of the key inputs, assumptions, and computations for each of the components.
# TABLE OF CONTENTS

CHAPTER 1: OVERVIEW ................................................................................................................5

1.1 HISTORICAL PERSPECTIVE ................................................................................................ 5

1.2 COMMITTEES AND PEER REVIEW ..................................................................................... 6

1.3 MODELING COMPONENTS ............................................................................................... 7

1.3.1 Demographic and Economic Forecasting Model ......................................................... 8
1.3.2 Interregional Commute Model .......................................................... 8
1.3.3 Urban Development Model .......................................................... 9
1.3.4 Transportation Forecasting Model .......................................................... 10

1.4 CHANGES IN FORECAST ASSUMPTIONS ........................................................................11

1.4.1 Demographic and Economic Forecasting Model ......................................................... 11
1.4.2 Interregional Commute Model .......................................................... 12
1.4.3 Urban Development Model .......................................................... 12
1.4.4 Transportation Forecasting Model .......................................................... 12

1.5 ORGANIZATION OF THE REPORT .................................................................................... 13

CHAPTER 2: DEMOGRAPHIC AND ECONOMIC FORECASTING MODEL .....................................14

2.1 HISTORY .......................................................................................................................... 14

2.2 MODEL STRUCTURE ........................................................................................................ 14

2.3 DEMOGRAPHICS ............................................................................................................. 16

2.3.1 Population Components .......................................................................................... 16
2.3.2 Components of Change .......................................................................................... 17
2.3.3 Labor Force .......................................................................................................... 19
2.3.4 Group Quarters Population .................................................................................. 19
2.3.5 Household Population and Total Households ..................................................... 19

2.4 ECONOMIC ACTIVITY .................................................................................................... 19

2.4.1 Market Index ......................................................................................................... 20
2.4.2 Employment Equations ........................................................................................ 21
2.4.3 Gross Regional Product ...................................................................................... 21
### 5.5 HOUSING STOCK COMPONENT, PARCEL FORECAST .................................................. 51

### 5.6 OTHER CHARACTERISTICS COMPONENT, ZUMS AND SGRAS .......................... 51
- 5.6.1 Occupied Units by Structure Type .................................................................................. 52
- 5.6.2 Household Population, Group Quarters, and Employed Residents ............................... 52
- 5.6.3 Income Distribution ......................................................................................................... 53
- 5.6.4 Civilian Employment by Industrial Sector ........................................................................ 53

### 5.7 2030 REGIONAL GROWTH FORECAST UPDATE KEY ASSUMPTIONS .................. 54

### CHAPTER 6: TRANSPORTATION MODELS .................................................................. 55

#### 6.1 INTRODUCTION ....................................................................................................... 55

#### 6.2 SURVEY INPUTS ....................................................................................................... 58
- 6.2.1 1995 Travel Behavior Survey .......................................................................................... 58
- 6.2.2 2001 Caltrans Statewide Survey ....................................................................................... 59
- 6.2.3 2001-2003 Regional Transit Survey .................................................................................. 59
- 6.2.4 External Trip Surveys ....................................................................................................... 59
- 6.2.5 Traffic Generator Studies ................................................................................................. 60
- 6.2.6 1991 Visitor Survey .......................................................................................................... 60
- 6.2.7 Census 2000 Transportation Planning Package ................................................................. 60
- 6.2.8 2000 Market Research Survey .......................................................................................... 60
- 6.2.9 Traffic Counts .................................................................................................................... 60
- 6.2.10 Transit Passenger Counts ............................................................................................... 61
- 6.2.11 2006 Vehicle Occupancy and Classification Study .......................................................... 61

#### 6.3 GROWTH FORECAST INPUTS ................................................................................. 61

#### 6.4 HIGHWAY NETWORK INPUTS .............................................................................. 62
- 6.4.1 Highway Facilities ............................................................................................................. 62
- 6.4.2 Highway Attributes .......................................................................................................... 63
- 6.4.3 Highway Capacities .......................................................................................................... 63
- 6.4.4 Highway Travel Times ...................................................................................................... 65

#### 6.5 TRANSIT NETWORK INPUTS .................................................................................. 66
- 6.5.1 Transit Facilities ............................................................................................................... 66
- 6.5.2 Transit Attributes .............................................................................................................. 67
- 6.5.3 Travel Times ...................................................................................................................... 67
- 6.5.4 Fares ................................................................................................................................... 68
- 6.5.5 Transit Walk Access .......................................................................................................... 68
- 6.5.6 Transit Auto Access .......................................................................................................... 69

#### 6.6 TRIP GENERATION .................................................................................................. 70
- 6.6.1 Model Structure ............................................................................................................... 71
- 6.6.2 Model Calibration ............................................................................................................. 74

#### 6.7 PATHBUILDING, SKIMMING, AND UTILITY CALCULATIONS ............................. 74
LIST OF TABLES

Table 1  Total Fertility Rates\(^3\) by Ethnicity 2030 Regional Growth Forecast Update
San Diego Region................................................................................................................... 27

Table 2  Ethnic Shares of Domestic Net Migration 2030 Regional Growth Forecast Update
San Diego Region................................................................................................................... 28

Table 3  Ethnic Distribution of International Net Migration 2030 Regional Growth Forecast
Update San Diego Region .....................................................................................................29

Table 4  Development Type Codes................................................................................................. ..... 35

Table 5  A.M. Peak Period IRCM Travel Times, 2004..........................................................................37

Table 6  Housing Unit Capacities by MSA and Extra-Regional Areas ...............................................38

Table 7  Home Price Attractiveness Ratios by MSA and Extra-Regional Areas......................... 39

Table 8  IRCM Commute Probabilities, 2004* .....................................................................................40

Table 9  Allocation Probabilities from Place of Work to Place of Residence 2004 – 2010 .......... 41

Table 10 Housing Units Built for New Workers in the San Diego Region, 2004 – 2030.................. 42

Table 11 Comparing the Baseline and the Final 2030 Regional Growth Forecast Update
in the Year 2030..................................................................................................................... 43

Table 12 Transit Mode Definitions.............................................................................................. ......... 66

Table 13 Trip Generation Model Inputs............................................................................................... 71

Table 14 Trip Generation Model Output............................................................................................. 71

Table 15 Regional Control Variables.............................................................................................. 73

Table 16 Trip Distribution Model Inputs........................................................................................... 76

Table 17 Trip Distribution Model Outputs........................................................................................... 76

Table 18 Mode Choice Model Inputs................................................................................................. 78

Table 19 Mode Choice Model Output............................................................................................... 78

Table 20 Mode Choice Time and Cost Coefficients............................................................................. 83

Table 21 Short First Wait Time Assumptions (Minutes) .......................................................................85

Table 22 Added Transfer Time (Minutes) ............................................................................................86

Table 23 Mode Choice Constants....................................................................................................... 89

Table 24 Application of Modal Constants........................................................................................... 90

Table 25 Highway Assignment Model Inputs...................................................................................... 93
Table 26 Highway Assignment Model Outputs

Table 27 Transit Assignment Model Inputs

Table 28 Transit Assignment Model Output

Table 29 Population, Housing, and Employment in the Year 2030, 2030 Cities/County Forecast and 2030 Regional Growth Forecast Update San Diego Region

Table 30 Total Fertility Rates in the Year 2030, 2030 Cities/County Forecast and 2030 Regional Growth Forecast Update San Diego Region

Table 31 Household Size 2030 Cities/County Forecast and 2030 Regional Growth Forecast Update San Diego Region

Table 32 Housing Unit Capacity Under Existing Plans and Policies, 2000 and 2004 by Major Statistical Area

Table 33 Employment Capacity Under Existing Plans and Policies, 2000 and 2004 by Major Statistical Area

Table 34 Housing Units in the Year 2030, 2030 Regional Growth Forecast Update and 2030 Cities/County Forecast by Major Statistical Area

Table 35 Civilian Employment in the Year 2030, 2030 Regional Growth Forecast Update and 2030 Cities/County Forecast by Major Statistical Area
LIST OF FIGURES

Figure 1  2030 Regional Growth Forecast Update Models ................................................................. 7
Figure 2  DEFM Sector Interactions.................................................................................................. 15
Figure 3  DEFM Population Components......................................................................................... 16
Figure 4  Determining Military Population in DEFM ...................................................................... 17
Figure 5  Computing Adjusted Civilian Population in DEFM ........................................................... 18
Figure 6  DEFM Housing Model ...................................................................................................... 23
Figure 7  Persons per Household San Diego Region 1990 – 2030 .................................................. 30
Figure 8  Capacity Derivation.......................................................................................................... 37
Figure 9  Geographic Areas for the Interregional Commuting Model ........................................... 36
Figure 10 Key Components of the Urban Development Model .................................................... 46
Figure 11 UDM Flow of Information ............................................................................................... 48
Figure 12 Transportation Modeling Process .................................................................................. 56
Figure 13 Nested Mode Choice Model Structure ......................................................................... 80
EXECUTIVE SUMMARY

Historically the San Diego region has had ample land available for new development, and has grown at a fairly constant rate. Our forecast models reflected these conditions. But what happens when existing land use plans and policies no longer provide sufficient land for future growth? The San Diego region faces this challenge today, with less than thirty years of residential capacity left given current plans and predicted growth rates. This capacity constraint poses both a policy challenge and a modeling challenge. We already see evidence of this constraint in increased interregional commuting as workers choose to live in Riverside County or Northern Baja California and commute into the San Diego region for work. To address this issue in the short term, SANDAG staff added a new Interregional Commute Model component to the suite of modeling programs used for the forecast. The current forecasting system is described in great detail in the following pages. Over the long term, we are working on building an entirely new model framework to project future growth patterns in the region.

The 2030 Regional Growth Forecast Update is based solely on the current, adopted general and community plans of the 18 cities, and the most recent (June 2006) version of the County’s General Plan update. It includes no assumptions about how local plans and policies might evolve over time in response to the region’s continuing growth. The current forecast provides an assessment of where our plans of today, if left unchanged, will likely take us in coming decades. The creation of the first Regional Comprehensive Plan (RCP) was one of the catalysts for taking this approach to the 2030 Regional Growth Forecast Update.

However, as noted above, future forecasts may result in different outcomes. The RCP is intended to provide guidance for future plan changes. Basing our forecasts on existing plans and policies provides us with an important tool to help monitor the RCP progress in maintaining and improving the region’s quality of life.

SANDAG uses four models in its forecasts: (1) the Demographic and Economic Forecasting Model (DEFM), (2) the Interregional Commute Model (IRCM), (3) the Urban Development Model (UDM) and (4) the Transportation Forecasting Model (TransCAD). These model components are described in detail in Chapters 2 through 6. A noteworthy feature of the forecasting process is the feedback of information from one model to another. For example, information from DEFM is used in the IRCM and then the output from the IRCM is used to modify the output from DEFM. Similarly, data from UDM are major inputs to the transportation model, and then transportation model data are used in subsequent UDM calculations. A key feature of our modeling system is the central role that land use and transportation policies play in determining future travel patterns and the associated location of people, houses, and jobs.

The first model component, DEFM, is an econometric forecasting model with a demographic module. DEFM produces an annual forecast of the size and structure of the region’s economy and a demographic forecast consistent with that future economy. For the economic forecast, DEFM relates historical changes in the region’s economy to historical changes in the United States (U.S.) economy.
using input-output and econometric methodologies. The demographic module uses a cohort-survival model to forecast population by age, gender, and ethnicity. DEFM produces a wealth of data about the region’s future economic and demographic characteristics. Among the more important elements are the size and composition of the population, employment by industrial sector, household and personal income, housing units by structure type, vacancy status and persons per household, labor force, and school enrollment.

The second model component is the Interregional Commute Model (IRCM). The 2030 Regional Growth Forecast Update is the second SANDAG forecast to include an IRCM, reflecting a growing trend for San Diego’s workforce to reside outside the region. Thus, the purpose of the IRCM is to account for individuals who work in the region but live outside its boundaries. The IRCM predicts the residential location of workers based upon accessibility to job sites, home prices, and the availability of residential land. Inputs to IRCM include future job sites within our region and potential residential sites located in the San Diego region, Orange County, southwest Riverside County, Imperial County, and Tijuana/Northern Baja California. The model also accounts for relative home prices across the comparison areas. Additional factors include the forecast of housing unit and employment growth from DEFM and commuting probabilities that vary based on the length of the commute. The output from the IRCM is future housing units containing San Diego region workers that will be built in the region, and those that will be built in surrounding regions.

As the third model component, the Urban Development Model (UDM) allocates changes in the region’s economic and demographic characteristics to jurisdictions and other geographic areas within the region. UDM satisfies the federal requirements specified in the Clean Air Act Amendments of 1990 and the Transportation Equity Act for the 21st Century (TEA-21). These legislative acts mandate that transportation plans consider the long-range effects of the interaction between land uses and the transportation system. Among UDM inputs are the current spatial distribution of jobs, housing units, income, and population, land use inputs that include the plans and policies of the 18 cities and the County of San Diego, and the current and future transportation infrastructure. Three major premises underlie UDM the UDM forecast of residential activities: employment location is a primary determinant of residential activity location; the longer a work trip, the less likely a person makes the trip; and increased residential development opportunities translate to greater residential growth potential. Lastly, the interactions between UDM and the transportation model are handled in a sequential manner.

TransCAD, the current transportation software package used to forecast travel activity, is the fourth model component. It uses datasets that are maintained in the geographic information system (GIS). The transportation model requires two major inputs. One input is the forecast of housing and nonresidential land uses from UDM. The other key input is the highway and transit system networks. There are four steps to the transportation model. The model generates person trips, then determines trip destinations using a gravity-based model, allocates these trips to various modes, and finally assigns vehicle trips to highway networks and transit trips to transit networks.

SANDAG strives to stay in the forefront of forecasting technology by subjecting its efforts to peer review and presenting the methodology at relevant meetings and conferences. The forecasting process, including meetings and model documentation, is open to the public.
We produce a new forecast every three to five years to incorporate updated data, changing trends, and new policies. The current forecast is known as the 2030 Regional Growth Forecast Update; prior forecasts included the 2030 Cities/County Forecast and the 2020 Forecast.

A number of important changes in forecast data and assumptions occurred with the current forecasting effort. You can find details on crucial changes, and resulting impacts on the forecast, in Chapter 7. For example, in DEFM, one important change is the base year population. The 2030 Regional Growth Forecast Update uses a 2004 estimate produced by the California Department of Finance (DOF) as its base, in contrast to the 2030 Cities/County Forecast which used a 2000 Census base. Because the 2004 DOF estimate is higher than anticipated, the 2030 projected population also is higher than we predicted in our prior forecast. Other changes in DEFM occurred in the areas of fertility rates, household formation, and labor force participation rates.

With regard to the Interregional Commute Model, the current forecast adds enhancements, including home price weighting factors and the inclusion of Orange and Imperial Counties as potential residential locations for San Diego region workers.

In the 2030 Regional Growth Forecast Update, adopted general plans and policies were used as land use inputs to the UDM. The adopted plans are from the 18 incorporated jurisdictions, and for the unincorporated areas, the County's June 2006 Draft of the General Plan Update was used. The 2020 Forecast had simulated smart growth development patterns by incorporating approximately 150 Transit Focus Areas (TFA), but had not been intended to be consistent with adopted local land use plans and policies.

Two fundamental changes to the transportation model affected many model components: (1) we switched transportation modeling software from TRANPLAN to TransCAD, and (2) we updated the model calibration year from 1995 to 2000. During this process, model parameters were adjusted so that model-estimated transit and highway volumes would match 2000 observed data based on 2000 demographic, land use, and transportation network inputs. We detail other significant modifications in Chapter 6.

The remainder of the report provides detail on the individual components of the SANDAG forecasting system used in the 2030 Regional Growth Forecast Update, including the major individual model features and components, the assumptions and parameters and other major input requirements, and changes in forecast assumptions.

In each case, the summary model descriptions are designed to provide insight into the process and a basic understanding of the relationships among the models and the data requirements. You can find a complete technical description of each model in a separate set of formal technical documents available from SANDAG.
CHAPTER 1: OVERVIEW

SANDAG has been providing economic and demographic forecasts for more than 30 years, and transportation forecasts for more than two decades. These forecasts are an integral part of its planning process as well as that of other governmental and private organizations.

Forecasts are likely to change from effort to effort. These changes reflect updated data, changing trends, and changing policies, and each forecast is designated with a series number to distinguish between forecasting efforts over time. For example, the current forecast (Series 11 – 2030 San Diego Regional Growth Forecast Update) incorporates the new North American Industrial Classification System (NAICS) for employment data, and is the eleventh forecast completed since SANDAG began forecasting in the late 1970s.

SANDAG strives to stay in the forefront of forecasting technology. It uses “best practices” methodology adapted to local conditions. To ensure that this continues, SANDAG subjects its forecasting efforts to peer review by other forecasting professionals in the region. In addition, the forecasting methodology used by SANDAG is presented at national, regional, and local meetings of professional demographers, economists, and land use and transportation planners.

Forecasting at SANDAG is an open process. The models, inputs, and results are presented to professionals and policy-makers at forums which are open to the public. Many of the inputs come directly from jurisdictions and reflect current local policies. Future improvements to the forecasting process will focus on methodology and technology, quality of input data, peer review, and open and frank discussions with the users of the forecasts and the public.

The SANDAG forecasts comprise a complex set of assumptions, input data, computations, and model interactions. This report presents a basic description of the SANDAG forecast models used in the 2030 Regional Growth Forecast Update, including a general flow of information and some of the key inputs, assumptions, and computations for each of the components. It is not an exhaustive technical description of modeling fundamentals, nor is it a description of the entire process. These topics are addressed in other, more formal, documents.

1.1 HISTORICAL PERSPECTIVE

SANDAG has produced forecasts of demographic and economic growth in the region since 1971. Transportation forecasting at SANDAG began in 1981. The SANDAG forecasts are used by policymakers and the general public, as well as by public and private agencies throughout the region. For example, SANDAG uses the forecasts to develop the Regional Transportation Plan (RTP), the Regional Comprehensive Plan (RCP), and the Air Quality Conformity Plan. Local jurisdictions use the forecasts for general plan updates and capital facilities planning, including environmental impact reports (EIR), as well as for local transportation planning. Other agencies, such as the San
Diego County Water Authority and the San Diego Regional Energy Office, use aspects of the SANDAG forecasts to develop plans for providing these essential services.

The SANDAG forecasts represent the changes we can anticipate for the region and its communities based on well-proven computer models and the best available information at the time the forecast is produced. They are meant to help policy and decision-makers prepare for the future and are not an expression for or against growth.

Unlike most prior forecasts, the 2030 Regional Growth Forecast Update includes no assumptions about how local plans and policies might evolve over time in response to the region’s continuing growth. The creation of the first Regional Comprehensive Plan (RCP) is one of the catalysts for taking a different approach to the 2030 Regional Growth Forecast Update. Rather than including assumptions regarding potential future plan changes, this forecast is based solely on the current, adopted general and community plans of the 18 cities. For the unincorporated area, the forecast is based on the most recent (June 2006) draft of the County’s General Plan update, as the Board of Supervisors feels that it most accurately reflects the County’s future direction. Hence, the 2030 Regional Growth Forecast Update provides an assessment of where our plans of today, if left unchanged, likely will take us over the coming decades.

However, general plans do change over time. While the forecast looks out to the year 2030, the horizon year of current local plans is typically 2010 or 2020. As those plans evolve, future forecasts may result in different outcomes. The RCP is intended to provide guidance for future plan changes. Basing our forecasts on existing plans and policies provides us with an important tool to help monitor the RCP progress in maintaining and improving the region’s quality of life.

1.2 COMMITTEES AND PEER REVIEW

The SANDAG forecasts are not done in isolation. We work closely with a wide range of professionals outside the agency when preparing forecasts. For the regional forecast, SANDAG convenes a Regionwide Forecast Technical Advisory Working Group, which is composed of experts in demography, housing, economics, and other disciplines from state and local agencies, local universities, and the private sector. This committee is responsible for reviewing the regional model structure, data inputs, and assumptions. Feedback from the committee is incorporated into the model. The committee also evaluates the forecast results.

SANDAG also relies on the Regional Planning Technical Working Group for advice on the forecast, which provides information for jurisdictions, communities and other areas within the region. This working group comprises the local jurisdictions’ planning directors or their designees and representatives from other agencies within the region that use the forecast data for facility and infrastructure planning. This working group assists with local land use assumptions that are among the more important inputs to the forecasting process.

The transportation model has been reviewed at the Southwest Region Transportation Model User Group and at the State Transportation Modeler User Group. Moreover, SANDAG makes extensive use of the transportation model for local as well as regional studies, which contributes to the model’s continual evaluation and updating. It also exposes the model to scrutiny by transportation planners associated with the jurisdictions, the two transit agencies, and private consultants.
1.3 MODELING COMPONENTS

The SANDAG forecasting model consists of four components: (1) the Demographic and Economic Forecasting Model (DEFM), (2) the Interregional Commute Model (IRCM), (3) the Urban Development Model (UDM), and (4) the Transportation Forecasting Model (TransCAD). All of the models used at SANDAG incorporate “best practices” used by Metropolitan Planning Organizations and Councils of Governments throughout the nation. In addition, SANDAG continually evaluates and refines its models, incorporating updated techniques and information as necessary.

Figure 1
2030 Regional Growth Forecast Update Models

Figure 1 illustrates the modeling process and the flow of information from model to model. The feedback of information from one model to another is noteworthy. For example, information from DEFM is used in the IRCM and then the output from the IRCM is used to modify the output from DEFM. Similarly, data from UDM are major inputs to the transportation model, which then influence subsequent UDM calculations. A key feature of our modeling system is the central role that land use and transportation policies play in determining future travel patterns and the associated location of people, houses, and jobs.
1.3.1 Demographic and Economic Forecasting Model

DEFM is an econometric forecasting model with a demographic module. The purpose of DEF M is to forecast annually the size and structure of the region’s economy and to produce a demographic forecast consistent with that future economy. With regard to the economic forecast, DEF M relates historical changes in the region’s economy to historical changes in the U.S. economy using input-output and econometric methodologies. A forecast of the U.S. economy produced by Moody’s/Economy.com is a key driver of the region’s economic forecast.

The demographic module uses a cohort-survival model to forecast population by age, gender, and ethnicity. This model uses assumptions about age- and ethnicity-specific birth rates to forecast births. Deaths in the population are forecast based on assumptions about gender- and ethnicity-specific death rates. Assumptions about birth and death rates are based on the national trends forecast by the Census Bureau and recent trends observed for this region. DEF M forecasts both international and domestic migration. Our forecast of international migration relies on national trends forecast by the Census Bureau and on the region’s historical share of U.S. international migration. Illegal migration is not explicitly treated in the model. The linkage between the economic forecast and the demographic forecast occurs primarily through domestic migration. In DEF M, domestic migration to the region is determined by analyzing the quality of the region’s economy compared to the quality of the U.S. economy. If the region’s economy is doing better than the rest of the U.S. economy, positive migration occurs. If the region’s economy is not doing as well as the nation’s economy, migration can be either small or negative.

DEFM produces a wealth of data about the region’s future economic and demographic characteristics. Among the more important elements are the size and composition of the population, employment by industrial sector, household and personal income, housing units by structure type, vacancy status and persons per household, labor force, and school enrollment.

1.3.2 Interregional Commute Model

The 2030 Regional Growth Forecast Update is the second model to include an IRCM. Historically, nearly the entire San Diego workforce resided in the region. However, this is changing. As evidence accumulates on the rapidly increasing numbers of interregional commuters and their impact on our population and economy, it is important to incorporate this impact into the methodology used to create our forecasts. The purpose of the IRCM is to account for individuals who work in the region but live outside its boundaries.

The IRCM predicts the residential location of workers based upon accessibility to job sites, home prices, and the availability of residential land. Inputs to IRCM include future job sites within our region and potential residential sites located in the San Diego region, Orange County, southwest Riverside County, Imperial County, and Tijuana/Northern Baja California. The model also accounts for relative home prices across areas within San Diego and surrounding areas. Additional factors include the forecast of housing and employment growth from DEF M and commuting probabilities that vary based on the length of the commute.
Including the IRCM in the forecasting process creates a direct link between local land use policies and interregional commuting. Results from the IRCM indicate that more housing opportunities within the region lead to lower levels of interregional commuting. Furthermore, the specific location of housing opportunities within the region impact interregional commuting patterns. Housing opportunities that are in or near urban centers reduce interregional commuting to a greater extent than housing opportunities in the rural back country.

The output from the IRCM is future housing units containing San Diego region workers that will be built in the region and those that will be built in Orange, Riverside, or Imperial Counties or Tijuana/Northern Baja California. These outputs then are used for two modeling purposes. First, a revised regional forecast is produced that matches the number of new housing units predicted to locate within the region. That is, data from the IRCM are fed back into DEFM to more fully account for interregional commuting in our regional forecast. The second output, housing units containing San Diego workers built outside the region, is used as a partial determinant of future traffic volumes on the major corridors linking Orange, Riverside, and Imperial Counties and Tijuana/Northern Baja California with the San Diego region, which are important inputs to our transportation demand forecasts.

### 1.3.3 Urban Development Model

UDM allocates changes in the region’s economic and demographic characteristics to jurisdictions and other geographic areas within the region. In particular, UDM is based on the spatial interrelationships among economic factors, housing and population factors, land use patterns, and the transportation system. These interrelationships not only provide an accurate way of determining the 2030 Regional Growth Forecast Update, but UDM also satisfies the federal requirements specified in the Clean Air Act Amendments of 1990 and the Transportation Equity Act for the 21st Century (TEA-21). These legislative acts mandate that transportation plans consider the long-range effects of the interaction between land uses and the transportation system.

Among UDM inputs are the current spatial distribution of jobs, housing units, income, and population. Critical to UDM are land use inputs that include the plans and policies of the 19 local jurisdictions and the current and future transportation infrastructure. These include phasing for new roads and streets, freeways, and transit lines.

Three major premises underlie UDM forecast of residential activities.

- Employment location is a primary determinant of residential location.
- The longer the work trip, the less likely a person makes that trip.
- The more opportunities for residential development, the greater the potential for residential growth.

UDM captures the link between work place location and residential location through commuting patterns and travel times within the region furnished by the transportation model. By using current and future trends in travel behavior, UDM can account for the other factors that determine where people might live within the region, such as land values, multiple worker households, income, and neighborhood preferences.
Not only does the spatial distribution of employment opportunities influence the location and demand for housing, but the reverse is true as well, especially for population-serving employment such as retail trade and services. UDM handles this relationship by assuming a lag between residential development and subsequent location of new jobs. Other factors that determine the future location of employment opportunities within the region are

- transportation characteristics, including home-based shopping travel behavior
- the location of employment reflecting the economies of scale businesses gain by locating near like-businesses
- the opportunities for additional employment growth

While the travel patterns influence the forecast of both residential and employment activities, these activities also influence travel patterns. The SANDAG modeling system handles the interactions between UDM and the transportation model in a sequential manner. Within a given forecast period, the output from UDM directly influences the transportation system forecast for that same period (e.g., 2004 to 2010). The transportation system forecast then influences the UDM allocation in the subsequent period (e.g., 2010 to 2015).

1.3.4 Transportation Forecasting Model

TransCAD is the current transportation software package used to forecast travel activity. It uses datasets that are maintained in the geographic information system (GIS). The transportation modeling steps include

- generating average weekday person trips
- estimating trip movements between areas
- allocating trips to different modes of transportation
- assigning vehicle trips to road segments
- assigning transit trips to transit routes

The transportation model requires two major inputs. One input is the forecast of housing and nonresidential land uses from UDM. These inputs are used to determine the number of trips expected. The other key input is the highway and transit system networks.

The transportation model first generates person trips by applying trip generation rates to households stratified by structure type and the amount of nonresidential land stratified by land use type. It then determines trip destinations using a gravity-based model, which distributes trips according to a mathematical relationship between the number of trips generated from, or attracted to, an area and its travel time from other areas. It then allocates trips to various modes: drive alone, two-person carpool, 3 or more person carpool, transit, and non-motorized.
These allocations are based upon the cost and time of traveling by a particular mode compared to the cost and time of traveling by other modes. For example, vehicle trips on a more congested route would be more likely diverted to transit than a vehicle trip on a less congested route. Income also is considered when assigning mode choice. Research from surveys has shown that higher income travelers are more influenced by the level of service of a mode than travelers with lower incomes.

A common misconception about the mode choice model is that it underestimates future transit use for expanded transit alternatives because model calibration is based upon current conditions. This is not the case. The model estimates transit use for each zone-to-zone movement based upon the quality of transit service relative to other modes. Existing trolley corridors provide a basis for determining potential transit use with high quality transit service. As more light-rail, bus rapid transit (BRT), and bus services are provided, the model recognizes the resulting transit service improvements and shifts travel to transit from other more congested modes. As a result, the model forecasts a 24 percent increase of the work trip transit mode share between 2004 and 2030, when an expanded transit system is expected to be in place. This forecasted increase in transit mode share exceeds historical changes in transit mode share. For example, US Census Bureau statistics show San Diego’s work trip transit mode share increased by only 5 percent between 1980 and 2000, a time in which COASTER and trolley service was added.

Finally, TransCAD assigns vehicle trips to highway and transit trips to transit networks. Under highway assignment vehicular trips are loaded onto segments that provide the shortest travel time between travel analysis zones (TAZ). These assignments take into consideration posted speed limits, signal delays, and congestion delays. Similarly, transit assignment loads transit trips onto transit routes that provide the shortest travel time between TAZs, considering transit stop delay times and frequency of service in addition to the time spent in the transit vehicle.

1.4  CHANGES IN FORECAST ASSUMPTIONS

The 2030 Regional Growth Forecast Update is similar to the 2030 Cities/County Forecast, but differs from our previous 2020 Forecast. The 2030 Cities/County Forecast predicted a regional population of 3,855,085 in year 2030, while for the same year the 2030 Regional Growth Forecast Update predicts a total population of 3,984,753, or 3.4 percent higher. Part of the difference is a result of the base year population. The 2030 Cities/County Forecast predicted a 2004 population of 3,011,093 in the region, while the official estimate for 2004 is approximately 2,000 persons higher (3,013,014).

1.4.1  Demographic and Economic Forecasting Model

One major difference between the 2030 Regional Growth Forecast Update and its predecessor, the 2030 Cities/County Forecast is in the base year population. Our Cities/County Forecast used a 2000 Census base, and the 2030 Regional Growth Forecast Update uses a 2004 estimate produced by the California Department of Finance (DOF) as its base. DOF produces official population estimates each year that are used to allocate state subvention funds to jurisdictions.

There also are a number of key assumptions that changed between the 2030 Cities/County Forecast and the 2030 Regional Growth Forecast Update. Many of these changes contributed to the differences between forecasts. First, fertility rates are lower in the Update. This is due to a more rapid decline in Hispanic fertility during the 1990s than what was predicted. In addition, recent trends in
San Diego and other areas of Southern California indicate that household formation rates have decreased. The effect of this is to increase household size in the future relative to our past forecast, thus reducing the demand for housing units.

Assumptions concerning labor force participation rates (LFPRs) vary slightly between the two forecasts. The LFPR is the percent of the adult population that is working or actively seeking employment. In general, the rates are higher in the 2030 Regional Growth Forecast Update compared to the 2020 Forecast. The increase is based upon updated national forecasts from the U.S. Bureau of Labor Statistics. Furthermore, increases in LFPRs, particularly among Hispanic and Asian women, are consistent with our assumptions of lower fertility rates. The consequence of increasing LFPRs is that a greater proportion of the adult population is available as workers. Thus, as the number of jobs increases, the need to migrate population into the region is partially negated by the availability of workers already residing in the region.

1.4.2 Interregional Commute Model

The 2030 Cities/County Forecast was the first to include an Interregional Commute Model. The current forecast, the 2030 Regional Growth Forecast Update, adds enhancements to the Interregional Commute Model, including home price weighting factors and the inclusion of Orange and Imperial Counties as potential residential locations for San Diego region workers.

1.4.3 Urban Development Model

In the 2030 Regional Growth Forecast Update, adopted general plans and policies were used as land use inputs in UDM. Adopted plans from each of the 18 cities were modeled. In the unincorporated areas of the region, the County’s June 2006 draft of the General Plan Update served as the land use inputs.

1.4.4 Transportation Forecasting Model

Two fundamental changes to the transportation model affected many model components: (1) we re-estimated and calibrated the mode choice model, and (2) we updated the model calibration year from 2000 to 2004. The update of the mode choice model included the addition of trip subtypes for toll users and a finer breakout of transit types. This caused changes to programs that handled the highway networks and the trip assignment procedures for both highway and transit. For the calibration year update, model parameters were adjusted so that model-estimated transit and highway volumes would match 2003/04 observed data based on January 2004 demographic, land use, and transportation network inputs.

In June 2005, SANDAG hosted a national peer review of our transportation model conducted through the U.S. Department of Transportation Travel Model Improvement Program (TMIP). TMIP helps conduct peer reviews “to ensure that technical products, procedures and/or processes being used or developed meet the agency’s needs, the standards of professional practice, and/or Federal, state, or local planning requirements.” Results from the peer review can be viewed at: http://tmip.fhwa.dot.gov/services/peer_review_program/documents/sandag/
Additionally, a 2006 Independent Transit Review Panel further evaluated transit patronage forecasts. These reviews generated several near-term improvements to the transportation model. Some of those identified improvements are listed on this page, such as the mode choice model update and the trip generation program update, while others are included in future development work.

Some of the other more significant modifications included:

- Incorporating a trip distribution feedback loop that utilizes an aggregated set of Traffic Analysis Zones called Trip Distribution Zones (TDZ). The TDZ system enables the feedback loop process to finish in a reasonable amount of time. The feedback loop utilizes TDZ level composite utilities to perform the trip distribution.

- Updating the trip generation program to estimate college and school trip productions using population age subgroups.

- Updating the external traffic forecasting process for Orange, Riverside, and Imperial County cordons to account for increased interregional commuting. Traffic volumes increase overall in the region, but particularly on Interstate 15 (I-15) which serves southwest Riverside County commuters.

- Modifying the volume adjustment procedure and calibration process to take advantage of Performance Monitoring System (PeMS) data from the freeway ramp meter system. The additional locations have nearly doubled the traffic data coverage for better calibration along the urban freeway system.

1.5 ORGANIZATION OF THE REPORT

The remainder of the report provides more detail on the individual components of the SANDAG forecasting system used in the 2030 Regional Growth Forecast Update, including the major individual model features and components, the assumptions and parameters, and other major input requirements. Chapter 2 discusses features of the Demographic and Economic Forecasting Model. Chapter 3 describes the derivation of housing and employment holding capacity based on land use plans and policies. While not a specific model per se, land use plans and policies are a critical aspect of our forecasting system. Chapter 4 describes the flow of information, the major inputs and the linkages for the Interregional Commute Model. Chapter 5 discusses the computational details of the Urban Development Model. The transportation planning model components are described in Chapter 6. Finally, Chapter 7 presents the key differences in assumptions between our previous 2030 Cities/County Forecast and the 2030 Regional Growth Forecast Update.

In each case, the summary model descriptions are designed to provide insight into the process and a basic understanding of the relationships among the models and the data requirements. A complete technical description of each model is provided in a separate set of formal technical documents that are available from SANDAG.
CHAPTER 2: DEMOGRAPHIC AND ECONOMIC FORECASTING MODEL

The Demographic and Economic Forecasting Model (DEFM) is a simultaneous, nonlinear econometric model designed to forecast population and economic variables for the San Diego region from a set of basic assumptions. The model produces twenty- to thirty-year forecasts.

2.1 HISTORY

The initial concept of DEFM in the late 1970’s was the result of a cooperative modeling effort that combined the Integrated Population and Employment Forecasting Model (IPEF), developed by SANDAG, and the Economic Impact Analysis System (EIAS), developed by the County of San Diego. With some improvements and modifications, the original model structure was used successfully for 18 years. In 1996, reflecting advances in computer technology and the need to reconfigure some parts of the model’s logic, a major update of the modeling framework and associated software was made. The resulting model provided an advanced interactive modeling system that retains the recognized qualities of previous DEFM versions. During 2003, DEFM was revised to improve its ability to analyze forecast alternatives, to streamline database updates and model calibration procedures, and to accommodate changes in racial classifications in Census 2000.

The primary function of the model is to produce mid-range and long-range demographic and economic forecasts for the San Diego region. Essential model inputs include assumptions about birth and death trends, international and domestic migration, and national economic and demographic forecasts, as well as forecasts for the California population and economy. These forecasts act as independent driving variables in the model, supplying the overall trend and direction that the local demographics and economy are likely to follow.

Although the model’s structure was designed with an emphasis on long-range forecasts, DEFM produces annual forecasts for hundreds of variables for the period 2000 through 2030. DEFM also can be used for forecasts beyond 2030 with appropriate economic and demographic assumptions. A major emphasis in developing DEFM was producing a system that can be updated for minimal cost and that can test alternative forecast scenarios. While certain aspects of the model reflect the unique characteristics of the San Diego region, the underlying concepts of the model are applicable to most urban regions.

2.2 MODEL STRUCTURE

In general, the model is a synthesis of two widely used techniques. A cohort-survival method is used for demographic characteristics. This method considers such factors as birth rates, death rates, and the age, sex, and ethnic distribution of the resident population to arrive at forecasts of demographic variables. Economic sector relationships are developed using time-series/regression
methods. The resulting econometric equations provide forecasts of employment, income, and other economic variables based on assumptions about national, state, and local growth patterns and local inter-industry relationships.

DEFM has several major components. The general flow of information is illustrated in Figure 2. The model is simultaneous in nature, and most major variables are interrelated directly or indirectly. For example, the level of economic activity, as measured by employment or output, depends in part on the size of the local population and income levels. Income, in turn depends in part on employment and labor market conditions. Over time, the population responds to economic conditions through impacts on net migration levels. Thus, local economic activity depends on local population, but local population also depends on economic activity. This type of circularity is a central feature of simultaneous models. The structure of DEFM is designed to capture the main interdependencies and interactions that exist in a dynamic economy.

As illustrated in Figure 2, the linkages between the demographic and economic sectors are numerous. A simultaneous solution algorithm reconciles the relationships among population, income, and economic activity. Output, employment, and labor productivity levels are forecast for 50 selected private-sector industries, identified by specific two-, three-, or four-digit North American Industrial Classification System (NAICS) codes. The industries are selected to represent the most important activities in the region and to allow aggregation of these detailed activities into a set of economic clusters that have been defined for the region.

**Figure 2**
DEFM Sector Interactions
2.3 DEMOGRAPHICS

Population is forecast for single-year of age categories by gender and ethnicity for civilian population and total population. Uniformed military population and military dependents and the associated age, gender, and ethnic group distributions are exogenous inputs to the model. The eight ethnic groups are defined as: (1) Hispanic, (2) Non-Hispanic White, (3) Non-Hispanic Black, (4) Non-Hispanic American Indian, (5) Non-Hispanic Asian, (6) Non-Hispanic Hawaiian and Pacific Islanders, (7) Non-Hispanic Others, and (8) Non-Hispanic Two or More races.

Summary data for each ethnic group include total population, civilian population, births, deaths, total fertility rate, life expectancy, net migration, and population for each of several age group aggregates (0-4, 5-14, 15-18, 19-64, and 65+). Age, gender, and ethnic details also are forecast for labor force and for school enrollment by five levels (nursery school, kindergarten, elementary, high school, and college). Detailed forecasts also are developed for group quarters population, household population, and heads of household.

2.3.1 Population Components

The demographic forecasts are based on age, gender, and ethnic detail of the population in the most recent estimate year (2004). The civilian population is determined by subtracting the number of military in uniform from the total population. The adjusted civilian population is determined by subtracting the military dependent population from the civilian population. The relationship among the population components is illustrated in Figure 3.

Figure 3
DEFM Population Components
2.3.2 Components of Change

Military Population. Figure 4 illustrates the approach used to forecast the military population. The total number of uniformed military is an exogenous input. This total is allocated to age, gender, and ethnic groups based on a set of allocation factors derived from the census. The military dependent population for each cohort is estimated as a proportion of the uniformed military population, also derived from the census. Uniformed military and military dependents are summed to obtain total military population by age, gender, and ethnic group.

Births to military dependents and deaths for the military population are computed and these values contribute to the region’s totals for births and deaths. However, the military population is not “survived” from one year to the next. This is appropriate given the high levels of geographic mobility among uniformed personnel and their dependents, and mobility between military and civilian status. Finally, during the historical period, births to military families in each ethnic group are compared to control values based on vital statistics for the region. Calibration factors are computed as the ratio of the control value to the computed value. In the forecast period, these factors are extended based on the value in the final calibration period.

Figure 4
Determining Military Population in DEFM

Adjusted Civilian Population. The adjusted civilian population is forecast using a cohort-survival method as illustrated in Figure 5. In each year, the civilian population is the civilian population in the previous year less civilian deaths, plus civilian births, plus net civilian migration. The detailed survival and fertility computations are performed for population subgroups by age, gender, and ethnic group. Summing across ethnic groups yields total population by age and gender.
**Births.** Natural increase is equal to births minus deaths. Adjusted civilian births (excluding births to military families) are forecast from the previous year's female population, using exogenous age-specific birth rates for women in each ethnic group. The births are split into male and female components using historical ratios estimated from vital statistics data for the San Diego region. For the historical period, the actual and predicted birth data are used to compute calibration factors. For the forecast period, these calibration factors are extended based on the value in the final calibration period.

**Deaths.** Deaths are forecast from the adjusted civilian population in the preceding year, using forecast survival rates by age, gender, and ethnicity. For the historical period, deaths for each ethnic group are summed and compared with control total values for civilian deaths in the region. The ratio of the control value to the computed value is the calibration factor for that year. For the forecast period, these calibration factors are extended based on the value in the final calibration period.

**Survived Population.** Deaths are subtracted from the previous year's adjusted civilian population. The surviving population in each age group is moved into the next age group for the next forecast interval. Births to the adjusted civilian population are adjusted for infant survival rates and are placed in the first age group (under 1) to complete the forecast of survived adjusted civilian population.
Migration. Net migration (population change due to migration) is modeled in two pieces. International net migration is modeled as a share of total U.S. immigration. Due to a lack of reliable data, illegal immigration is not specifically treated in the model. Domestic net migration is related to economic conditions in San Diego relative to the U.S. and to recent employment gains. Economic conditions include the relative employment rate and the relative wage rate.

Migration components are further divided by age, gender, and ethnicity. First, the estimates of net migration are distributed to ethnic and gender groups. Then age-specific migration rates for each ethnic group and gender are used to estimate the detailed age distribution within each group.

2.3.3 Labor Force

The natural civilian labor force is calculated from the civilian population by multiplying civilian population in each age, gender, and ethnic group by a natural labor force participation rate. The natural labor force participation rates are defined to represent the level of participation that occurs at full employment (defined by an unemployment rate of about 5%).

Actual labor force participation rates will be lower during periods of high unemployment. Under periods of low unemployment, labor force participation rates can rise above the natural rates, as additional people are drawn into the workforce. These variations are modeled based on a set of elasticities of labor force participation with respect to employment rates, where employment rates reflect the level of employment relative to the natural labor force.

2.3.4 Group Quarters Population

The population living in group quarters is forecast by age, gender, and ethnic group for uniformed military living in barracks or onboard ship, college students living in dormitories, and for other persons in group quarters accommodations. Other group quarters population includes persons living in boarding houses, homes for the disabled, rest homes, jails, and other group living situations. The age and gender specific rates that are used to forecast group-quarters populations are from the latest census and held constant throughout the forecast period.

2.3.5 Household Population and Total Households

Household population is calculated by subtracting the total group quarters population by age, gender, and ethnicity from the total population. Household headship rates, which give the fraction of population that is a household head, are applied to the household population by age, gender, and ethnicity to determine the number of households. Headship-rate parameters are exogenous to the model and are derived from census data. During the forecast, these parameters are modified through a set of elasticities that are applied to changes in the price of housing relative to income per household. If housing prices increase faster than income, fewer new households would be formed.

2.4 Economic Activity

In DEFM the level of economic activity is modeled in terms of employment and output for each of the 50 industries in San Diego County and an additional six activity categories for government. For each industry, output provides a direct measure of the quantity of goods and services produced in
that industry. Employment represents the main input into the production process. Other inputs, which are not represented in the model, include capital equipment, raw materials, and energy. For most industries, DEFM models output directly based on indices of demand and competitiveness. Output is derived according to employment levels and labor productivity forecasts.

Activity is modeled for a list of industries defined specifically for the San Diego region. Each industry is a collection of 2- to 4-digit NAICS sectors. An effort was made to provide as much detail as possible relevant to the definition of economic clusters that had been defined as part of the Regional Economic Prosperity Strategy.

Most of the employment equations have a common form that specifies output as a linear function of a composite market index that depends on a comprehensive set of explanatory variables. The demand component of the market index depends on output levels in other local industries, indicators of household and government final demand, and indicators of national and international export demand for local goods. The supply component of the market index depends on local costs and productivity levels, providing a measure of the relative competitiveness of San Diego businesses. The market indices are constructed using transaction weights and regional purchase coefficients from a San Diego input/output table constructed specifically for the 50 selected industries. The final importance of each market index is determined by econometric estimation for each industry.

2.4.1 Market Index

For most local industries, the exceptions being agriculture and mining, construction, and government, the level of economic activity is determined by a combination of factors reflecting local, state, and national economic conditions. These factors include local population and income, output levels in closely related industries, levels of government spending, and cost conditions.

The market index has two parts. The first part captures trends in demand for output produced in the San Diego region. The second part captures the relative competitiveness of goods and services produced in the San Diego region. Together, the combined index reflects a combination of demand and supply factors that are expected to determine the size of the market for regional employment, and the local share of our market.

The demand portion of the index is constructed using weights from an estimated Input/Output (I/O) table for 2001 for San Diego County. The specific table used to compute the index weights for this purpose was prepared by IMPLAN, which provides regional tables based on the most recent national tables and a variety of other relevant regional information.

The I/O transactions table gives the estimated gross dollar flows for each industry in the region. For a given industry row, the dollar flows represent the amount of local output estimated to be purchased by each local industry and by each of several export and final demand categories, including local residents, state and local governments, the federal government, the rest of the U.S., and the international economy. For each industry row, these gross dollar flows are converted to fractions that sum to one, giving an indication of the relative importance of each demand category.

The variables used to indicate the level of activity in each final demand sector depend on the sector involved. For example, government demand for output from the service industries is most closely
related to the level of government activity in the local economy. However, government purchases of manufactured goods may be more strongly related to national spending levels. Similarly, San Diego exports for manufacturing industries are most directly related to the level of national activity in each specific industry. This implies the use of industry-specific activity measures for the export sector for these categories.

The regional competitiveness index represents the relative cost of business in the region. This index is computed using relative wage rates, relative productivity levels, relative capital costs, and relative fuel costs. Increases in the regional competitiveness index will occur when any of the local cost elements decrease relative to U.S. costs, or when local labor productivity increases relative to national productivity. Conversely, if local costs outstrip national costs or if local productivity gains lag behind national gains, local competitiveness will decline. When these types of changes occur, demand will be focused toward or away from the local economy, depending on the degree to which the industry involved is competitive.

The demand index and competitiveness index are combined into a single market index. In forming this combination, the importance of the competitiveness index is assumed to depend on the degree to which there is competition with outside providers of the goods and services produced by an industry. For industries that are largely locally based, such as legal services, the competitiveness index will be a relatively unimportant factor, and the elasticity of demand with respect to local costs and productivity will be small. For industries that are export based, the reverse is true, and the elasticity of demand for San Diego output with respect to local costs and productivity will be large.

For most sectors, the levels of economic activity are estimated using econometric equations that contain the market index variables as the main explanatory factor. For the remaining sectors, including agriculture, construction, and government, also are econometric equations also are used but they contain other independent variables, such as population and the level of nonagricultural employment.

2.4.2 Employment Equations

The employment forecasts for each industry are translated into output forecasts based on the projected values for labor productivity. A full model of labor productivity would account for changes in technology, investments in physical capital, human capital characteristics of the San Diego region’s population, and investments in local infrastructure. Because there are no reliable data for any of these variables, an exogenous approach is taken in DEFM. Specifically, labor productivity is modeled as an exogenous factor that depends on national trends in labor productivity.

2.4.3 Gross Regional Product

Forecasts of output by industry are summed to provide an estimate of Gross Regional Product (GRP). This bottom-up estimate will not necessarily agree with the data series for GRP developed by the San Diego Regional Chamber of Commerce, which is based on estimates of Gross State Product for California and personal income data for the San Diego region and California. A bridging equation is used to calibrate the bottom-up estimates from the DEFM industries with the aggregate value from the Chamber.
One of the final demand sectors represents exports from the San Diego region to neighboring Orange County. Although a detailed model of the Orange County economy is not part of DEFM, linkages between the two regions are modeled. This is accomplished by including a simplified model of gross regional product in Orange County, modified by changes in the San Diego region’s economy. Because Orange County GRP feeds back into the activity equations as a source of final demand, this provides an interaction between the two economies. That is, any increase in the San Diego region’s forecast will increase the forecast for Orange County, which will, in turn, feed back to further increase the San Diego region’s forecast.

2.5 CONSTRUCTION

The construction sector covers the level of residential building activity and residential and nonresidential construction values. Activity levels and values are based on local demand for homes and nonresidential buildings and national economic conditions, captured by national construction levels.

2.5.1 Housing Supply

The DEFM housing sector flow of information is illustrated in Figure 6. Housing units are forecast by structure type as a function of the previous year’s stock plus the completion of last year’s residential permit authorizations. For single family and multifamily housing stocks, DEFM uses historical permit realization rates that are less than 100 percent. The stock of manufactured housing units (mobile homes) is held constant at the base-year amount.

2.5.2 Vacancy Rates

Housing demand is determined by the number of forecasted households, which is computed in the Demographic sub-model based on preference factors for housing by structure type, household headship rates, and elasticities with respect to housing prices. Vacancy rates are computed from the supply and demand for housing units.

2.5.3 Housing Unit Authorizations

The number of new housing units authorized by building permits in a forecast year is positively related to local demand for new homes and to national housing market conditions, and is inversely related to the housing stock vacancy rate. Local demand depends on the increase in the number of households and the replacement of old housing stock. No consideration is given to local mortgage market conditions since secondary mortgage markets rather than local deposit inflows serve as the main source of mortgage funds. Given these secondary markets, the national housing market variables are assumed to account for national and therefore local mortgage market conditions.

Permit activity is allocated between single and multifamily authorizations based on an equation that depends on the single family share for national construction.
Figure 6
DEFM Housing Model

Housing Supply

Permits

National Conditions

SF Permits

MF Permits

Trend

SF Stock

MF Stock

MH Stock

Total Stock

Change in Household

Vacancy Rate

Housing Demand

Total Households

Household Population

Headership Rates

Price of Housing
2.5.4  Construction Value and Nonresidential Construction

The real value of authorizations for new residential units is influenced by the level of single family and multifamily permits. The nominal value of authorizations depends on the real value and the level of construction costs.

Valuation of the new nonresidential construction is forecast by a regression equation relating valuation to the gain in local employment and to national construction market conditions. National conditions are captured by the value of nonresidential construction investment in the U.S. economy.

2.6  REVENUE AND EXPENDITURES

DEFM contains data on revenue and expenditures for the San Diego region and the cities and school districts within the region. Revenue includes property taxes, retail sales, federal and state grants and fines, service fees, assessments, and so on. Expenditures include educational costs and other local government expenditures. Revenue and expenditure forecasts are based on regression models that relate the level of dollar flows to measures of the scale of the region and the level of economic activity.

2.6.1  Revenue

Local government revenues are modeled in five parts. First, property tax revenues are modeled as a function of assessor’s market value. The remaining components are state and federal grants, sales tax revenues, and other revenues.

The base for property taxes is termed “assessor’s market value” (A.M.V). Because of limitations imposed by the Gann Appropriations Limit, the response of A.M.V to market conditions occurs with a lag. In times of price increase, the associated increase in assessed market values is limited unless there is a change in ownership. However, over time, as property changes hands, the A.M.V will eventually reflect the market value as captured by the transaction price. Also, in times of declining value, A.M.V will follow with some lag as properties turn over or as owners request assessment updates.

Property tax revenues of local government agencies are forecast from the assessor’s market value tax base. Historically, the overall average rate for total property taxes collected (since Proposition 13) reflects the one percent full value tax and additional debt service in voter-approved tax rate areas. The regression equation indicates a slope of about 1.16 percent as the average realized tax rate.

Federal revenue sharing, which was a source of local government revenues through the mid-1980s, has been discontinued. Other federal grants and state grants are a major source of funding for education and health and welfare programs. Total revenues from these sources are modeled as a function of San Diego population and average daily public school attendance (ADA).

Local revenues from retail sales taxes are set to 2.25 percent of Taxable Retail Sales. Other revenues include fines, fees, service assessments, etc. These revenues represent most of the unconstrained local revenues not affected by spending limitations. Since 1979, these revenues grew proportionately faster than the other sources of revenues and now make up the majority of non-education related local government revenue. Since these revenues are closely linked to local
economic and demographic conditions, a historically estimated equation is used that relates the level of revenues to population and economic activity.

2.6.2  Expenditures

Local government expenditures are modeled in two pieces. The first covers educational expenditures and the second covers other local government expenditures. Educational expenditures are forecasted based on an estimated relationship between real expenditures and ADA. Local government expenditures are modeled based on the historical relationship between these real expenditures and real revenues less education expenditures.

2.7  PRICES

Four price variables appear in DEFM, including the consumer price index, the average price of a single family home, a construction cost index, and a wage rate index. All real income and price data in DEFM are based on constant (year 2000) dollars. All price deflators are computed from the U.S. Department of Commerce Consumer Price Index (CPI), with 1982-1984 average = 100. For industrial output, the implicit price deflator for U.S. Gross Domestic Product (GDP) is used. The coefficients of the IMPLAN input/output matrix used in DEFM are expressed in 2001 dollars.

Construction costs are modeled as a function of a national cost index modified for relative wage levels in the San Diego region. A second factor relates national costs with a measure of the level of construction activity in the region. This measure is computed based on dwelling unit authorizations per household in the region. When this ratio is high, construction costs will be slightly higher, reflecting high levels of demand. When this ratio is low, slack conditions will result in reduced construction costs.

Housing price level forecasts are based on a historical relationship with an adjusted income variable. Adjusted income is defined to include average household income plus a dynamic wealth term reflecting past capital gains on homes. This dynamic term is based on the change in housing prices over a previous 6-year period.

The adjusted income term is multiplied by a vacancy rate adjustment centered on 4 percent. Vacancy rates above 4 percent will result in reduced housing price levels. Vacancy rates below 4 percent will place upward pressure on housing prices. The vacancy rate effect on home prices is modeled using elasticity on the inverse of the vacancy rate.

The local CPI is estimated to follow its national counterpart up to the influence of differential changes in local and national housing prices. The elasticity on the relative price of housing is set to 1.25 percent, which is the weight for housing costs in the CPI. By using this elasticity, a 10 percent increase in the relative cost of housing in the San Diego region will cause a 1.25 percent increase in the San Diego CPI.

The wage rate index for the San Diego region is modeled as a function of the U.S. earnings index and the difference between unemployment rates in San Diego and the U.S. The model is structured so that each percentage point difference between local and national unemployment rates takes 1.5 percent off of the explanatory variable index. For example, if the local unemployment rate is 5 percent and the national rate also is 5 percent, the modifier for unemployment rates is a
multiplier of 1.0 and has no effect. If the local unemployment rate is 6 percent and the national rate
is 4 percent, this 2 percent difference reduces the modifier to 0.97, indicating less pressure on San
Diego wages relative to the national wage rate. Conversely, if the local unemployment rate is 4
percent and the national rate is 6 percent, this 2 percent difference increases the modifier to 1.03,
indicating upward pressure on wages in the San Diego region relative to national wages. The
coefficient on the product of the national wage rate and the unemployment modifier is estimated
based on historical relationships.

2.8 INCOME

Personal income forecasts for San Diego County residents are developed for the following income
sources (adjusted for place of residence):

- payroll (wage and salary income)
- other labor income
- proprietors' income
- dividends, interest, and rent
- transfer payment sources
- net of social security payments

The income equations provide estimated relationships between components of income and a variety of
explanatory variables. Civilian payroll depends on forecasts of employment, wages, and the industry
mix of employment. The industry mix variable is calculated using 2000 payroll per employee values for
the 50 private-sector employment categories. (Again, this is the base year for the data in the IMPLAN
input/output relationships). In each year, these values are weighted by the fraction of employment in
each industry, and the resulting weighted average is divided by the 2000 weighted average.

Forecasts of military payroll depend on the number of uniformed military and general wage trends
in the private sector. Other labor income is assumed to depend on civilian payroll levels and
U.S. ratios of other labor income to payroll. Similarly, proprietors' income is assumed to depend on
civilian payroll and U.S. ratios of proprietors' income to payroll. Dividends, interest and rental
income depend upon regional population and national income for the same income sources.

Transfer income is forecast for several components. Real retirement income is a function of the
population over 65 years of age. Real unemployment transfer income is a function of the number of
unemployed persons in the economy. Real public assistance transfer income and other transfer
income are modeled to depend on total population.

The income components are combined to obtain regional personal income, after subtracting social
security contributions. Social Security contributions are assumed to depend on the level of civilian
payroll. A residence adjustment is made to account for the income of local residents who work
outside the area and for the income of people who work locally, but live outside the region.

Disposable personal income is calculated by subtracting forecasts of personal tax payments from
total personal income. Taxes paid out of personal income include federal income taxes, state
income taxes and personal property taxes. Because the property tax variable includes both
payments by households and businesses, only two-thirds of the total is subtracted in computing disposable income. This fraction represents the part of total property tax payments paid by households against residential properties.

2.9 USER CONTROLS

One of the principal features of DEFM is the ability for the user to effectively change or influence every major equation or relationship. DEFM has an extensive set of multiplicative and additive adjustments (shifts) that can be applied to nearly every forecast variable during a forecast. These can be used to simulate policy changes, exogenous shocks to an economy or observed or predicted changes in local conditions that may differ from the historical perspective offered by the econometrics. In practice, these shifts are what make DEFM a planning and simulation tool in addition to being a pure forecasting model.

2.10 2030 REGIONAL GROWTH FORECAST UPDATE KEY ASSUMPTIONS

This section describes the key assumptions that were used in DEFM in preparing the 2030 Regional Growth Forecast Update. The demographic module requires assumptions about birth rates, death rates and labor force participation rates, as well as assumptions about factors that influence the age, sex and ethnicity of international and domestic migration and changes in household size.

The independent variable drivers for the economic equations mainly consist of national, regional and state-level employment and output data. Historical DEFM data sets come from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and the California Employment Development Department. In addition, DEFM uses a national forecast that is purchased from Economy.com and a regional input/output model purchased from IMPLAN. Most econometric equations are estimated on time series data that cover the period 1970 to 2004. Some equations have historical data back to 1950.

2.10.1 Demographic Assumptions

Table 1 contains the fertility rates used in the 2030 Regional Growth Forecast Update.

<table>
<thead>
<tr>
<th>Year</th>
<th>Hispanic</th>
<th>White</th>
<th>Black</th>
<th>American Indian</th>
<th>Asian</th>
<th>Hawaiian &amp; Pacific Island</th>
<th>Other</th>
<th>Two or More Races</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2.97</td>
<td>1.67</td>
<td>2.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>2.12</td>
<td>1.67</td>
<td>2.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 The total fertility rate is the average number of children that a woman will have during her lifetime.
2030 fertility rates are based on the Census Bureau’s most recent national projection. Different projection series are used depending on the 2000 base-year fertility rates for the region. The Census Bureau’s Middle Series rates reflect national historical trends in fertility, demographic theory, and recent survey data of high school senior women about their future fertility. The Low Series rates were created by decreasing the Middle Series rates by 15 percent in 2025 and 25 percent in 2050.

The Low Series was used for 2030 rates for Hispanic, White, and American Indian, Asian, Hawaiian and Pacific Islanders, Others, and Two or More Races because it was found to track more closely with current fertility rates for those groups.

The rates for Blacks for 2030 were taken from the Middle Series because their current national and local rates were similar.

Forecast life expectancy assumptions were evaluated against recent data including 2000 Census results and 1999 death certificate information. We believe that the current U.S. projections were reasonable for all ethnic/race groups through 2030 and therefore were used for the 2030 Regional Growth Forecast Update.

Table 2 illustrates the expected shift in the ethnicity of domestic migrants to the San Diego region during the forecasted period. These shifts are based upon the expected changes in the ethnic composition of the California population, which accounts for 60 percent of San Diego’s domestic migration.

<table>
<thead>
<tr>
<th>Year</th>
<th>Hispanic</th>
<th>White</th>
<th>Black</th>
<th>Am Indian</th>
<th>Asian</th>
<th>Hawaiian &amp; Pac Island</th>
<th>Other</th>
<th>Two or More Races</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>100%</td>
<td>-80%</td>
<td>-12%</td>
<td>0%</td>
<td>60%</td>
<td>32%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2030</td>
<td>47%</td>
<td>30%</td>
<td>6%</td>
<td>2%</td>
<td>13%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
</tr>
</tbody>
</table>

The domestic net migration level for all ethnic groups is determined from economic factors.

Domestic net migration is distributed into ethnic groups according to factors based on the ethnic distribution of California residents, changing over time to reflect shifts in the ethnic composition of the state.

The age pattern of domestic net migrants relies on net migration rates for each sex and ethnic group based on census data. These rates are held constant over the forecast period and applied to the survived population to capture changes in the age structure over time.
Table 3 contains the ethnic distribution of international migrants assumed for the 2030 Regional Growth Forecast Update.

### Table 3

**Ethnic Distribution of International Net Migration**

**2030 Regional Growth Forecast Update**

**San Diego Region**

<table>
<thead>
<tr>
<th>Ethnic Group</th>
<th>Non Hispanic</th>
<th>Hispanic</th>
<th>White</th>
<th>Black</th>
<th>Am Indian</th>
<th>Asian</th>
<th>Hawaiian &amp; Pac Island</th>
<th>Other</th>
<th>Two or More Races</th>
</tr>
</thead>
<tbody>
<tr>
<td>42%</td>
<td>26%</td>
<td>4%</td>
<td>0%</td>
<td>22%</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The level of international net migration is based on the current middle series projection of U.S. net international migration, which ranges between 720,000 and 1,067,000 from 2000 to 2030. DEFM assumes that a constant share (1.9%) of U.S. migrants will locate in the San Diego region each year, derived from the relationship between U.S. and regional international migration during the 1990s.

International net migration is distributed into ethnic groups according to factors computed from an average of census data and data from the Bureau of Citizenship and Immigration Services on country of origin from 1990 to 1995. This distribution does not change during the forecast period. Migrants are equally split between males and females for each ethnic group, except the Asian and Others group, which assumes a split of 45 percent for males and 55 percent for females.

The age pattern of international net migrants is based on a proportionate distribution for each sex and ethnic group according to census and INS data and does not change during the forecast.

Due to lack of reliable data, illegal immigration is not specifically addressed.

Figure 7 illustrates the historical and forecasted change in household size (average persons per household). Household size is inversely related to household formation (as measured by household headship rates) in that lower household formation for the same population size means that on average more persons will live in each house. Between 1990 and 2000, household size increased from 2.68 to 2.73. The increasing trend continues over the 30-year forecast period.

There are two main reasons for this future pattern in household size. First, household formation rates decline from 2000 to 2010 based on the assumption that that our household size will move toward that of Orange County, which had a household size of 3.0 in 2000. This assumption is consistent with historical trends, and was agreed upon by the Regional Planning Technical Advisory Committee. Second, as discussed in Chapter 4, in the 2030 Regional Growth Forecast Update around 99,000 fewer housing units are built in the region due to interregional commuting. One impact of that lower housing construction in the future is higher household sizes. In a Baseline Forecast alternative that assumed these 99,000 units would be built in the region, the region’s household size would only be 2.75.
2.10.2 Key Economic Assumptions

Most of the economic assumptions are a function of the model structure, econometric estimation, and treatment of the residuals. Other key assumptions include:

- Local labor force participation rates follow U.S. trends to 2010 by age, sex and ethnicity. The trend is continued to 2030. Overall participation rates increase, though some individual rates do not change. Rates for different ethnic groups are converging, though total convergence does not occur by 2030.

- Price changes average 2.5 percent annually between 2004 and 2030. They are slightly higher than the national inflation rate due to faster increases in the region’s housing costs.

- Projected changes in local labor productivity by sector mirror national level trends.

- The region’s unemployment rate fluctuates around 4.5 percent.

2.10.3 U.S. and State Forecasts

The primary sources of independent variables in the employment and output equations and for trends in key demographic parameters are long-range national and state economic and population forecasts.
U.S. Long-Range Economic Forecast


- The economy's underlying growth rate will be slightly slower than in the past, particularly after 2010, when the first wave of baby boomers begins to retire. Inflation rises slowly.
- Annual growth in real GDP averages 3.2 percent between 2004 and 2010 and 2.4 percent between 2010 and 2020. It slows considerably after 2020 (2.0%).
- Inflation averages 2.7 percent annually between 2000 and 2010, 2.2 percent between 2010 and 2020, and 2.1 percent annually between 2020 and 2030.

U.S. Long-Range Population Forecast


- Components of population change
  - Total fertility rates for all non-Hispanic ethnic groups approach replacement level of 2.1 births per female by 2030. Total fertility rates for Hispanics decline from 2.9 in 2000 to 2.3 in 2030.
  - Life expectancy rises approximately 3.5 years between 2000 and 2030, from 74.1 to 77.6 for males and from 79.8 to 83.6 for females.
  - Net international migration ranges from 720,000 to 980,000 per year during the 2000 to 2030 period.
- Average annual population growth slows to about 0.8 percent between 2000 and 2030.

California Forecast

Source: California State Department of Finance (DOF), Demographic Research Unit, May 2004. “County Population Projections with Age, Sex and Race/Ethnic Detail, July 1, 2000 – 2050.”

- California’s population reaches 48.1 million in 2030, an increase of 11.7 million or 32 percent over the most current estimate for July 1, 2004.
- The ethnic mix changes significantly between 2004 and 2030. By 2030, Hispanics are about 47 percent of the population, up from 35 percent in 2004. Non-Hispanic Whites decline from 44 percent to 30 percent. In 2030, non-Hispanic Blacks remain at about 6 percent of the population.
CHAPTER 3: LAND USE PLANS AND POLICIES

3.1 ROLE OF PLANS AND POLICIES IN THE FORECAST

Determining the amount and location of housing unit and employment capacity in the region is a key to allocating our long-range regional forecast to jurisdictions, communities, and neighborhoods. These capacities represent key policy inputs to the forecasting process, reflecting current land use plans and policies, as well as the implementation of smart growth development strategies throughout the region. Land use data collected from the local jurisdictions provides policy inputs to both the Urban Development Model (UDM) and the Interregional Commute Model (IRCM).

That there is a lack of housing unit capacity in the region’s current general and community plans with respect to long-range population and economic forecasts has been known for years. The two previous forecasts dealt with this issue in different ways. The Series 8 Forecast, released in 1995, simply assumed slight residential density increases across the board in all jurisdictions. That approach was criticized as being somewhat arbitrary, and not addressing the nexus between land use and transportation.

The 2020 Forecast, released in 1999, was the first SANDAG attempt to model future smart growth development patterns. Residential and employment capacity was added throughout the urban areas of the region in the form of transit-oriented development within walking distance around some 150 current and future transit stops, called transit focus areas (TFA). In areas where several TFAs were clustered, however, the resulting land use patterns sometimes were too far removed from current plans, causing concern for some jurisdictions.

The 2030 Cities/County Forecast was developed as a component of the Regional Comprehensive Plan (RCP). This forecast is based on current plans and policies of the incorporated jurisdictions and the June 2006 draft General Plan update for unincorporated areas.

Like the 2030 Cities/County Forecast, no smart growth areas other than those contained in the current plans and policies of the jurisdictions were included in the land use assumptions for the 2030 Regional Growth Forecast Update.

3.2 HOUSING AND EMPLOYMENT CAPACITY

SANDAG uses a multilevel geographic reference system. The foundation of the system is the SANDAG Geographic Reference Area (SGRA). The approximately 1,800 SGRAs are the result of overlaying several layers of geographic boundaries: census tracts, community planning areas, city boundaries, spheres of influence, and zip codes. Census tracts also are split using other criteria (e.g. ridgelines) to develop traffic analysis zones for use in the transportation models. Housing unit and employment capacity is determined for each SGRA.
Before the capacities can be calculated, a great deal of “land use inputs” data must be gathered and corroborated. SANDAG relies heavily on the involvement of the local jurisdiction staffs for this task. First, a set of maps is prepared for local review. For the City of San Diego there is a map set for each community planning area. The 17 other cities receive maps depicting activity within their general plan boundaries.

The local staffs last reviewed a full set of maps in 2002 in preparation for the 2030 Forecast released in 2002. Each of the maps depicted a different aspect of land use: (1) planned land uses (i.e. the general or community plan), (2) existing land uses, (3) areas that are fully or partially constrained from development for policy or environmental reasons, and (4) areas that have the potential to redevelop (change use) or infill (intensify the existing use). The local planners reviewed each map for completeness and accuracy, noting any corrections directly on the maps. In addition, they provided SANDAG with information about any “site specific” projects. These are development projects that are currently under construction or have final approval and financing. As the maps were returned, SANDAG staff made the necessary edits to the various GIS databases.

For the 2030 Forecast Update, each jurisdiction, with the exception of the County of San Diego, was provided with two land use input maps for review. The first map illustrated the jurisdiction’s general plan. The second depicted areas within the city that were vacant and developable and areas where redevelopment and/or infill might occur. Each of the 18 jurisdictions was asked to review each map and to confirm its accuracy. If errors were found, the jurisdictions were asked to make corrections by noting these on each map. The maps were then returned to SANDAG and the changes were geo-coded into the database.

The inputs for the unincorporated areas were handled differently. At the time of the forecast, the County was engaged in a major update to its general plan. The County had created an interim land use layer that was being considered for adoption by the Board of Supervisors. This land use layer and the population and housing unit targets were referred to by the County as the “June 2005 Working Copy” and were modeled for the 2030 Forecast Update.

Once the databases are updated, the process of determining housing and employment capacity begins. The program GPALL evaluates current land use, planned land use, the existence of constraints, redevelopment potential, and other characteristics to determine the appropriate development type code. The development type code is used in the Urban Development Model (UDM) to determine where activity can occur during the forecast period. Sixteen types of land are identified through the program (listed in Table 4). For forecasting purposes, redevelopment is defined as a change of use, and infill means an intensification of the same use. Agricultural Redevelopment is a special case. In many parts of the region, land in existing agricultural use is actually planned for some other use, and may eventually develop with that other use. Therefore, unless the underlying general or community plan category is Agriculture, or there is a constraint to development, land in agricultural use is considered to be developable for nonagricultural uses.
In the next step, the CAPACITY program computes the housing unit and/or employment capacity for each development type code within each parcel. By definition, areas assigned a development type code of 1 or 2 have no remaining capacity. Also by definition, areas that are vacant or agricultural and developable (codes 3 and 10) always have remaining capacity, which is calculated as:

$$\text{Remaining Capacity} = \text{Acres} \times \text{Density}$$

Housing unit densities are prescribed by the general or community plan. Most plans use density ranges, such as 4 to 8 units per acre, and the local planners identify where within each range development usually occurs. On vacant land, the midpoint (50 percent) of the range is typical, which in this case means the land would develop at 6 units per acre. On redevelopment or infill land, 75 percent or 100 percent of the range is common. Therefore, a 4 to 8 units per acre range would yield either 7 (75 percent) or 8 (100 percent) units per acre. Employment densities are based on observed regional parameters and are specific to almost 50 different employment land uses.
Remaining capacity for nonagricultural redevelopment areas (codes 7, 8, 9, 11, 12, 15) also is calculated using the above formula. In these cases, however, existing activity is removed first. For example, in areas that have the potential to redevelop from existing single family use to multifamily use (code 8), single family units are removed before the multifamily units are added. The removal of existing activity means that areas can have negative capacity. For example, in areas identified with the potential for residential to employment redevelopment (code 7), the existing housing would be replaced with nonresidential activity, and the housing unit capacity would be a negative number equal to the number of existing units in the year 2000. Potential infill areas (codes 4, 5, 6) add units or employment to the already existing activity up to, but not exceeding, the prescribed density. There is no loss of activity in infill areas.

Program output comprises database tables that are used in the allocation modules of UDM. The derivation of capacity is illustrated in Figure 8.

Once a capacity database is created, it is subjected to a series of computerized checks for consistency and accuracy. If inconsistencies or inaccuracies are discovered, the source of these are determined and corrected and the capacity database is recalculated. This process is iterated until an acceptable capacity database is created.

The data are aggregated for jurisdictions and community plan areas. Tables illustrating existing housing units and employment and housing and employment capacities are constructed and sent to each jurisdiction for their review and comment. If a jurisdiction determines that the capacities generated by the capacity program are inconsistent with their current plans and policies, the inconsistencies are noted and corrected and the capacity database is recomputed and subjected to the computerized checks. The new capacities then are forwarded to the jurisdictions for their review. This process is repeated until there is consensus among the jurisdictions that the capacity database is a reasonable representation of their current plans and policies.
Figure 8
Capacity Derivation

Raw Land Use Files

GPALL
Development Code Assignment

Land Use Files with Development Code

GIS Aggregation

Regional Land Use File

Base Year Employment and Housing

CAPACITY

Parameters

Modeling Database Tables
CHAPTER 4: INTERREGIONAL COMMUTE MODEL

The 2030 Regional Growth Forecast Update is the second SANDAG forecast to include an Interregional Commute Model (IRCM). The purpose of the model is to account for individuals who work in the region but live outside its boundaries. Historically, the amount of interregional commuting into and out of the San Diego region had been relatively small. However, recent evidence indicates that interregional commuting is increasing rapidly. Between 1990 and 2000, for example, the number of workers commuting from Riverside County to job sites in the San Diego region has increased four-fold.

The IRCM predicts the residential location of the workers holding new jobs created in the San Diego region in the future using a gravity model. The residential location can be either inside the San Diego region, in Orange County, southwest Riverside County, Imperial County, or in Tijuana/Northern Baja California.

The IRCM assigns the residential location of workers based upon the accessibility of potential residential sites to job locations, the availability of residential land for development, and the relative price of homes. There are three basic tenets of the IRCM. First, as commuting time from work to possible residential locations increases, the probability of choosing those locations decreases. Second, more land available for residential development increases the potential for residential growth. Third, lower home prices also are an attraction factor in residential location. These three basic tenets also underlie the gravity model used in the Urban Development Model (UDM).

The results from the IRCM are used to modify the DEFM regional forecast. The initial regional forecast, referred to as the Baseline, is modified to reflect the fact that not all housing units, population, employment, and other elements predicted by the Baseline forecast will occur in the region. Rather, some residential and economic activity will occur in nearby areas outside the region.

4.1 ACCESSIBILITY

Accessibility is measured in terms of travel times from potential residential sites to potential work sites. These travel times represent year 2000 peak-period A.M. travel times, based on our transportation model. Within the San Diego region, the IRCM uses seven Major Statistical Areas (MSAs) as the geographic analysis units (Figure 9). MSAs were selected because they better approximate the units of geography in southwest Riverside County and Tijuana/Northern Baja California, and Traffic Analysis Zones (TAZs) nest within them. A travel-time matrix for the year 2000 was produced by calculating the average of TAZ travel times between MSAs.
Figure 9
Geographic Areas for the Interregional Commuting Model
Additional assumptions were made about commuting from surrounding regions. Commute times were calculated from each MSA to the borders between the San Diego region and the other four regions. For commutes into southwest Riverside County, an additional 40 minutes was added to the commute times. These additional minutes account for the travel time it takes to reach the San Diego County line from communities within southwest Riverside County. For Orange County commuters, 35 minutes were added for travel time within Orange County. 42 minutes were added for travel time within Imperial County. For commutes from Mexico, an additional 60 minutes were added to the travel time from the international border to the MSA. These additional minutes accounted for border wait-times and for the travel time it takes from communities in Mexico to the border.

The data in Table 5 show the travel time matrix used in the IRCM. For example, in 2000 it took 48 minutes to travel from a workplace on the North County East MSA to the North City MSA. These data indicate that the commute time between the South Suburban MSA is less to Tijuana/Northern Baja California than it is to the two North County MSAs. Similarly, commute times between the North County MSAs and southwest Riverside County are less than the commute times between these MSAs and many areas throughout the region.

### Table 5

**A.M. Peak Period IRCM Travel Times, 2004**

<table>
<thead>
<tr>
<th>Place of Residence</th>
<th>Central</th>
<th>North City</th>
<th>South Suburban</th>
<th>East Suburban</th>
<th>North County West</th>
<th>North County East</th>
<th>East County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>15</td>
<td>40</td>
<td>17</td>
<td>33</td>
<td>61</td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td>North City</td>
<td>29</td>
<td>16</td>
<td>34</td>
<td>44</td>
<td>47</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>South Suburban</td>
<td>28</td>
<td>54</td>
<td>16</td>
<td>45</td>
<td>76</td>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td>East Suburban</td>
<td>42</td>
<td>67</td>
<td>47</td>
<td>17</td>
<td>91</td>
<td>84</td>
<td>47</td>
</tr>
<tr>
<td>North County West</td>
<td>75</td>
<td>58</td>
<td>81</td>
<td>93</td>
<td>16</td>
<td>31</td>
<td>98</td>
</tr>
<tr>
<td>North County East</td>
<td>56</td>
<td>46</td>
<td>61</td>
<td>72</td>
<td>32</td>
<td>17</td>
<td>86</td>
</tr>
<tr>
<td>East County</td>
<td>66</td>
<td>92</td>
<td>71</td>
<td>47</td>
<td>100</td>
<td>86</td>
<td>21</td>
</tr>
<tr>
<td>Riverside</td>
<td>107</td>
<td>96</td>
<td>112</td>
<td>123</td>
<td>77</td>
<td>62</td>
<td>127</td>
</tr>
<tr>
<td>Tijuana/N. Baja Calif.</td>
<td>90</td>
<td>120</td>
<td>71</td>
<td>111</td>
<td>142</td>
<td>137</td>
<td>135</td>
</tr>
<tr>
<td>Orange County</td>
<td>122</td>
<td>126</td>
<td>128</td>
<td>140</td>
<td>62</td>
<td>83</td>
<td>164</td>
</tr>
<tr>
<td>Imperial County</td>
<td>121</td>
<td>147</td>
<td>126</td>
<td>102</td>
<td>170</td>
<td>150</td>
<td>95</td>
</tr>
</tbody>
</table>
4.2 AVAILABILITY OF RESIDENTIAL LAND

Besides commuting times, the availability of residential land has significant influence on the allocation of future workers in the IRCM. Potential residential activity in the San Diego region is obtained from the land use policy inputs discussed in Chapter 3 and measure the number of additional housing units that could potentially be built under the assumptions used in the 2030 Regional Growth Forecast Update. For the southwest Riverside County area, we used the latest housing unit forecast contained in the 2025 Regional/County Growth Forecast produced by the Southern California Association of Governments. This forecast was published in June 2004. To measure the potential residential activities in Tijuana/Northern Baja California, we used a forecast of housing units (produced by the Colegio de la Frontera Norte and the Parsons Transportation Group in November 2000).

Table 6 contains the future housing unit capacities used in the IRCM. As the data indicate, of all the areas included in the IRCM, southwest Riverside County has the largest residential potential (542,700), while the East County MSA has the smallest (14,600). It also is interesting to note that southwest Riverside County alone has the potential to build more than one-half of the number of units slated for the entire San Diego region.

Table 6
Housing Unit Capacities by MSA and Extra-Regional Areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Housing Unit Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>80,500</td>
</tr>
<tr>
<td>North City</td>
<td>43,200</td>
</tr>
<tr>
<td>South Suburban</td>
<td>47,500</td>
</tr>
<tr>
<td>East Suburban</td>
<td>34,300</td>
</tr>
<tr>
<td>North County West</td>
<td>23,100</td>
</tr>
<tr>
<td>North County East</td>
<td>48,000</td>
</tr>
<tr>
<td>East County</td>
<td>14,600</td>
</tr>
<tr>
<td>San Diego Region*</td>
<td>291,200</td>
</tr>
<tr>
<td>Southwest Riverside County</td>
<td>542,700</td>
</tr>
<tr>
<td>Tijuana/N. Baja Calif.</td>
<td>120,000</td>
</tr>
<tr>
<td>Orange County</td>
<td>164,600</td>
</tr>
<tr>
<td>Imperial County</td>
<td>49,200</td>
</tr>
<tr>
<td>Extra Region</td>
<td>876,500</td>
</tr>
<tr>
<td>Total interregional Area</td>
<td>1,167,700</td>
</tr>
</tbody>
</table>

* Units that could potentially be built based on current plans and policies land use inputs from the 2030 Regional Growth Forecast Update.
4.3 RELATIVE PRICE OF HOUSING

In addition to commuting times and the availability of residential land, home prices have an impact on residential location in the IRCM. Lower-priced homes are an attraction factor in residential location in the model. Home price data for MSAs within the San Diego region were aggregated from August 2005 zip code sales prices reported by DataQuick Information Systems. Orange, Riverside, and Imperial County home prices were also collected from DataQuick, as reported in the San Diego Union Tribune. Finally, data for Tijuana was compiled from a representative sample of homes obtained from Focus Investigacion de Mercados – Tijuana. The prices were turned into an Attractiveness Ratio of the San Diego County sales price divided by the area’s sales price. Thus, areas with home prices lower than the county average have an Attractiveness Ratio greater than one, and higher-priced areas have a ratio lower than one.

Table 7 contains the Home Price Attractiveness Ratios used in the IRCM. As the data indicate, the lowest priced area is Tijuana/Northern Baja. The highest priced area is North County West MSA.

<table>
<thead>
<tr>
<th>Area</th>
<th>Attractiveness Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>0.96</td>
</tr>
<tr>
<td>North City</td>
<td>0.85</td>
</tr>
<tr>
<td>South Suburban</td>
<td>1.03</td>
</tr>
<tr>
<td>East Suburban</td>
<td>1.00</td>
</tr>
<tr>
<td>North County West</td>
<td>0.78</td>
</tr>
<tr>
<td>North County East</td>
<td>0.92</td>
</tr>
<tr>
<td>East County</td>
<td>1.13</td>
</tr>
<tr>
<td>San Diego Region</td>
<td>1.00</td>
</tr>
<tr>
<td>Southwest Riverside County</td>
<td>1.29</td>
</tr>
<tr>
<td>Tijuana/N. Baja Calif.</td>
<td>5.42</td>
</tr>
<tr>
<td>Orange County</td>
<td>0.82</td>
</tr>
<tr>
<td>Imperial County</td>
<td>2.96</td>
</tr>
</tbody>
</table>

* Ratio higher than one indicates that the area has relatively low-price housing. Ratio lower than one indicates relatively high-price housing.
4.4 TRAVEL TIME AND ALLOCATION

The travel times were converted into probabilities by comparing the length of the commute to the likelihood of making the commute. These probabilities are derived from a mathematical function that relates the probability of commuting a specific distance to the log of the time it takes to make that commute. Table 8 contains the IRCM commute time probabilities. For example, the probability in the year 2004 of living in the East Suburban MSA and commuting to Central MSA was 0.0509.

Table 8
IRCM Commute Probabilities, 2004*

<table>
<thead>
<tr>
<th>Place of Residence</th>
<th>Central</th>
<th>North City</th>
<th>South Suburban</th>
<th>East Suburban</th>
<th>North County West</th>
<th>North County East</th>
<th>East County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>0.1391</td>
<td>0.0595</td>
<td>0.1382</td>
<td>0.0971</td>
<td>0.0100</td>
<td>0.0149</td>
<td>0.0139</td>
</tr>
<tr>
<td>North City</td>
<td>0.1152</td>
<td>0.1391</td>
<td>0.0953</td>
<td>0.0396</td>
<td>0.0337</td>
<td>0.1019</td>
<td>0.0062</td>
</tr>
<tr>
<td>South Suburban</td>
<td>0.1174</td>
<td>0.0189</td>
<td>0.1390</td>
<td>0.0389</td>
<td>0.0029</td>
<td>0.0054</td>
<td>0.0061</td>
</tr>
<tr>
<td>East Suburban</td>
<td>0.0509</td>
<td>0.0065</td>
<td>0.0337</td>
<td>0.1385</td>
<td>0.0003</td>
<td>0.0008</td>
<td>0.0329</td>
</tr>
<tr>
<td>North County West</td>
<td>0.0034</td>
<td>0.0129</td>
<td>0.0013</td>
<td>0.0003</td>
<td>0.1390</td>
<td>0.1074</td>
<td>0.0003</td>
</tr>
<tr>
<td>North County East</td>
<td>0.0154</td>
<td>0.0374</td>
<td>0.0103</td>
<td>0.0048</td>
<td>0.1041</td>
<td>0.1383</td>
<td>0.0006</td>
</tr>
<tr>
<td>East County</td>
<td>0.0074</td>
<td>0.0003</td>
<td>0.0049</td>
<td>0.0329</td>
<td>0.0002</td>
<td>0.0006</td>
<td>0.1362</td>
</tr>
<tr>
<td>Riverside County</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0024</td>
<td>0.0098</td>
<td>0.0000</td>
</tr>
<tr>
<td>Tijuana/N. Baja Calif.</td>
<td>0.0004</td>
<td>0.0000</td>
<td>0.0049</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Orange County</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0093</td>
<td>0.0008</td>
<td>0.0000</td>
</tr>
<tr>
<td>Imperial County</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

* Probabilities do not sum to 1.00 for each work place because they reflect only the typical commute time and not all commute times. Probabilities change during the thirty-year forecast interval to reflect forecasted changes in the transportation network and anticipated increases in traffic volume.

These commute probabilities then are multiplied by the potential of residential activity within each area (i.e. the capacities in Table 6) and the housing price attractiveness factor (Table 7). These weighted probabilities then are normalized so that the sum of the probabilities for each place of work equals 1.0. Table 9 contains the normalized probabilities of working in one area and living in another in the year 2004. These normalized or allocation probabilities represent the likelihood of working in an area and living in another area, taking into account commute times and probabilities and the availability of land for residential activity.
### Table 9
**Allocation Probabilities**
*from Place of Work to Place of Residence*
*2004 - 2010*

<table>
<thead>
<tr>
<th>Place of Work</th>
<th>Central</th>
<th>North City</th>
<th>South Suburban</th>
<th>East Suburban</th>
<th>North County West</th>
<th>North County East</th>
<th>East County</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potential for Jobs</strong></td>
<td>22,072</td>
<td>38,785</td>
<td>14,133</td>
<td>6,614</td>
<td>13,393</td>
<td>14,682</td>
<td>1,176</td>
</tr>
<tr>
<td><strong>Place of Residence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>0.455</td>
<td>0.355</td>
<td>0.412</td>
<td>0.456</td>
<td>0.064</td>
<td>0.057</td>
<td>0.211</td>
</tr>
<tr>
<td>North City</td>
<td>0.179</td>
<td>0.393</td>
<td>0.135</td>
<td>0.088</td>
<td>0.101</td>
<td>0.185</td>
<td>0.045</td>
</tr>
<tr>
<td>South Suburban</td>
<td>0.242</td>
<td>0.071</td>
<td>0.262</td>
<td>0.115</td>
<td>0.012</td>
<td>0.013</td>
<td>0.058</td>
</tr>
<tr>
<td>East Suburban</td>
<td>0.074</td>
<td>0.017</td>
<td>0.044</td>
<td>0.287</td>
<td>0.001</td>
<td>0.001</td>
<td>0.221</td>
</tr>
<tr>
<td>North County West</td>
<td>0.003</td>
<td>0.018</td>
<td>0.001</td>
<td>&lt; 0.00</td>
<td>0.205</td>
<td>0.095</td>
<td>0.001</td>
</tr>
<tr>
<td>North County East</td>
<td>0.029</td>
<td>0.127</td>
<td>0.018</td>
<td>0.013</td>
<td>0.378</td>
<td>0.302</td>
<td>0.005</td>
</tr>
<tr>
<td>East County</td>
<td>0.005</td>
<td>&lt; 0.00</td>
<td>0.003</td>
<td>0.033</td>
<td>0.000</td>
<td>0.001</td>
<td>0.439</td>
</tr>
<tr>
<td>Riverside</td>
<td>0.004</td>
<td>0.015</td>
<td>0.002</td>
<td>0.002</td>
<td>0.135</td>
<td>0.339</td>
<td>0.006</td>
</tr>
<tr>
<td>Tijuana/N. Baja Calif.</td>
<td>0.010</td>
<td>0.002</td>
<td>0.123</td>
<td>0.003</td>
<td>0.001</td>
<td>0.001</td>
<td>0.005</td>
</tr>
<tr>
<td>Orange County</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.103</td>
<td>0.006</td>
<td>0.000</td>
</tr>
<tr>
<td>Imperial County</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.002</td>
<td>0.000</td>
<td>0.000</td>
<td>0.008</td>
</tr>
<tr>
<td><strong>Sum of all areas</strong></td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

### 4.5 Model Logic

The model begins with the expected spatial distribution by MSA of the increase in jobs during the increment 2004 to 2010. The anticipated job growth for the region comes from the Baseline forecast and is allocated to the MSAs in proportion to their potential for additional employment growth. This potential is based on the land use policy inputs described in Chapter 3. Using the allocation probabilities, workers are assigned to residential locations. These workers then are converted to housing units by using a regional workers-per-household factor that is derived from the Baseline forecast and represents the ratio of the change in jobs to change in housing units from 2004 to 2030. The allocation of housing units to each MSA and to surrounding regions is then evaluated against the housing capacity of each geographic area. If the housing units exceed the capacity, the excess is subtracted from the allocation and reconverted into workers. These are unallocated workers.

At this point, the beginning capacities are replaced with the remaining housing unit capacities and the normalized probabilities of place of work to place of residence are recalculated. (Note that MSAs that reached their initial capacities now have a housing capacity of zero and therefore, a
normalized probability of place-of-work to place-of-residence of zero.) The unassigned housing units then are allocated in this second iteration of the model. These procedures are repeated until all housing units are allocated to MSAs or areas outside the region.

After all housing units for the first increment are allocated, the model is recalibrated for the second increment (2010 – 2015) using the remaining housing unit capacities, the commute times associated with that increment, and the forecast of employment associated with the second increment. The procedures are repeated until all housing units are allocated for the second increment. The above procedures are replicated until the last housing unit is allocated for the 2025 to 2030 increment.

4.6 RESULTS

The main result from the IRCM is the number of new housing units containing workers who are employed in the San Diego region that will be built in the region and the number that will be built in one of the four surrounding regions. These results then are used for two modeling purposes. First, a revised regional forecast is produced that matches the number of new housing units predicted to locate within the region. Second, the number of housing units containing San Diego workers that are located outside the region is used as a partial determinant of future traffic volumes on the major transportation corridors linking southwest Riverside County, Orange County, Imperial County, and Tijuana/Northern Baja California with the San Diego region.

Table 10 contains the results of the IRCM for the 2030 Regional Growth Forecast Update. The IRCM predicts that over the 26-year forecast period, an additional 99,400 housing units containing workers from the San Diego region will be built outside the region. This is 26 percent of the new units needed to house the expected increase in the region’s workers.

While the availability of housing adjacent to the region is a contributing factor to interregional commuting, the location of future housing activity within the region also is important. When the region’s housing opportunities are put in competition with areas outside the region, even though there is capacity “on the books” in the rural back country, it is not as attractive to potential residents and would not likely develop over the next 30 years. For example, of the approximately 14,600 housing unit capacity located in the East County MSA, the IRCM predicts that 16 percent of it would still be available by 2025.

### Table 10

<table>
<thead>
<tr>
<th>Areas</th>
<th>New Housing Units*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside San Diego Region</td>
<td>289,000</td>
</tr>
<tr>
<td>Outside San Diego Region</td>
<td>99,000</td>
</tr>
<tr>
<td>Total</td>
<td>388,000</td>
</tr>
</tbody>
</table>

* Values rounded to nearest 1,000.

Lowering the regional housing unit forecast has consequences for other indicators as shown in Table 11. The 2030 Regional Growth Forecast Update has 6.8 percent fewer housing units than predicted by the Baseline Forecast in the year 2030. This translates into 2.0 percent fewer people.
The region declines by relatively fewer persons than housing units because there is an increase in the average number of persons per household of 4.2 percent to 2.87, indicating slightly more crowding. In addition to fewer housing units and population, the 2030 Regional Growth Forecast Update predicts fewer jobs than the Baseline forecast. Most of this difference relates to jobs in construction, retail trade, and services that are directly related to the lower forecast of housing and population. Another negative outcome is that average housing costs increase by more than 10 percent.

Table 11
Comparing the Baseline and the Final 2030 Regional Growth Forecast Update in the Year 2030

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Final</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td>Population</td>
<td>4,067,170</td>
<td>3,984,753</td>
<td>-82,417</td>
</tr>
<tr>
<td>Civilian Employment</td>
<td>1,853,893</td>
<td>1,828,614</td>
<td>-25,279</td>
</tr>
<tr>
<td>Housing Stock</td>
<td>1,484,690</td>
<td>1,383,803</td>
<td>-100,887</td>
</tr>
<tr>
<td>Persons per Household</td>
<td>2.75</td>
<td>2.87</td>
<td>0.12</td>
</tr>
<tr>
<td>Vacancy Rate</td>
<td>4.56%</td>
<td>3.76%</td>
<td>-0.01</td>
</tr>
<tr>
<td>Home Price</td>
<td>$1,082,737</td>
<td>$1,206,857</td>
<td>124,120</td>
</tr>
</tbody>
</table>

These findings from the IRCM and revised regional forecast are consistent with the analysis and conclusions from a report entitled “Evaluation of Growth Slowing Policies for the San Diego Region” released by SANDAG in October 2001. That report demonstrated how the region would likely respond to an imbalance between the supply and demand for housing brought about by a reduction in housing unit construction (supply). These responses included increased interregional commuting, more crowding (higher household sizes), and a tighter housing market (vacancy rates). The proportionate reduction in population, therefore, is less than that for housing units because some of that population demand is being absorbed inside the region by the willingness of people to live in larger households.

4.7 2030 REGIONAL GROWTH FORECAST UPDATE KEY ASSUMPTIONS

The IRCM as used in the 2030 Regional Growth Forecast Update makes a number of key assumptions:

- forecasts of housing units in Orange County, southwest Riverside County, Imperial County, and Tijuana/Northern Baja California are correct
- estimates of commute times between IRCM geographic areas during the forecast period are correct
- relationship between place of work and place of residence observed in 2000 remains the same through 2030
- relative price of homes converges by 50 percent over the forecast horizon.
CHAPTER 5: URBAN DEVELOPMENT MODEL

5.1 OVERVIEW AND KEY RELATIONSHIPS

The Urban Development Model (UDM) allocates employment, population, housing and income from the regional forecast to produce the 2030 Regional Growth Forecast Update. UDM is designed to forecast the location of residential and nonresidential activity within the region. In particular, UDM is based on the spatial interrelationships among economic factors, population and housing factors, land use patterns, and the transportation system, providing an accurate way of determining the 2030 Regional Growth Forecast Update. UDM also satisfies the federal requirements specified in the Clean Air Act Amendments of 1990 and the Transportation Equity Act for the 21st Century (TEA--21). These legislative acts mandate that transportation plans consider the long-range effects of the interaction between land uses and the transportation system.

Figure 10 illustrates the major components of UDM and its relationships to the regional forecast and transportation model. UDM provides a forecast at 5-year periods. Figure 10 illustrates the relationships between two periods, shown as Time Period n and Time Period n + 5 years.

Four major premises underlie UDM forecast of residential activities.

1. Employment location is a primary determinant of the location of residential activities.
2. The longer the work trip, the less the likelihood that a person makes that trip.
3. The more land that is available for residential development, the greater the potential for residential growth.
4. Residential growth occurs only in areas with additional capacity for residential development.

UDM captures the link between work place location and residential location through commuting patterns and travel times for both highways and transit within the region furnished by the transportation model. By using current and future trends in travel behavior, UDM approximates the responses to the other factors that determine where people might live within the region, such as land values, multiple worker households, income, and neighborhood preferences.
UDM combines the transportation and land use factors mathematically to determine the likelihood that an employee at his or her place of work will reside in alternative residential locations around the region. In general, areas closer to employment opportunities are more attractive to employees as potential residences than areas further away from their place of employment. Therefore, as available residential capacity closer to work places is consumed, new employees are forced to travel longer distances to find suitable residential locations. A major feature of this approach is that residential growth in jurisdiction is influenced not only by job growth within that jurisdiction, but also by job growth in surrounding areas and, to a lesser extent, job growth in other parts of the region.
After UDM determines the residential location of employed residents, it uses several local factors to derive households, housing stock, and population. UDM forecasts these local factors based on regional trends and other indicators including housing mix (i.e., single family units, multifamily units, and mobile homes).

Not only does the spatial distribution of employment opportunities influence the location and demand for houses, but the reverse is true as well, especially for population-serving employment such as retail trade and services. UDM handles this relationship by assuming a lag between residential development and the subsequent location of new jobs (indicated in Figure 10 by the arrow from the residential forecast at Time Period \( n \) to the employment forecast at Time Period \( n+5 \) years). Other factors that determine the future location of employment opportunities within the region are:

1. Transportation characteristics, including home-based shopping travel behavior,
2. The existing and previously forecasted locations of employment, reflecting the economies of scale businesses gain by locating near like-businesses, and
3. The capacity for additional employment growth.

The two arrows between land use characteristics and the employment and residential forecast components in Figure 10 reflect the iterative nature of these relationships, an important aspect of UDM. As noted, the availability of land and capacity for development influence the forecast of both residential and employment activities. The demand for these activities, in turn, influences future land supply and capacity. For example, an area adding residential activity consumes land and reduces the capacity for future residential development. Therefore, changes in land supply and capacity affect the allocation of activity in subsequent forecast years. Land consumption rates in UDM reflect densities in the existing plans or in a specified alternative. UDM does not allow growth to exceed the capacity implied by the available land and densities. It reconciles supply with demand by allocating excess demand to the closest area (in terms of travel time) that contains an available supply of land.

While travel patterns influence the forecast of both residential and employment activities, these activities also influence travel patterns. As Figure 10 shows, The SANDAG modeling system handles the interactions between UDM and the transportation model in a sequential manner. Within a given forecast period, the output from UDM directly influences the transportation system forecast for that same period, as shown by the arrow from the UDM box to the transportation model box. This transportation system forecast then influences the UDM allocation in the subsequent period, shown by the arrow leading from the transportation model at Time Period \( n \) to the UDM box at Time Period \( n+5 \) years.

UDM has three major components as illustrated in Figure 11. The first component allocates regional employment. The spatial distribution of employment is a key factor in determining the location of residential activity, which is done in the second component of UDM. The final component of UDM provides a forecast of other demographic and economic characteristics including occupied units, population, household income, and employment by industrial classification. UDM allocates to progressively smaller areas using a two-step allocation procedure. The first step allocates activities to 218 Zones for Urban Modeling (ZUM), which are generally groups of census tracts that conform to jurisdiction or community planning area boundaries. The second step allocates the ZUM forecast
to more than 800,000 parcel polygons, which are geographic areas based on assessor’s parcels. For simplicity, the parcel polygons will be referred to simply as “parcels” for the remainder of the document.

Figure 11
UDM Flow of Information

5.2 CIVILIAN EMPLOYMENT COMPONENT, ZUM FORECAST

The ZUM forecast of civilian employment relies on the basic algorithm of the EMPAL modeling system developed by S.H. Putman and Associates. SANDAG modified this algorithm to accommodate the specialized modeling requirements for the San Diego region.

UDM uses a modified version of a singly-constrained spatial interaction equation to determine the location of civilian employment. The modifications include a multivariate, multi-parametric attractiveness function; a lagged variable included outside the spatial interaction formulation; and a procedure that allows for ZUM-specific constraints. Civilian employment location is a function of the location of households (lagged five years); the distribution of existing and previously forecasted
employment; the opportunities for civilian employment development based on capacities (described in Chapter 3) and the travel time between ZUMs. UDM solves the equation in terms of the civilian employment share rather than directly as the number of jobs. The civilian employment share is the proportion of the region’s civilian employment forecast that locates in a particular ZUM. UDM includes an option to modify the forecast shares with additive adjustment factors (K-factors). K-factors allow the incorporation of calibration error directly into the forecast and provide a way to inform the model of any special cases of ZUM attractiveness or unattractiveness, such as restricting development in sensitive habitat areas.

UDM converts the civilian employment shares into a civilian employment number by multiplying the shares by the regional civilian employment forecast, adjusted for site-specific activities. Site-specific activities inform the model of the exact locations and sizes of known developments completed after 2004, the base year of the 2030 Regional Growth Forecast Update. UDM then creates the employment change in each ZUM by subtracting the base year employment from the employment forecast and applies any user-specified overrides. Unlike K-factors, which allow the equation to determine civilian employment location in response to the adjusted attractiveness in one or more ZUMs, overrides specify a value for the civilian employment change in a ZUM. In general, UDM responds to these overrides by adjusting the forecast in ZUMs without overrides to match the regional civilian employment forecast.

5.3 CIVILIAN EMPLOYMENT COMPONENT, SGRA FORECAST

UDM next allocates the ZUM civilian employment change to parcels based on their development priority, defined as accessibility to residential and civilian employment activities. This priority is a weight that measures the combined amount of housing and civilian employment activities within a one-half-mile of the parcel. A larger weight indicates a greater accessibility or a higher development priority of a parcel.

The UDM land use accounting for civilian employment is based on the type of development planned in a parcel. Development on employment infill land requires no land use accounting because these areas do not change land use. For vacant areas, UDM reduces the land use-specific vacant acres and increases the acres in the corresponding developed land use category. On redevelopment land, UDM reduces residential acres (e.g., developed single family) and increases acres in the specific developed civilian employment category (e.g., neighborhood shopping center). UDM determines the amount of acres shifted from the percent of the parcel capacity developed. If a parcel is completely developed, all of its vacant and redevelopment acres are converted to the new civilian employment land use(s). For a partially developed parcel, UDM computes the percent of its civilian employment capacity used and then applies that percent to the vacant or redevelopment acres to determine the number of acres changing use.

5.4 HOUSING STOCK COMPONENT, ZUM FORECAST

The housing stock (vacant plus occupied units) allocation module of UDM distributes single family stock, multifamily stock, and mobile homes. The single family and multifamily ZUM allocation is based on a singly-constrained spatial interaction gravity model formulation. The general equation used in UDM relies on the forecast employment, commuting probabilities and travel times, and the opportunities for residential development based on capacities developed in Chapter 3.
For each unit type, the ZUM allocation occurs first, followed by the parcel allocation. As illustrated in Figure 10, UDM first allocates multifamily stock, then single family stock, and finally mobile homes. It follows this structure-type order because multifamily development occurring on land converting from single family or mobile home use causes the demolition of single family stock and mobile homes. Similarly, single family development occurring on land converting from mobile home use causes the demolition of mobile homes. UDM first must determine lost units before allocating the regional forecast for any structure type. As with employment, user-supplied overrides can specify a structure type-specific housing stock value for any ZUM. In general, UDM responds to these overrides by adjusting the ZUM forecast without overrides to match the regional housing stock forecast.

Using the spatial interaction gravity models, UDM first determines the residential location of workers throughout the region, which is adjusted to conform to the regional forecast of workers living in the San Diego region. It repeats this allocation twice, once for workers living in single family homes and then for workers living in multifamily homes. These allocated workers are referred to as employed residents.

UDM then determines the housing units needed to house these employed residents using two ZUM-specific rates. UDM forecasts these rates using regional trends and other indicators including housing structure type. One rate, known as the employed residents per household rate, determines the number of households needed to accommodate the forecast of employed residents. The rate for each ZUM reflects characteristics that determine the typical number of workers in each house, such as local unemployment rates, multiple-worker households, labor force participation rates, age structure, and income. UDM applies the same rate to the single family and multifamily employed residents. These household forecasts are interim output and are finalized in the last component of UDM. ZUM-level vacancy rates, specific to each structure type, are applied to the households to determine the housing stock forecast for single and multifamily units. UDM controls these housing stock forecasts to their respective regional forecasts, which UDM adjusts for site-specific activity and units lost from redevelopment.

To facilitate the single family and multifamily housing stock allocations to parcels and a more accurate forecast of land consumption, UDM distributes the housing stock change to general land use categories. For multifamily these three categories are redevelopment (converting existing employment, single family, and mobile home uses), infill (intensifying existing multifamily use), and vacant. For single family, the four categories are redevelopment (converting existing mobile home use), infill (intensifying existing single family use), vacant low density (≤ 1 unit per acre), and vacant urban (> 1 unit per acre). For each structure type, UDM assigns the housing stock change into these categories based on their relative capacities in a ZUM.

UDM then allocates mobile homes to ZUMs. UDM forecasts mobile homes by factoring base year mobile homes to the regional forecast, both quantities adjusted for site-specific activities and for mobile homes lost to redevelopment activities. To complete the housing stock forecast for each structure type, UDM adds or subtracts the site-specific housing in a ZUM. Finally, the ZUM forecast of total housing stock is the sum of the forecasts for each structure type.
5.5 HOUSING STOCK COMPONENT, PARCEL FORECAST

UDM next allocates the ZUM housing stock change to parcels in the following manner. This general logic also is used to allocate civilian employment to parcels. UDM develops the parcels according to their accessibility order (development priority). UDM begins by allocating housing stock gains to the most accessible parcel with capacity, based on a comparison of the unallocated ZUM change and housing stock capacity in that parcel. If the housing stock capacity is used up in that parcel (i.e., it becomes fully developed) and unallocated ZUM housing stock change remains, UDM finds the next most accessible parcel with capacity and allocates to it. This process continues until UDM completely allocates the ZUM housing stock change (i.e., parcel capacity is greater than or equal to the unallocated ZUM housing stock change). UDM does this allocation process separately for single and multifamily housing stock and for their general land use categories in a ZUM. If UDM places new multifamily units on redevelopment land, it demolishes any single family housing stock or mobile homes. If UDM places new single family units on redevelopment land, it demolishes any mobile homes.

To complete the parcel housing stock forecast, UDM allocates the ZUM mobile home forecast. UDM forecasts mobile homes by factoring base year mobile homes in a parcel to the ZUM forecast, both quantities adjusted for site-specific activities and mobile homes lost to redevelopment activities. Finally, the parcel forecast of total housing stock is the sum of each structure type.

The UDM land use accounting for residential development also is based on the type of development planned in a parcel. Development on single or multifamily infill land requires no land use accounting because these areas do not change land use. For vacant areas, UDM reduces the land use-specific vacant acres and increases the acres in the corresponding developed land use category. On multifamily redevelopment land, UDM reduces single family or mobile homes acres and increases multifamily acres. On single family redevelopment land, UDM reduces mobile homes acres and increases single family acres. UDM determines the amount of acres shifted according the percent of the parcel’s capacity developed. If a parcel is completely developed, all of its vacant and redevelopment acres are converted to the new residential land use(s). For a partially developed parcel, UDM computes the percent of its residential capacity used and then applies that percent to the vacant or redevelopment acres to determine the number of acres changing use.

5.6 OTHER CHARACTERISTICS COMPONENT, ZUMs AND SGRAs

UDM uses the civilian employment and housing stock forecasts as inputs for the allocation of the other characteristics. Again, UDM does ZUMs first and then allocates the ZUM other characteristic forecasts to SGRAs. The other characteristics that UDM forecasts are occupied units by structure type (single family, multifamily, and mobile homes), household and group quarters population (e.g., population living in nursing homes, college dorms, prisons, or military barracks), employed residents, household income distribution, and civilian employment by industrial category. UDM produces ten household income categories, and fourteen civilian employment categories. It also provides a forecast of uniformed military employment. Changes in uniformed military employment are external to the model and are treated as site-specific activities.
5.6.1 Occupied Units by Structure Type

ZUM occupied units are computed by structure type and added together to get total occupied units, using the same procedure for each structure type. A structure type-specific vacancy rate forecast is applied to the housing stock forecast. This initial forecast of occupied units is adjusted to match the regional control using a single-factor raking procedure. A $\pm 1$ vector adjustment corrects rounding errors, insuring the occupied units do not exceed total units. This method adds or subtracts 1 from ZUMs in their numeric order until the regional control is satisfied.

SGRA occupied units are calculated by structure type and added together to get total occupied units. The process begins by multiplying the SGRA housing stock forecast by structure type-specific occupancy rates ($1 - \text{vacancy rate}$). The vacancy rate forecast is derived by adjusting the SGRA base year vacancy rate by the change in the ZUM rate. If there are 20 or fewer base year units, the ZUM vacancy rate forecast is used. UDM insures that the occupied unit allocation does not exceed the housing stock and does not violate the ZUM control. The ZUM control total is reduced as the MGRA occupied units are developed. If the ZUM control is not zero after all SGRAs are processed, a $\pm 1$ vector adjustment corrects the rounding error.

5.6.2 Household Population, Group Quarters, and Employed Residents

ZUM household population and employed residents are computed from the normalized occupied units forecast by multiplying them by the persons per household and employed residents per household forecasts respectively. The controlling process for these variables is the same used for the occupied units. UDM insures that at least one person lives in every household; that is, the household population forecast is greater than or equal to the occupied units forecast. UDM also forecasts both civilian and military group quarters. Changes to military group quarters are completely reflected in site-specific data that are exogenous to the model. The non-site-specific civilian group quarters change is developed in the same way as the mobile home housing stock change, using a raking procedure in combination with the $\pm 1$ vector adjustment. Total population is the sum of household population, civilian group quarters population, and military group quarters population.

The SGRA allocation of household population and employed residents per household uses logic similar to the process for deriving occupied units. UDM insures that every occupied unit has at least one resident and that the household population and employed resident allocations do not violate the ZUM control.

Civilian and military group quarters forecasts also are produced for the SGRAs. Military group quarters are forecast by adding site-specific group quarters to the base year military group quarters. The civilian group quarters are done in a similar fashion to the ZUM forecast: by factoring the SGRA base year civilian group quarters adjusted for site-specific activity to the forecasted ZUM change. The adjustment factor is produced by dividing the ZUM forecasted change adjusted for site-specific activities by the ZUM adjusted base year civilian group quarters population. This factoring process yields an initial value for the change in the SGRA civilian group quarters and the $\pm 1$ vector adjustment routine corrects rounding error. Total SGRA population is the sum of household population, civilian and military group quarters populations.
5.6.3  Income Distribution

ZUM household income distributions are computed by distributing household forecasts into an initial income distribution in one of three ways, depending on regional trends and user judgment: (1) the regional income distribution forecast; (2) the ZUM base year distribution; or (3) a modified lognormal curve. In most cases, the lognormal curve is used. Options 1 or 2 are used for ZUMs that exhibit aberrant income distributions that do not fit the lognormal curve well or had too few households in the base year to properly calibrate the lognormal curve.

Three ZUM-level parameters are needed to solve the modified lognormal curve: (1) median income, (2) standard deviation factor, and (3) calibration exponent. The latter two parameters are the inputs developed from an income distribution calibration. The median income forecast is the base year median adjusted for the change in the regional median. The modified lognormal curve determines the proportionate distribution of households across income categories. These proportions are adjusted by a calibration factor that keeps the forecast consistent with the base year distribution. A plus-minus 2-way iterative proportionate adjustment method controls the initial ZUM household income distributions to both the ZUM occupied units forecast and the regional income distribution forecast. This controlling method uses separate factors for adjusting gains and losses and a least-squares adjustment to achieve the 2-way convergence required.

The SGRA household income distribution forecast requires several passes through the SGRAs, treats losses and gains separately, and employs a cumulative probability distribution algorithm for determining the allocation. The technical description of this methodology is complex and beyond the scope of this report. A detailed description of this method is available in the formal documentation for UDM entitled, Series 11 Subregional Allocation, Technical Description Volume 2, SANDAG, February 2006.

5.6.4  Civilian Employment by Industrial Sector

UDM produces civilian employment forecasts for 14 sectors: agriculture and mining; construction; manufacturing; wholesale trade; retail trade; transportation and warehousing, and utilities; information; finance and real estate; professional and business services; education and health services; leisure and hospitality; other services; government; and self-employed and domestic workers.

Site-specific civilian employment is distributed into sectors for each ZUM by using the sector distribution that existed in the base year. The regional increment is then adjusted to account for the site-specific values. To complete the employment allocation, the non-site-specific ZUM change is distributed into the 14 civilian employment sectors. An initial distribution is computed and controlled, using the plus-minus iterative procedure, to the adjusted regional change and the ZUM total non site-specific civilian employment change. After controlling, the employment increment for each sector is obtained by summing the site-specific and non-site-specific changes.

Several conditions determine the initial distribution of the ZUM non-site-specific employment change into sectors. First, sectors with a regional decrement are distributed using the ZUM base year employment in that sector relative to the region’s base year employment in that sector. To maintain the proper ZUM control total, the ZUM change is increased by subtracting the allocated decrements from it. The distribution of the adjusted ZUM control into the remaining sectors depends on direction
of the ZUM control prior to the adjustment made for the allocation of regional decrements. If that control is negative, the ZUM base year employment distribution is used. If it is positive, a weighted average of the ZUM base distribution and regional change distribution is used. The weights are based on the size of the ZUM increment to its base year civilian employment. For a ZUM with little or no base year employment or an employment increment equal to or greater than its base year employment, this method in effect defaults to the regional distribution. The allocation to civilian employment sectors for a ZUM with a small increment relative to its base year employment is influenced primarily by its base year employment sector distribution.

The allocation of the ZUM non site-specific civilian employment sectors to the SGRAs also uses the same cumulative probability distribution algorithm used for the income distributions to SGRAs. When the allocation is completed, site-specific totals are added and the adjusted base represents the correct forecast of civilian employment by sector. To complete the MGRA employment forecast, the uniformed military is computed by adding the site-specific change to its base year value.

5.7  2030 REGIONAL GROWTH FORECAST UPDATE KEY ASSUMPTIONS

The fundamental assumptions that underlie UDM were discussed previously. Another main assumption of UDM is that the current land use plans and policies do not change over the forecast period.

The other assumptions of UDM include the calibrated values for employment and income equations and for determining commuting probabilities from place of work to place of residence. The employment equation calibration coefficients “match” the gravity model estimates for 2000 with observed data. In a similar fashion, calibration is used to determine the ZUM-level parameters for the lognormal equation used to forecast household distributions. The income distribution model was calibrated from Census 2000 income data. Commuting probabilities used in the residential allocation are represented by curves calibrated from the year 2004 highway and transit from work to home travel times.
CHAPTER 6: TRANSPORTATION MODELS

6.1 INTRODUCTION

Transportation models are designed to compute transportation system impacts such as traffic volumes, traffic speeds, and transit ridership for transportation network and policy alternatives given land use and demographic forecasts from the IRCM, UDM, and DEFM. SANDAG makes use of an advanced four-step transportation modeling process of trip generation, trip distribution, mode choice, and assignment to forecast travel activity in the San Diego region. Figure 12 illustrates how the four-step process is run in iterations or stages and combined with additional input and output functions to form the complete modeling chain.

TransCAD, created by Caliper Corporation, is a transportation planning computer package used by SANDAG to provide a framework for performing much of the computer processing involved with modeling. Another software package used extensively in the modeling process is ArcInfo, distributed by Environmental Systems Research Institute, Inc. This geographic information system (GIS) maintains, manipulates, and displays transportation, land use, and demographic data. SANDAG has written numerous FORTRAN and Visual Basic programs that provide linkages between TransCAD and ArcInfo. Other programs manipulate data and perform some modeling functions such as trip generation and mode choice.

SANDAG has extensive experience with both transportation modeling software and ArcInfo. SANDAG used TRANPLAN between 1981 and 2004 for a wide range of modeling applications, and then switched to TransCAD in 2004. ArcInfo first was installed at SANDAG in 1985. TRANPLAN and ArcInfo have been used in conjunction for transportation modeling since 1987.

The SANDAG transportation modeling and database maintenance is performed on a mix of Windows servers and individual personal computers. The time necessary to execute the entire transportation modeling process on these machines is about 16 hours, which is felt to be the maximum run time in order to provide reasonable turnaround on modeling projects. Turnaround time is important since SANDAG performs hundreds of model runs each year that range in scope from quantifying traffic impacts of individual development projects to evaluating system level impacts of alternative growth scenarios and transportation facilities for the Regional Transportation Plan (RTP). All of these modeling projects make use of the same basic procedures and data sets. The complexity of modeling procedures and the number of zones, time periods, iterations, modes and other factors determine model execution time. All of these factors have been evaluated so that the model functions within the 16-hour limit.
Figure 12
Transportation Modeling Process

Model Inputs
- Growth Forecasting
  - Dwelling Units
  - Land Use
  - Employment
- Highway Coding
  - Time/Distance/Cost (Highway Links)
- Transit Coding
  - Time/Distance/Fare (Transit Links/Routes)

First Stage
- Trip Generation
  - Person Trips Ends (MGRAT/TAZ/TDZ)
    (Detailed Purposes)
- Highway Skimming
  - Generalized Costs (TAZ to TAZ)
    (Generalized Purposes)
- Trip Distribution
  - Daily Person Trips (TAZ to TAZ)
    (Detailed Purposes)
- Vehicle Factoring
  - Highway Trips by Mode (TAZ to TAZ)
    (AM/PM/Off-Peak)
- Highway Assignment
  - Traffic Volumes (Highway Links)
    (AM/PM/Off-Peak)

Feedback Loop
- Highway Skimming
  - Times/Costs by Mode (TDZ to TDZ)
    (AM/PM/Off-Peak)
- Transit Skimming
  - Times/Fares by Mode (TAP to TAP)
    (Peak/Off-Peak)
- Utility Calculations
  - Daily Composite Utilities (TDZ to TDZ)
    (Generalized Purposes)
- Trip Distribution
- Vehicle Factoring
- Highway Assignment
- Emissions Modeling
  - Air Pollutant Emissions (ROG/CO/NOX)

Final Stage
- Highway Skimming
- Transit Skimming
- Mode Choice
- Highway Trips by Mode (TAZ to TAZ)
  (AM/PM/Off-Peak)
- Transit Trips by Mode (TAP to TAP)
  (Peak/Off-Peak)
- Highway Assignment
- Transit Assignment
  - Transit Volumes (Peak/Off-Peak)
    (Route/Link/Stop)
Before running the models in production, a considerable amount of time is spent calibrating model parameters and validating model accuracy. The purpose of calibration is to develop model relationships that can accurately reflect existing travel behavior, so there is confidence the models can be used to forecast future travel behavior. For example, the models correctly estimate current trolley ridership so they should be able to forecast future ridership on proposed trolley extensions and on new bus rapid transit service. Most recently the models were recalibrated to year 2004 conditions before use in the 2030 RTP. The next section of this chapter (Section 6.2) describes the survey data used in this calibration and validation process.

As indicated in Figure 12, the modeling process can be broken down into four phases. In the model input phase, growth forecast data files are assembled, and highway and transit networks are coded. Preparing inputs to the models is often the most time consuming part of a modeling project. Several sections of this chapter document the three major inputs for the rest of the modeling process:

- growth forecast inputs used to describe existing and planned land use patterns and demographic characteristics (Section 6.3)
- highway networks used to describe existing roadway facilities and planned improvements to the roadway system (Section 6.4)
- transit networks used to describe existing and planned public transit service (Section 6.5)

After preparing model inputs, there are four major steps of trip generation, trip distribution, mode choice, and assignment, along with a minor function of path-building and skimming. There is a section describing each of the modeling steps listed in the order that they are executed as follows:

- trip generation (Section 6.6)
- path-building and skimming (Section 6.7)
- trip distribution (Section 6.8)
- mode choice (Section 6.9)
- highway assignment (Section 6.10)
- transit assignment (Section 6.11)

One of the complexities of the modeling process is that transportation measures needed as input to a modeling step may not be produced until later in the modeling process. For this reason there are numerous iterations through the modeling process. As a starting point, the first-stage of the modeling process makes use of simplified trip distribution, mode choice, and highway assignment procedures to produce initial highway travel time forecasts for use in the subsequent feedback loop phase.

Processing may stop after the first stage for small scale modeling projects to reduce costs for outside clients without seriously compromising mode accuracy. However, regional planning studies proceed on to a feedback loop phase and a final stage of mode choice and assignment. These additional stages incorporate the effects of traffic congestion on destination choice and mode choice. For example, people in heavily congested corridors may choose shopping locations closer to home rather than contend with traffic delays. Conversely, widening a congested freeway may make fringe housing
more accessible and increase average commute trip lengths. This relationship between trip length and congestion is one aspect of induced travel.

The details of performing the trip distribution, mode choice, and assignment steps vary depending on which stage of the modeling process is being executed. These variations are described in the sections of the report dealing with each modeling step.

6.2 SURVEY INPUTS

The transportation models make use of survey data to establish relationships between input variables and model-estimated results. For example, trip generation rates are applied to dwelling units from the growth forecasting process to determine the number of trips generated from residential areas. Data collection is costly and time consuming, so surveys are conducted relatively infrequently. This normally does not create a problem since underlying model relationships are relatively stable over time.

The following eight surveys provide most of the calibration data for the transportation models.

- 1995 Travel Behavior Survey
- 2001 Caltrans Statewide Survey
- 2001-2003 San Diego Regional Transit Survey
- External Trip Surveys
- Traffic Generation Studies
- 1991 San Diego Visitor Survey
- 2000 Census Transportation Planning Package
- 2000 Market Research Survey

Additional data sources are used to verify model estimates with observed data. Major sources of validation data are traffic counts from Caltrans and local jurisdictions, transit passenger counts from the SANDAG Transit Passenger Counting Program, and SANDAG Vehicle Occupancy and Classification Study.

6.2.1 1995 Travel Behavior Survey

Every ten years SANDAG conducts an extensive travel behavior survey which serves as the primary source for model calibration data. Since the results of the most recent 2006 Travel Behavior Survey will be not be available until mid-2007, the 1995 Travel Behavior Survey is the basis for the existing models. In the 1995 survey, 2,050 San Diego households were interviewed. Survey respondents provided a complete listing of trips made on a survey data with information such as start and end location, start and end time, trip purpose, and trip mode. Information also was collected about household, household member, and household vehicle characteristics. Survey responses were expanded to regional totals and tabulated to develop the following calibration data.

- Trip generation rates for the trip generation model
Trip length frequency distributions for the trip distribution model
Non-transit mode use percentages for the mode choice model

6.2.2 2001 Caltrans Statewide Survey

In 2001 Caltrans conducted a statewide activity-based household travel survey which had a San Diego sample size of 1,200 households. Of these households, 104 also had vehicles instrumented with GPS recorders. The resulting GPS vehicle trip sample was extensively analyzed to develop underreporting correction factors. These GPS correction factors were applied to both the 1995 and 2001 Travel Survey results prior to model estimation.

6.2.3 2001-2003 Regional Transit Survey

Every five years SANDAG, in cooperation with transit operators, conducts an on-board transit survey to obtain transit trip and transit user characteristics. The most recent survey, conducted between 2001 and 2003, provides data used to calibrate the transit portion of the mode choice model.

In the transit survey, surveyors stationed on-board buses, trolleys, and the COASTER distributed questionnaires to passengers over 12 years of age as they boarded the vehicle. Passengers filled out forms while they completed their trip and dropped off forms as they got off vehicles. About 50,000 surveys were returned with useable information, which were tabulated to obtain the following calibration and validation data:

- Transit trip shares by income level, trip purpose, and trip length for mode choice calibration
- Park-and-ride locations for coding transit network park-and-ride nodes
- Walk access distance distribution to set maximum walk access distances
- External transit trip table for external trip modeling
- Relationship of total boardings to linked trips for transit assignment validation
- Access mode percentages for transit assignment validation
- Zone-to-route trips for transit network validation
- Zone-to-zone trip tables for transit network calibration

6.2.4 External Trip Surveys

Roadside interview surveys are conducted periodically to determine the travel characteristics of trips coming into or passing through the San Diego region from outside the region. These surveys are difficult to collect since motorists must be stopped as they are entering or leaving the region and asked a series of questions about trip characteristics. Surveys conducted between 1986 and 1999 are used to obtain the following parameters:

- trip purpose distributions for the trip generation model
- external trip lengths for the trip distribution model
- through trips which are added to internal and internal-external trips
The 2006 Travel Behavior Survey contains an inter-regional component that will replace some of the older external survey data when it becomes available.

6.2.5  Traffic Generator Studies

These studies are conducted periodically to collect site level traffic data. The last major study, completed in 1999, placed traffic counters and video cameras at all entrances and exits to 26 survey sites, which included shopping centers, offices, schools, and housing developments. Traffic counts were totaled and averaged over five days to obtain average weekday trip generation totals for the sites. Trips rates then were calculated based on site characteristics such as number of employees, acres, and dwelling units. Travel behavior survey trip rates for nonresidential uses were adjusted to agree with traffic generator trip rates to correct for under-reporting of trips in travel behavior surveys.

6.2.6  1991 Visitor Survey

San Diego is a major convention and vacation destination. A small-scale visitor survey was conducted during the months of July, August and September 1991 to obtain a more complete picture of visitor travel patterns. Surveyors stationed outside selected hotels and tourist attractions questioned passers-by about their trips made on the previous day. Visitor trip generation rates and visitor trip lengths for gravity model calibration were obtained from this survey.

6.2.7  Census 2000 Transportation Planning Package

Since 1960, the decennial census “long form” has included a series of transportation related questions about work trips, including travel time, travel mode, and employment location. The Census 2000 Transportation Planning Package (CTPP) data had limited usefulness for model calibration due to Census Bureau data suppression procedures for protecting confidentiality. The American Community Survey (ACS) is a continuous survey process that is replacing the long form. ACS results will be available more frequently although suppression issues are expected to continue.

6.2.8  2000 Market Research Survey

In 2000 the Metropolitan Transit Development Board conducted a stated preference survey of 858 San Diego households to identify traveler attitudes towards new forms of public transit by market segments. The resulting datasets were used to estimate mode choice model parameters for comparison with models estimated from traditional revealed preference travel surveys.

6.2.9  Traffic Counts

Traffic counts, used in model validation, are obtained from a variety of different sources. Caltrans has about 50 permanent freeway traffic locations that are used to provide average weekday traffic counts by hour and direction. Caltrans has another program called PeMS (Performance Monitoring System) that provides counts at another 190 directional freeway locations where freeway ramp meters exist. Counts at additional locations will be available as the ramp metering system is expanded. PeMS outputs more detailed counts by five minute intervals and also outputs speed estimates which can be compared with model-estimated speeds. A third Caltrans program counts freeway on and off-ramps on a three-year cycle.
The City and County of San Diego and some of the other cities conduct comprehensive traffic count programs and maintain computerized count files. SANDAG converts traffic count stations into an ArcInfo point coverage and subsequently matches counts to network links. SANDAG also collects counts to produce a biennial Traffic Flow Map. Counts from this program are used for cities without computerized count files.

### 6.2.10 Transit Passenger Counts

SANDAG has operated a Passenger Counting Program since 1979, within which every bus route is counted once a year. Trips are counted by stationing surveyors on-board transit vehicles. Surveyors record the number of passengers boarding and alighting at each transit stop. The number of passengers onboard vehicles between stops is computed from the boarding and alighting data. Surveyors also record arrival and departure times at selected time points along a route. An up-to-date transit route and stop inventory is maintained as part of the Passenger Counting Program. Screenlines (imaginary lines that run across multiple transit paths) can be created to look at passenger flows through a corridor. Summing the number of passengers on-board each route that crosses a screenline yields the total screenline count. This helps equalize factors, such as changes in frequency or route path to look at corridor passenger flows over time.

Bus stop inventories from the Passenger Counting Program provide bus stop locations for transit network coding. The Passenger Counting Program also produces the following validation data for checking the accuracy of transit assignment estimates.

- Ons and offs at stops
- Screenline counts
- Boardings by route and mode
- Transit link passenger volumes

### 6.2.11 2006 Vehicle Occupancy and Classification Study

SANDAG and Caltrans station surveyors at 22 freeway locations to monitor trends in vehicle occupancy and vehicle classification. These counts are taken every five years. Vehicle occupancies from the most recent 2006 study were used to verify mode choice model estimates and vehicle classifications were input to air pollution emission modeling.

### 6.3 GROWTH FORECAST INPUTS

The number and location of people living and working in the San Diego region largely determine the amount of travel activity that occurs. The previous chapter described how population, employment, and land use forecasts are produced at the SANDAG smallest unit of geography, the over 800,000 parcel polygons.

Parcel polygons provide flexibility for designing zone boundaries, however, the current generation of transportation models is unable to efficiently use parcel level forecasts. Therefore, the parcel forecasts are aggregated to three different levels of a nested zone system that has been designed to maximize model accuracy while minimizing execution time. There are approximately 33,000 non-motorized zones (NMZ) that are the smallest unit of geography used by the transportation models. This
detailed zone system enables the models to accurately compute the amount of activity within walking
distance for input to the mode choice model. The highway assignment model makes use of a
4,605 traffic assignment zone system (TAZ) to obtain link level traffic volumes. Finally, a 2,000 trip
distribution zone system (TDZ) is used within the feedback loop process to determine trip flows
between zones.

TAZs range in size from individual blocks in Centre City San Diego up to 100,000 acres in sparsely
developed rural areas. SANDAG uses a relatively large number of TAZs to reduce the need for
developing sub-zones to address local planning needs. TAZ boundaries attempt to group areas with
similar land uses and access to the transportation system.

The zone systems include 12 external zones located where major roads cross the county line. These
external zones are used to represent travel between the San Diego region and other areas, such as
Riverside County, Orange County, and Mexico.

Most studies use regional growth forecasts directly, however the purpose of some studies is to
evaluate impacts on the transportation system of proposed land use changes. For example,
Environmental Impact Reports may identify traffic volumes on roadways in the vicinity of
proposed development projects with and without the proposed project. Cities may use the models
to evaluate traffic impacts of proposed General Plan changes. Recently there has been increasing
interest in smart growth development and SANDAG has evaluated regional land use alternatives
that implement smart growth principles to varying degrees. These land use studies modify the
SANDAG standard forecasts within the study area to reflect the proposed changes.

6.4  HIGHWAY NETWORK INPUTS

At many points in the modeling process a computerized representation of the highway system is
needed for obtaining inputs to the models. SANDAG uses GIS software to maintain highway
information in an ArcInfo master transportation coverage. Coverage is an ArcInfo term used to
describe all the individual files which together represent a geographic system in digital form. This
network coverage includes existing and planned freeways, toll lanes, HOV lanes, managed lanes,
ramps, surface streets classified on general plan circulation elements, and some local roads needed
for network connectivity. The network coverage also includes zone connector links, which are used
to schematically represent how traffic from zones accesses the street system.

The SANDAG master network files reflect facility improvements proposed in the most recent RTP
and General Plan circulation elements from each jurisdiction in the region. The purpose of many
planning studies is to look at the impacts of alternative highway improvements. Once these
planning studies are completed, recommended facility changes are coded into the master network.
At a more local level, the models are often used to evaluate traffic volume impacts of subdivision
plans that fine-tune standard highway assumptions.

6.4.1  Highway Facilities

Alignments for existing roads were originally obtained from SanGIS (another agency responsible for
maintaining various geographic databases) and have been updated extensively based on high
resolution digital aerial photography. Alignments for planned roads are derived from a number of
different sources including Caltrans route location studies, local general plan circulation elements,
environmental impact reports, and corridor studies.
ArcInfo automatically creates nodes at at-grade intersections. Coders insert additional nodes where traffic signals, stop signs, and ramp meters occur in between street intersections. The ArcInfo dynamic segmentation function also is used to code routes that indicate where turns are prohibited by physical barriers or signs.

6.4.2 Highway Attributes

Once highway alignments have been determined a large number of attributes are coded about each highway segment and node. A number of attributes are informational, such as street name, node numbers, link ID numbers, and functional classification. Other attributes, used to calculate travel time, include segment length (computed by ArcInfo from highway alignments), posted speed, one/two-way operation, and type of intersection control. Another set of attributes used to calculate capacity includes number of lanes, median condition, number of freeway auxiliary lanes, type of operation (mixed flow or high occupancy vehicle only), type of intersection control, and the number of through, left turn, and right turn lanes at intersection approaches. The phasing of new roads, improvements to existing roads, and in some cases the deletion of existing roads is identified using another set of attributes. Finally, additional attributes provide cross-references to traffic count files that are used for model calibration.

Many base year physical attributes can be obtained from high resolution digital photography. These include one/two way operation, location and type of intersection controls, median condition, and the number of main lanes, auxiliary lanes and through, right turn, and left turn intersection approach lanes. Planned highway improvements are obtained from local circulation elements, Regional Transportation Improvement Programs, local Capital Improvement Programs, and long range Regional Transportation Plans.

6.4.3 Highway Capacities

Highway network coverages for specific model years and alternatives are selected from the master transportation coverage. Computer programs convert these ArcInfo coverages to TransCAD highway networks by reformatting data items and computing additional attributes needed in the modeling process, such as capacities, travel times, distances, and costs from attributes coded on coverages.

Two capacities are calculated for each direction of a highway link: (1) intersection capacity which is the amount of traffic that can be accommodated by an intersection approach at the end of a link, and (2) mid-link capacity which is the amount of traffic a link could accommodate without intersection controls. Both intersection approach and mid-link capacities are computed on an hourly basis and then factored to A.M. peak period, P.M. peak period, and off-peak period capacities using hourly to time period expansion factors of 2.25, 2.85, and 11.1, respectively. These expansion factors are overridden with location specific expansion factors on freeways where hourly traffic counts are available.

Mid-link Capacity

Mid-link capacity calculations vary for four different types of facilities: freeways, freeway HOV/managed lanes, urban streets, and rural highways. Hourly directional freeway capacities are calculated using the equation below which multiplies the number of main lanes by a per lane carrying capacity supplied by Caltrans that varies between 1,900 and 2,100 vehicles per hour per lane. Auxiliary lane capacity, assumed to be 1,200 vehicles per hour per lane, is added to main lane
capacity. A capacity increase of 10 percent is phased in between 2010 and 2030 on freeway segments that are currently not metered, but are slated for ramp metering in the future.

\[ fwyc = (ml \times mlc + al \times 1200) \times (1.0 \rightarrow 1.1) \]

where:
fwyc = hourly directional freeway capacity (vehicles per hour) for link
ml = number of mixed-flow main lanes on link
mlc = capacity per lane for link (vehicles per hour per lane)
al = number of auxiliary lanes on link

It is assumed that single occupancy vehicle (SOV) usage of managed lanes will be controlled to keep speeds from falling below level-of-service “D” or 1,600 vehicles per lane. The number of lanes on managed lane facilities also can vary by time period, such as the existing Interstate 15 (I-15)HOV lanes which operate as two lanes southbound in the morning and two lanes northbound in the afternoon.

\[ hovc(tm) = hl(tm) \times 1600 \]

where:
hovc = hourly directional HOV capacity (vehicles per hour) for link in time period “tm”
hl = number of HOV lanes on link in time period “tm”

Mid-link capacities for urban street segments are calculated using the equation below. Two-lane rural highways typically can accommodate much less traffic and a lower capacity of 950 vehicles per hour per direction is assumed for these facilities.

\[ urbc = ln \times 1800 - 300 - 200 \times (m < 2) \]

where:
urbc = urban street mid-link capacity for link
ln = number of mid-block lanes on link
m = median code (0 or 1 indicates no median)

**Intersection Approach Capacity**

Because the most significant traffic congestion on urban streets often occurs at traffic signals, procedures have been developed to represent individual signal approach capacity within the model using the following equation.

\[ xc = (tl \times 1800 \times gc(fc,xfc,napp) + (rl + ll) \times tlc(fc)) \times 1.0 \rightarrow 1.1 \]

where:
xc = intersection approach capacity for link
tl = number of through lanes at intersection approach
gc = green-to-cycle time ratio
fc = functional classification of street
xfc = functional classification of cross street
napp = number of intersection approaches
rl = number of right turn lanes at intersection approach
ll = number of left turn lanes at intersection approach
tlc = per lane turn lane capacity that varies by functional classification
While actual signalized operation is very complex, this equation captures the primary factors that
determine capacity. A through lane capacity of 1,800 is multiplied by the number of approach lanes
that have been coded. The green-to-cycle time (GC) ratio is a traffic engineering term that quantifies
the fraction of total cycle time that is in the green phase for each intersection approach. Within the
model, GC ratios vary between 0.09 and 0.84 depending on the functional classification of intersecting
streets and number of approaches. For example, a prime arterial that intersects with another prime
arterial would have a lower capacity than one with the same approach lane configuration that
intersects with a local street. Similarly, two and three legged intersections have higher capacities than
four legged intersections because total cycle time is apportioned to fewer phases.

A turn lane capacity that varies between 100 and 250 vehicles per lane per hour depending on the
functional classification of the street is multiplied by the number of coded right and left turn lanes
and added to through lane capacity. Finally, future capacity increases of up to 10 percent are
phased in on regionally significant arterials as a result of improved signal coordination assumed in
the 2030 RTP.

A ramp meter is a special type of signal that controls the number of vehicles that can get on a
freeway during peak periods. Metering rates are determined by Caltrans and vary from ramp to
ramp depending on the location of the ramp and the severity of up-stream freeway congestion. An
average capacity of 1,000 vehicles per ramp meter is assumed unless location specific metering rates
are available.

Stop signs also impose significant reductions in the capacity of surface streets. The model computes
capacities of two-way and all-way stop-sign controlled approaches using equations similar to the
signalized intersection equation shown above. In a few locations capacities are affected by toll
booths and rail crossings where special capacity calculations are made.

Intersection capacity considerations are turned off for freeways and other links that have no
intersection controls by setting the capacity to a maximum value.

6.4.4 Highway Travel Times

As with capacities, separate link times and intersection times are computed for each highway
segment. Highway link travel times are computed using the following equation:

\[ tt(tm) = \frac{lg}{s} \]

where:

\( tt(tm) \) = travel time each link and time period (A.M. peak period, P.M. peak period, and off-peak)
\( lg \) = length on link
\( s \) = posted or adjusted speed on link

Travel times represent the free-flow link time (ArcInfo computed link length divided by the posted
speed). During the calibration process posted speeds may be varied by up to plus or minus 10 miles
per hour to better match model estimated traffic volumes with traffic counts. Adjusted speeds
replace posted speeds where coded.

Intersection times represent the delay time encountered at traffic signals and other intersection
controls under uncongested conditions. An intersection delay time of 10 seconds per signal or stop
sign accounts for idling time, acceleration/deceleration time, and the likelihood of being stopped at
a signal. Baseline ramp meter times of one minute are assumed for peak period networks. Ramp meters are assumed to be turned off during off-peak hours and so no off-peak ramp meter delays are added.

These input link and intersection travel times reflect free-flow conditions without congestion. Individual link and intersection congestion delays are computed later in the highway assignment step based on forecasted, link-specific traffic volumes.

6.5  TRANSIT NETWORK INPUTS

Transit modeling requires coded transit networks that represent existing and planned conditions. Like highway networks, transit networks are maintained in the master transportation coverage using ArcInfo. However, transit network coding is more complicated than highway coding because of the need to describe how individual transit routes operate over the transit system. Also added is the concept of transit modes which group transit routes with similar operating characteristics.

Table 12 describes how routes under each of these operators are assigned to seven transit modes. Regional and corridor bus rapid transit (BRT) modes represent a new type of transit service proposed in the 2030 RTP. BRT service would have stations similar to commuter rail and trolleys, and operating characteristics midway between rail and bus service. BRT service would be provided by advanced design buses operating on HOV lanes, grade-separated transit ways, and surface streets with priority transit treatments.

Table 12
Transit Mode Definitions

<table>
<thead>
<tr>
<th>Mode Number</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Commuter Rail</td>
<td>COASTER</td>
</tr>
<tr>
<td>5</td>
<td>Trolley/Light Rail</td>
<td>SDTI Orange/Blue Lines</td>
</tr>
<tr>
<td>6</td>
<td>Regional (Yellow Car) BRT</td>
<td>None (Proposed)</td>
</tr>
<tr>
<td>7</td>
<td>Corridor (Red Car) BRT</td>
<td>None (Proposed)</td>
</tr>
<tr>
<td>8</td>
<td>Commuter Express Bus</td>
<td>CTS Routes 810,820,830</td>
</tr>
<tr>
<td>9</td>
<td>Express Bus</td>
<td>SDTC Routes 20,30,50</td>
</tr>
<tr>
<td>10</td>
<td>Local Bus</td>
<td>SDTC Routes 1-9</td>
</tr>
</tbody>
</table>

6.5.1  Transit Facilities

Most transit routes run over the same streets, freeways, HOV lanes and ramps used in the highway networks. As a result the only additional facilities that are added to the transportation coverage for transit modeling purposes are:

- trolley and commuter rail lines,
- streets used by buses that are not part of local general plan circulation elements,
- transit ways that have been proposed as part of the 2030 RTP.
Nodes are located at each transit stop. The ArcInfo dynamic segmentation feature is used to maintain historical, existing, and planned transit routes. Existing routes and stops are modified up to several times a year as new time tables are published. A transit scheduling system (HASTUS) provides accurate existing bus transit stop information. Near term transit route changes are drawn from short-range plans produced by transit agencies. Longer range improvements are proposed as a part of the 2030 RTP and other transit corridor studies.

6.5.2 Transit Attributes

Transit node attributes describe stop type and park-and-ride availability at each node. Most transit network attributes are associated with routes. These attributes include transit operator, mode, and most importantly, frequency of service by time period (A.M. peak period, P.M. peak period, mid day, and night). Initial wait time and transfer time are significant factors that affect transit use and are computed from service frequencies. Existing frequencies are calculated based on published time schedules. Planned service frequencies may be policy based, such as establishing a minimum 15-minute frequency. Alternatively, future frequencies may be computed using vehicle capacity assumptions and forecasted ridership from previous model runs. For example, passenger demand may indicate that a 10-minute frequency is needed on some routes to avoid bus overcrowding.

6.5.3 Travel Times

Transit networks for different years and alternatives are selected from the master transportation coverage. Transit travel times on links between rail stations and bus stops are computed at this time. The following equation is used to determine bus speeds.

\[ bt(tm) = ht(tm) + bs \times dt(m) \]

where:
- \( bt \) = bus travel time on link during time period “tm”
- \( ht \) = congested highway travel time
- \( bs \) = number of bus stops on link
- \( dt \) = per stop delay time by mode “m”

Bus travel times are assumed to be a function of the number of bus stops on a link and highway travel time. Since highway times include congestion effects from the highway assignment step (Section 6.10), bus travel times are recomputed at different stages of the modeling process. Highway travel times are modified for the following special conditions before computing bus times:

- Freeway HOV lane speeds are assumed to be no lower than a level-of-service “D” speed of 62 miles per hour (MPH).
- Ramp meter delays at meters with HOV bypass ramps are assumed to be one-third of SOV times.
- The maximum legal speed limit is used for the free-flow bus speed on freeways, where as highway free-flow freeway speeds are set at five MPH above the speed limit to reflect observed speeds from survey data.
- Bus speeds of 35 MPH are assumed on selected freeways that allow buses to run on shoulder lanes when speeds on adjacent general lanes fall below 35 MPH.
Travel times on arterial streets used by BRTs are reduced by 10 percent to reflect the effects of bus priority treatments.

Stop delay times of 40 seconds, 30 seconds, and 18 seconds per stop are assumed for BRT, express bus, and local bus service, respectively. Express and local bus stop delays were calculated from observed data and include the effects of acceleration/deceleration, dwell time for boarding passengers, and likelihood of stopping at an individual stop. Longer delay times are assumed for BRT service since fixed stop operation is proposed for these routes.

Travel time procedures for rail service differ from the bus procedures described above. Most COASTER and trolley routes already exist, so speeds are obtained from published time schedules. Since rail service is normally not affected by highway congestion, base year station-to-station travel times are assumed to remain unchanged over the forecast period. The travel time effects of a proposed COASTER tunnel and several additional COASTER and trolley stops are obtained from outside studies.

Travel times for proposed trolley extensions are computed based on an assumed peak operating speed, a station dwell time of 20 seconds, and acceleration/deceleration times that vary according to station spacing and peak speed.

### 6.5.4 Fares

In addition to transit travel times, transit fares are required as input to the mode choice model. TransCAD procedures have been augmented to replicate the San Diego region’s complicated fare policies which differ among:

- buses which collect a flat fare of between $1.00 and $4.00 depending on the type of service,
- trolleys which charge a variable fare of between $1.25 and $3.00 depending on how many stations are traversed, and
- commuter rail which has a zone-based fare of between $4.00 and $5.50.

When transfers occur, the overall fare for the trip is set to the highest fare encountered. These fares represent cash fares and are factored later in the mode choice model to account for pass usage based on an analysis of survey data. Fares are assumed to remain constant in real dollars over the forecast period.

### 6.5.5 Transit Walk Access

Accurately specifying transit access opportunities is an important part of the transit forecasting process. A series of programs generates access files based on ArcInfo transit networks, trip generation forecasts by NMZ, elevation grids, and walk barriers. First, transit stops within walking distance of each NMZ are determined using the following formula.

\[
d(nmz, s) = \sqrt{(x_{nmz} - xs)^2 + (y_{nmz} - ys)^2} \times wfac(nmz) + abs(z_{nmz} - zs) \times 3
\]

where:
- \(d\) = distance between NMZ and stop “s”
- \(x_{nmz}\) = x coordinate of NMZ centroid
- \(y_{nmz}\) = y coordinate of NMZ centroid
- \(z_{nmz}\) = elevation of NMZ centroid

68
\( \text{wfac} = \text{walkability factor (1.1 or 1.5)} \)
\( \text{xs} = \text{x coordinate of transit stop} \)
\( \text{ys} = \text{y coordinate of transit stop} \)
\( \text{zs} = \text{elevation of stop} \)

Straight line distances are computed between each NMZ centroid and transit stop. The region has been broken down into two area types: traditional neighborhoods with grid pattern streets; and suburban neighborhoods with curvilinear street patterns. Walkability factors of 1.1 for traditional neighborhoods and 1.5 for suburban areas are applied to straight line distances so that walk distances better approximate real world conditions. Elevation differences between NMZ centroids and stops are added to horizontal distances after weighting differences by a factor of three to account for the additional difficulty of walking uphill. A maximum walk distance of three-quarter mile is assumed. NMZ-stop connections with a distance greater than the maximum walk distance are discarded as are connections that cross walk barriers. A walk barrier coverage has been developed that contains features such as ridge lines, steep slopes, water body boundaries, freeways, and fenced property lines that could block walk access.

All rail stations and BRT stops, and selected local and express bus stops are designated as transit access points (TAP) for use in transit modeling. TAPs are located approximately every one-half mile along a bus route. The mode choice model uses a walk access file of NMZ-TAP connections that are obtained by generalizing NMZ-transit stop connections found in the previous step.

Access opportunities within Centre City are too complicated to represent with these procedures. Instead, the closest TAP to each Centre City zone is identified. A Centre City walk network is coded that allows access to other TAPs in Centre City without explicitly coding each NMZ-to-TAP connection.

### 6.5.6 Transit Auto Access

Many transit users, who are outside walking distance of transit or have inconvenient feeder bus service, drive to park-and-ride lots or are dropped-off at transit stops. A transit auto access file is generated that represents these drive to transit opportunities.

Transit ridership survey results were analyzed to identify transit stops with significant auto access activity. The vast majority of auto access trips go to formal park-and-ride lots at rail stations and other bus transit centers. Trolley stations without parking lots also have significant auto access usage since passengers can be dropped off or possibly park on-street. The remaining auto access trips occur at shopping center and church lots adjacent to bus routes where informal park-and-ride usage can occur.

Formal park-and-ride lots, trolley stations without parking lots, and other informal lot locations are coded in an ArcInfo coverage. The parking space capacity of formal park-and-ride lots is coded, while a maximum of 25 spaces is assumed at other auto access locations. The mode choice model is able to capacity constrain auto access trips to produce more realistic ridership forecasts.

Within the modeling process, a computer program creates connections between TDZs and auto access locations, and calculates the peak period highway travel time and distance from the first stage highway assignment process. Rather than connecting all zones to all auto access locations, the following logic is used to limit the number of auto access connections to only those that are reasonable.
For each TDZ the program first analyzes formal park-and-ride lots along each commuter rail, light rail, BRT, and express bus transit route by direction. Auto access connections are created for the closest two upstream and downstream park-and-ride lots within a maximum eight mile drive distance.

For each TDZ the program next creates connections to the closest informal lot along each directional transit route that is within a maximum drive distance of two miles for local bus routes or four miles for commuter rail, light rail, BRT and express bus routes.

TDZs are connected to the closest formal park-and-ride lot when no other connections have been found.

The mode choice model treats trips that drive to transit and trips that are dropped off as two different modes. However, transit survey results did not show significant differences in the locations where these two types of transit access trips occur. Therefore a single auto access file is used to represent connections for both transit auto access modes.

6.6 TRIP GENERATION

The purpose of trip generation is to estimate the number of trips entering and leaving each zone on an average weekday for each forecast year. These trip end forecasts reflect new development, redevelopment, demographic, and economic changes that occur over time, using the inputs shown in Table 13.

The model computes person trips, which account for trips by all forms of transportation including automobiles, trucks, taxicabs, motorcycles, public transit, bicycling, and walking. Trips are generated for ten trip types: home-work, home-college, home-school, home-shop, home-other, work-other, other-other, serve passenger, visitor, and regional airport. These trip types are designed to group together trips with similar travel patterns. Trips are generated for each parcel polygon from the growth forecast model and then aggregated into the three zone systems used in the transportation models: non-motorized zones (NMZ), traffic assignment zones (TAZ), and trip distribution zones (TDZ). Table 14 illustrates the output from the trip generation model.

Each trip has two trip ends and the trip generation model calculates trip ends separately. One end is classified as a trip production and the other end as a trip attraction. The home end of home-based trips is defined as the production end and the other end is defined as the attraction end. The work end of work-other trips is defined as the production end and the other end as the attraction end. Other-other trip ends are split evenly into trip productions and trip attractions. Over a 24-hour period, roughly the same number of trips will originate in a zone as are destined there. However, residential zones will generate primarily trip productions while nonresidential zones will generate primarily trip attractions. The production/attraction distinction is important for the trip distribution model discussed in the next chapter.
Table 13  
Trip Generation Model Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwelling units by structure type</td>
<td>UDM</td>
</tr>
<tr>
<td>Population by age category</td>
<td>UDM</td>
</tr>
<tr>
<td>Land use acres by land use type</td>
<td>UDM</td>
</tr>
<tr>
<td>Employment by land use type</td>
<td>UDM</td>
</tr>
<tr>
<td>Unique generator trips</td>
<td>Traffic counts</td>
</tr>
<tr>
<td>External trips</td>
<td>Traffic counts, IRCM</td>
</tr>
<tr>
<td>Trip rates</td>
<td>Travel behavior surveys, Traffic generator studies</td>
</tr>
<tr>
<td>Regional control variables</td>
<td>DEFM, other studies</td>
</tr>
</tbody>
</table>

Table 14  
Trip Generation Model Output

<table>
<thead>
<tr>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person trip productions and attractions by zone and trip purpose</td>
</tr>
<tr>
<td>Income distribution of trip productions</td>
</tr>
<tr>
<td>Highway terminal times</td>
</tr>
<tr>
<td>Trip generation reports</td>
</tr>
</tbody>
</table>

6.6.1 Model Structure

Trips from residential areas are calculated by applying trip rates to the number of dwelling units in each parcel polygon categorized by three structure types: single family, multifamily, and mobile home. Total trips are split into productions and attractions by trip type and then balanced to regional control totals. The residential trip generation equation for non-school purposes has the following form.

\[ tp(zone, pu) = du(zone, st) \times rate(st) \times pf(st) \times ppuf(st, pu) \times pbfac(pu, pu) \]

\[ ta(zone, pu) = du(zone, st) \times rate(st) \times af(st) \times apuf(st, pu) \times abfac(pu, pu) \]

where:
- \( tp(zone, pu) \) = number of person trip productions in zone for each purpose
- \( du(zone, st) \) = number of dwelling units in zone by structure type
- \( rate(st) \) = person trip rate for structure type
- \( pf(st) \) = fraction of trip ends that are trip productions by structure type
- \( ppuf(st, pu) \) = fraction of trip productions in each purpose by structure type
- \( pbfac(pu, pu) \) = trip production balancing factor for each purpose
- \( ta(zone, pu) \) = number of person trip attractions
- \( af(st) \) = fraction of trip ends that are trip attractions by structure type
- \( apuf(st, pu) \) = fraction of trip attractions in each purpose by structure type
abfac(pu) = trip attraction balancing factor for each purpose.

Special procedures have been developed to estimate home-based university and home-based school trip productions that are largely generated by school age population subgroups.

\[ tp(z, pu) = pop(z, age) \times rate(age, pu) \times abfac(pu) \]

where:
- \( tp(z, pu) \) = number of person trip productions in zone for each purpose
- \( pop(z, age) \) = zone population by five year age category
- \( rate(age, pu) \) = person trip rate by age category and purpose
- \( abfac(pu) \) = trip production balancing factor for each purpose

Nonresidential trip rates are usually computed as trips per acre by 80 different land use categories. The form of the nonresidential trip generation equation is similar to the residential equation.

\[ tp(z, pu) = lu(z, lt) \times rate(lt) \times pf(lt) \times ppuf(lt, pu) \times abfac(pu, a) \]

where:
- \( lu \) = land use acres
- \( lt \) = land use type

Employee-based nonresidential trip rates have also been calibrated for the 80 land use categories. Employee rates yield the same number of regional trips as acres rates, although they produce a different pattern of trip making across the region. Employee-based trip rates are used for home-work trips to better match CTPP data. In addition, Centre City San Diego uses employee-based rates for all purposes. Centre City densities are much higher than regional averages so that acre-based rates underestimate travel. Centre City also has a greater potential for growth than is indicated by land use redesignations that determine acre-based trips.

Most model applications use the acre measure of nonresidential activity elsewhere in the region since acre-based forecasts are easier to understand, are subject to less uncertainty than employment forecasts, and produce traffic volumes that better match ground counts. Building square footage is expected to be added to future growth forecasts which should overcome problems with both the acre-based and employee-based procedures.

Trips from elementary schools, junior high schools, senior high schools, and golf courses are generated on a per site basis rather than the acre-based methodology described above. Trips from external zones are based on traffic counts on roads crossing the county boundary. These base year trips are factored to future years using output from the Interregional Commuting Model and trends in past traffic counts.

Trip ends calculated by these equations are superseded for a small number of NMZs that contain unique generators. Unique generators are major traffic generators where traffic counts indicate that applying standard trip rates would misrepresent actual trip making. Unique generators include all military bases, major tourist attractions, major beaches, Indian casinos, the University of California San Diego (UCSD), San Diego State University (SDSU), and Lindbergh Field.
Future year person trips are reduced by a small amount to reflect increased use of tele-working and e-commerce. Reduction factors of between three and five percent are applied to selected trip purposes and land use categories. The assumption is that some land use types such as office uses would be more likely to take advantage of tele-working than other uses such as hospitals.

By definition total trip productions must equal trip attractions at the regional level. However, imbalances between the two trip ends can occur since productions are estimated independently from trip attractions. Residential trip generation equations at the zone level also are relatively straightforward and ignore demographic trends such as the aging of the population over time. To overcome these problems, zone level trip productions and attractions are totaled for the region and balancing factors are calculated to match regional control totals for each trip purpose and forecast year.

Regional control totals are obtained by factoring base year trip totals by changes in logically related demographic, economic, and trip variables produced by DEFM and other models. These variables are listed in Table 15.

<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home-work</td>
<td>Total employment</td>
</tr>
<tr>
<td>Home-college</td>
<td>Trip productions</td>
</tr>
<tr>
<td>Home-school</td>
<td>Trip productions</td>
</tr>
<tr>
<td>Home-shop</td>
<td>Retail sales</td>
</tr>
<tr>
<td>Home-other</td>
<td>Service sector output</td>
</tr>
<tr>
<td>Work-other</td>
<td>Total employment</td>
</tr>
<tr>
<td>Other-other</td>
<td>Total trips</td>
</tr>
<tr>
<td>Serve passenger</td>
<td>Auto passenger trips</td>
</tr>
<tr>
<td>Visitor</td>
<td>Visitor sector output</td>
</tr>
<tr>
<td>Regional airport</td>
<td>Air passenger trips</td>
</tr>
</tbody>
</table>

A TDZ income level distribution of home-based trip productions is needed as input to the mode choice model. While residential trips are being generated, dwelling unit trip rates by income level are applied and zone level trips by income level are accumulated.

Another mode choice model input is a set of production and attraction end highway terminal times which represent the time spent looking for a parking space and traveling from a parking space to a final destination. The trip generation model processes dwelling unit and land use data which enables weighted terminal times to be calculated for each zone. For example, multifamily dwelling units tend to have less convenient parking than single family houses, so the model assumes a one-minute single family terminal and a two-minute multifamily terminal time. Thus zones with larger concentrations of apartments will have longer production end terminal times.
6.6.2 Model Calibration

Trip generation rates are established from travel behavior survey data and traffic generator studies. Trip rates were initially calculated by expanding trips reported in the 1995 Travel Behavior Survey to the region, tabulating trip ends by purpose and land use, and dividing total trip ends by either the total number of acres, total number of employees, or total number of dwelling units in each land use category. A significant underreporting of trips is found with travel behavior surveys. Trip rates computed from the 1995 Travel Behavior Survey were adjusted to match trip rates found in the 2001 Caltrans GPS survey and traffic generator studies.

6.7 PATHBUILDING, SKIMMING, AND UTILITY CALCULATIONS

The purpose of this part of the modeling process is to find distances, times, costs and other impedances between zones for input to the trip distribution and mode choice models based on coded highway and transit networks described in Sections 6.4 and 6.5. As indicated in Figure 12, the skimming process is repeated numerous times during a model run in order to reflect changes in travel times due to the interaction between travel demand and highway congestion.

TransCAD makes use of a “generalized cost” measure, which combines the effects of time valued at $0.35 per minute and distance valued at $0.15 per mile. In the highway skimming process a minimum path algorithm finds the shortest generalized cost path between each zone pair and then calculates network impedances over the minimum cost path. Different network impedances are skimmed at different points in the modeling process. Initially TAZ level free-flow generalized costs are output for the first stage trip distribution model. In both the feedback loop process and in the final modeling stage, TDZ level distances, times, and toll costs are output for up to eight highway modes that are described in the mode choice section. Peak and off-peak period skims are created to reflect the varying level of congestion in the two time periods. After the skimming process, intra-zonal times and costs are added where appropriate using a “nearest neighbor” technique.

Two different techniques are used to determine non-motorized skims. Since most non-motorized trips are short distance trips, SANDAG detailed 33,000 non-motorized zones (NMZ) are used where possible to reflect the increased likelihood of walking and biking offered by mixed use developments. NMZ-to-NMZ distances are calculated using the equation shown in Section 6.5.5 for nearby NMZs within 1.5 miles. For trips longer than 1.5 miles, non-motorized distances are calculated at the more generalized TDZ level from a subset of coded highway networks without freeways and ramps. This two level approach is used to properly account for most non-motorized trips without seriously increasing model execution time.

The transit skimming process calculates minimum cost paths between transit access points (TAPs) instead of zones. TAPs, described in Section 6.5.5, are selected transit stops that are used to represent access to the transit system. The following four sets of paths are created for modes defined in Table 12:

- A.M. peak period local bus (mode 10)
- A.M. peak period premium service (all modes 4-10)
- Mid-day local bus
- Mid-day premium service
By creating separate premium service and local bus paths, the model is able to split trips between the two types of service. For example, some transit riders may choose local bus routes over faster, but more expensive rail service serving the same corridor. The A.M. peak period is used to represent peak period transit service and mid-day service is used to represent off-peak conditions.

Next, TransCAD determines the following transit impedances over minimum generalized cost paths between each pair of TAPs.

- Number of transfers
- Cash fare
- First wait time
- Transfer wait time
- Transfer walk time
- Commuter rail In-vehicle time (mode 4)
- Light rail In-vehicle time (mode 5)
- BRT in-vehicle time (modes 6 and 7)
- Express bus in-vehicle time (modes 8 and 9)
- Local bus In-vehicle time (mode 10)
- Main mode indicator

First wait and transfer wait times are computed as one-half of the headway on routes serving the TAP pair. For example, a trip that gets on a bus arriving every 30 minutes and transfers to a trolley arriving every 15 minutes, would have a first wait time of 15 minutes and a transfer time of 7.5 minutes. Long first waits are factored down later in the mode choice model to reflect the inconvenience of infrequent service without over penalizing this service. A premium transit path could use a number of different modes. The main mode indicator indicates the mode that is used for the longest distance.

In the feedback loop process, trips are distributed based on a composite utility measure that combines peak and off-peak times and costs for highway, transit, and non-motorized modes. A special version of the mode choice model, described in Section 6.9, computes composite utility values by weighting utilities for individual time periods and modes by their share of total trips.

6.8 TRIP DISTRIBUTION

The trip distribution model links together person trip productions and attractions from the trip generation model to determine trip movements between zones. The model produces trip tables that contain a row for each production zone and a column for each attraction zone. Cells in the table contain the number of trips estimated between zone pairs. Tables 16 and 17 list inputs to the trip distribution model and some of the major outputs.

The model is designed to modify trip patterns in response to new land use developments and transportation facility changes. For example, the opening of a new shopping center would shift trips from other nearby shopping areas to the new development. Another example would be the introduction of mixed-use development. In this case the model would yield shorter trip lengths by recognizing the increased opportunity for interaction between residential and commercial areas in the development. The model also modifies trip patterns as new roadways are added, accounting for one component of “induced” traffic.
Table 16
Trip Distribution Model Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip productions and attractions by zone and trip purpose</td>
<td>Trip Generation Model</td>
</tr>
<tr>
<td>Impedances between zones</td>
<td>Network Skimming</td>
</tr>
<tr>
<td>Highway terminal times and parking costs</td>
<td>Trip Generation Model</td>
</tr>
<tr>
<td>K-Factors</td>
<td>Travel Behavior Surveys</td>
</tr>
<tr>
<td>Friction factors gamma function parameters</td>
<td>Travel Behavior Surveys</td>
</tr>
</tbody>
</table>

Table 17
Trip Distribution Model Outputs

<table>
<thead>
<tr>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily production-attraction person trips between zones by purpose</td>
</tr>
<tr>
<td>Trip distribution reports</td>
</tr>
</tbody>
</table>

6.8.1 Model Structure

A gravity model function distributes trips between zones. The model allocates trip productions from each zone to other zones in direct proportion to the number of attractions in other zones and in inverse proportion to the impedance between zones using the following formula.

\[
t(zp, za, pu) = tp(zp, pu) \times \frac{ta(za, pu) \times ff(ti(zp, za), pu) \times kf(za, zp, pu)}{\sum ta(zx, pu) \times ff(ti(zp, zx), pu) \times bfac(za, zp)}
\]

where:
- \( t = \) Number of trips between zones “za” and “zp” for each purpose
- \( tp(zp, pu) = \) Trip productions in zone “zp” for purpose “pu”
- \( ta(za, pu) = \) Trip attractions in zone “za” for purpose “pu”
- \( ff = \) Friction factor for travel impedance “ti” and purpose “pu”
- \( kf = \) K factor between zones “zp” and “za” for purpose ‘pu’
- \( ti(za, zp, pu) = \) Travel impedance between zones “zp” and “za”
- \( bfac(za, zp) = \) Balancing factors for zones “za” and “zp”
- \( n = \) number of zones

The term “impedance” is a measure of the difficulty of travel between two zones. The trip distribution model is run repeatedly in the overall modeling process shown in Figure 12. Different impedance measures are used at different stages of the modeling process. The previous section describes how impedance measures are calculated. First stage trip distribution uses generalized costs based on free flow times and distances as the impedance measure to distribute trips between 4,605 TAZs. The first stage model is designed to be the starting point for the feedback loop process or can be run as a stand alone application for simple model applications.

The feedback loop process makes use of a more complicated measure of impedance which is the composite utility from the mode choice model based on times and costs of travel for peak and off-peak conditions. Using composite utilities instead of free flow generalized costs enables the
feedback process to reflect more subtle effects of changes to the transportation system on travel patterns. For example, widening a freeway may reduce congestion and lead to longer distance trip lengths. Major transit investments could also produce transit travel times that are more competitive with the automobile and cause more trips to be made within the transit corridor. The feedback loop trip distribution model distributes trips between the more aggregated 2,000 TDZs so that reasonable model execution times are maintained.

Each trip purpose has a different average trip length that ranges from 3 miles for other-other trips to 19 miles for regional airport trips. A gamma function generates friction factors for each trip purpose. These friction factors determine the likelihood of a trip being made in each impedance increment and are used in the trip distribution model to reflect trip length differences by trip purpose. For example shop trips, which are much shorter than commute trips, have friction factors that diminish more rapidly than work friction factors.

The model uses a set of friction factors for each trip purpose for the two stages of the modeling process. These friction factors remain unchanged over the forecast period; however, this does not mean that the model produces the same average trip length for all areas of the region and all forecast years. Rather the model reflects trip length differences resulting from different spatial locations of activities. Thus, rural areas that are far from most employment centers would have longer home-work trips than more centrally located areas near Centre City and other major employment sites.

A number of gravity model iterations are performed to bring gravity model attraction estimates in line with trip generation estimates. The first model iteration typically overestimates trips to highly accessible areas and underestimates trips to inaccessible areas. The program computes doubly-constrained balancing factors by dividing estimated productions and attractions into input productions and attractions. The resulting factors are applied to estimated trips in the next iteration. This process continues until the model closes with a criterion of 0.01.

K-factors have been developed to account for special conditions that are not accounted for by the standard gravity model formulation.

6.8.2 Model Calibration

Gravity model calibration involves adjusting gamma function parameters until model estimated trip length frequency distributions agree with observed trip length frequencies from the 1995 Travel Behavior Survey and 2001 Caltrans Statewide Survey. A TransCAD procedure estimates initial gamma function parameters that best fit an estimated trip length distribution to observed data. Manual adjustments to these gamma function parameters are necessary before finalizing the calibration process. After this calibration process is complete, K-factors are applied to selected zonal interchanges so that model-estimated trip patterns better match observed data for the following conditions:

- Home-college trips to San Diego State University and University of California San Diego
- Coronado Bridge crossings
- Inter-zonal other-other and work-other trips
- High transit use corridors
6.9 MODE CHOICE

The mode choice model splits total person trips from the trip distribution model into trips by individual forms of transportation called modes. The mode choice model is designed to link mode use to demographic assumptions, highway network conditions, transit system configuration, land use alternatives, parking costs, transit fares, and auto operating costs. Tables 18 and 19 list major mode choice model inputs and outputs.

Table 18
Mode Choice Model Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person trips between zones by purpose</td>
<td>Trip Distribution Model</td>
</tr>
<tr>
<td>Trip distances between zones</td>
<td>Highway Network</td>
</tr>
<tr>
<td>Peak/off-peak period highway travel times</td>
<td>Highway Network</td>
</tr>
<tr>
<td>Peak/off-peak period highway distances</td>
<td>Highway Network</td>
</tr>
<tr>
<td>Peak/off-peak period highway tolls</td>
<td>Highway Network</td>
</tr>
<tr>
<td>Non-motorized distances</td>
<td>Non-motorized Network</td>
</tr>
<tr>
<td>Peak/off-peak period transit times</td>
<td>Transit Network</td>
</tr>
<tr>
<td>Peak/off-peak period transit fares</td>
<td>Transit Network</td>
</tr>
<tr>
<td>Transit walk and auto access assumptions</td>
<td>Transit Network</td>
</tr>
<tr>
<td>Automobile operating cost per mile</td>
<td>National Forecasts</td>
</tr>
<tr>
<td>Parking costs</td>
<td>Parking Surveys</td>
</tr>
<tr>
<td>Highway terminal times</td>
<td>Trip Generation Model</td>
</tr>
<tr>
<td>Trips by income level</td>
<td>Trip Generation Model</td>
</tr>
<tr>
<td>School bus percentages</td>
<td>Travel Behavior Survey</td>
</tr>
<tr>
<td>Model parameters</td>
<td>Model Calibration</td>
</tr>
<tr>
<td>Daily to time period factors</td>
<td>Travel Behavior Surveys</td>
</tr>
</tbody>
</table>

Table 19
Mode Choice Model Output

<table>
<thead>
<tr>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin-destination highway vehicle trips between zones by time period</td>
</tr>
<tr>
<td>Transit trips between TAPs by time period</td>
</tr>
<tr>
<td>Mode choice reports</td>
</tr>
</tbody>
</table>
Many applications make use of the mode choice model. Generating transit patronage forecasts for trolley extensions and other transit improvements is a common use. This model also produces performance measures used to evaluate alternative transportation network and land use scenarios.

Proposed transit improvements reduce the time of making a trip by transit and the model shifts trips to transit from other modes in response to these improvements. Conversely, new or widened highways would increase speeds for motorists and the model would increase automobile travel at the expense of transit usage. This mode shift that occurs with highway improvements is one component of induced demand.

The model reduces automobile travel and increases transit and non-motorized travel in response to smart growth land use alternatives that guide development into areas around transit stations and into mixed-use areas. These land use changes reduce trip lengths and make non-motorized travel more attractive. Increasing development around transit stations shortens station access times and increases the number of trips accessible to transit.

The model assumes that travelers make logical and systematic decisions about which form of transportation to take based on knowledge of the time and cost of completing a trip by alternative modes. The model is sensitive to a wide range of facility improvements and policies; however, the model is currently insensitive to programs designed to alter mode use without altering times or costs, such as:

- Advertising campaigns to increase the use of transit, bicycling, or ridesharing,
- Rideshare matching programs,
- Construction of bicycle lanes,
- Replacing older buses to increase the attractiveness of transit, and
- Providing safer and more comfortable transit stops.

A common misconception about the mode choice model is that it underestimates future transit use for expanded transit alternatives because model calibration is based upon current conditions. This should not be the case. The model estimates transit use for each zone-to-zone movement based upon the quality of transit service relative to other modes. Existing trolley corridors provide a basis for determining potential transit use with high quality transit service. As more light rail, BRT, and bus service is provided, the model recognizes the resulting transit service improvements and shifts travel to transit from other modes. As a result, the model forecasts a 24 percent increase of the work trip transit mode share between 2000 and 2030, when an expanded transit system is expected to be in place. This forecasted increase in transit mode share exceeds historical changes in transit mode share. For example, US Census Bureau statistics show San Diego’s work trip transit mode share increased by only 5 percent between 1980 and 2000, a time in which COASTER service was added and trolley service was expanded. The doubling in transit mode share also are exceeds transit mode share increases forecasted in most other urban areas.

6.9.1  Model Structure

SANDAG uses a nested mode choice mode that splits total person trips into 25 different submodes in a hierarchical fashion as illustrated in Figure 13. Initially, school bus trips are factored out of total trips. These trips affect a small percentage of all trips, but are a significant proportion of school trips. Next trips are split into auto, non-motorized, and transit modes. The term "auto" is used generically
to include travel by automobiles, pick-ups, vans, trucks, taxicabs, and motorcycles. Auto trips are further divided into submodes based on vehicle occupancy (drive alone, two person shared-ride, and three or more person shared-ride vehicles) and type of facility.

**Figure 13**

**Nested Mode Choice Model Structure**

The RTP proposes a number of different types of restricted use freeway facilities. In addition to general purpose freeway lanes the RTP includes:

- **High Occupant Vehicle (HOV) Lanes.** HOV lanes can only be used by buses and shared-ride vehicles with two or more occupants. Under some conditions HOV lanes may be restricted to vehicles with three or more occupants. HOV lanes now exist on I-5 north of State Route (SR) 56 and are planned for many other freeways.

- **Managed Lanes.** These multi-lane HOV facilities are sometimes called high occupancy toll (HOT) lanes. In addition to shared-ride vehicles, managed lanes are open to drive alone vehicles that are willing to pay a toll. There are currently managed lanes on I-15 between SR 163 and Miramar Road. Managed lanes are being extended on I-15 and are planned for portions of I-5, I-805, and SR 52.

- **Toll Roads.** The SR 125 toll road currently under construction is an example of this type of facility. Toll roads require all vehicles, both drive alone and shared-ride, to pay a toll in order to use the facility.
When vehicle occupancy categories are matched with facility types, the following eight auto submodes are possible.

- **Drive Alone/Non-Toll Trips.** These trips, restricted to general purpose lanes, are made up of drive alone trips that choose not to pay to use toll roads or managed lanes.
- **Drive Alone/Toll Trips.** These are toll-paying drive alone trips can use all types of facilities except HOV-only lanes.
- **Two Person Shared-Ride Non-Toll/Non-HOV Trips.** These trips, restricted to general purpose lanes, include shared-ride trips that choose not to pay to use tolled facilities, and trips that are eligible to use HOV lanes but choose not to do so.
- **Two Person Shared-Ride Non-Toll/HOV Trips.** These are shared-ride trips that choose to use an HOV lane, but are unwilling to pay a fee to use tolled facilities.
- **Two Person Shared-Ride Toll/HOV Trips.** These are toll-paying shared-ride trips that can use all types of facilities.
- **Three or More Person Shared-Ride Non-Toll/Non-HOV Trips.**
- **Three or More Person Shared-Ride Non-Toll/HOV Trips.**
- **Three or More Person Shared-Ride Toll/HOV Trips.**

All HOV lanes in the RTP are proposed as two person HOV lanes, so the two person and three or more person shared-ride modes are allowed to use the same facilities. Some studies need to evaluate the impacts of restricting HOV lanes to vehicles with 3+ occupants. In these cases, 2 person shared-ride trips would only be allowed on general purpose lanes.

Non-motorized trips (pedestrian and bicycle trips) reflect the effects of land use, trip purpose, and competing transportation modes. However, estimation procedures do not allow non-motorized facility issues to be addressed. For example, bicycle paths are not explicitly coded and thus do not affect non-motorized trip forecasts. A more rigorous approach is prevented by the small scale of non-motorized facilities and the lack of before and after data showing the effects non-motorized improvements have on non-motorized travel.

Transit trips are subdivided by transit access modes (walk, drive, and drop-off) and transit ride modes (commuter rail, light rail, BRT, express bus, and local bus). The three transit access modes determine how transit riders get to and from transit stops. Riders who walk at both trip ends are classified as transit-walk trips. Drive access trips are those trips where the rider gets to or from a transit stop by either driving or carpooling. Trips where the rider is dropped-off or picked up are classified as drop-off trips. Access mode is important in quantifying transit level-of-service. Drive access usually shortens overall transit trip times, but is limited to locations with park-and-ride access and to riders who have an automobile available for the trip.

Transit ride modes represent travel behavior and nonquantifiable service differences between the five modes. For example, light rail and commuter rail are perceived as being more reliable and comfortable than bus, and will generate higher ridership than local bus service in the same corridor. It is assumed that the BRTs being proposed in the 2030 RTP will act midway between bus and rail service.
The model computes mode use separately for two time periods, three income levels, and six trip purposes. The two time periods split travel into peak and off-peak hours. The peak period extends from 6:00 a.m. to 9:00 a.m. and 3:00 p.m. to 6:00 p.m. The off-peak period covers the remaining 18 hours of the day. It is important to evaluate mode use separately for the two time periods because the quality of service can vary dramatically by mode. For example, transit operators often provide more frequent transit service during peak hours, reducing wait times for transit riders. Conversely, highway congestion is at its worst during peak hours making auto modes less attractive relative to transit.

Mode use also varies by income level. People in low-income households tend to own fewer automobiles and hence make more trips by transit and carpooling. People in upper-income households tend to be mode time sensitive and as a result choose modes based on time and convenience rather than cost. Households are split into three income categories:

- low income households with annual incomes less than $30,000 (constant 1999 dollars)
- high income households with incomes more than $60,000
- middle income households made up of the remaining households

There also is a strong relationship between mode use and trip purpose. For example, most students are below driving age so school trips generate almost no drive alone trips but have a very high rate of transit, school bus, and non-motorized mode use. Home-other trips tend to be made with other household members, so that two and three or more person auto modes are more heavily used than other trip types. In order to reduce computer processing time, the ten trip purposes from trip generation and distribution are collapsed into six purposes for mode choice by combining home-shop and home other trips, and combining work-other, other-other, visitor, and regional airport trips.

### 6.9.2 Utility Computations

Before determining mode shares the model computes utility measures for each mode based on a combination of a number of time and cost components that are weighted using the coefficients shown in Table 20. Cost coefficients by income level and low income time coefficients were determined in a recently completed model estimation project. After applying the model it was felt that higher income trips were not sensitive enough to time as indicated by:

- Too few high income trips on the COASTER which has high fares but offers travel times competitive with the automobile
- Too many transit trips from high income areas
- Too few peak period managed lane trips when tolls are higher than the off-peak period but travel time savings are more significant

Subsequently time coefficients were stratified by income level in addition to cost coefficients, which had the desired effect of reducing the severity of these problems.
Utilities for auto modes are computed for each TDZ pair, time period, and income group and purpose using the following equation.

\[ auu(m, p, i) = (auivt(m, t, iz, jz) \times tcoef(1, p, i) + (termp(iz) + terma(jz)) \times tcoef(2, p, i) + (p \cos t(p, jz) + toll(m, t, iz, jz) + audist(m, t, iz, jz) \times cpm) \times ccoef(p, i)) / (nclow \times ncmid \times nctop) \]

where:

- \( auu \) = auto utility for mode “m” purpose “p” and income group “i”
- \( auivt \) = auto in-vehicle travel time between zones for mope and time period “t”
- \( tcoef \) = time coefficient for purpose from Table 20
- \( termp \) = terminal time at production end
- \( terma \) = terminal time at attraction end
- \( pcost \) = parking cost at attraction end
- \( toll \) = toll facility cost (if any)
- \( audist \) = auto distance between zones
- \( cpm \) = cost per mile to operate an automobile
- \( nclow \) = nesting coefficient at lowest level of nest (0.55)
- \( ncmid \) = nesting coefficient at middle level of nest (0.65)
- \( nctop \) = nesting coefficient at top level of nest (0.85)

### Table 20

**Mode Choice Time and Cost Coefficients**

<table>
<thead>
<tr>
<th>Time/Cost Component</th>
<th>Purpose/Income</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Home-Work/College</td>
<td>Home-Other</td>
<td>Other-Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>1. Auto In-Vehicle</td>
<td></td>
<td>-0.028</td>
<td>-0.056</td>
<td>-0.084</td>
<td>-0.016</td>
<td>-0.032</td>
<td>-0.048</td>
<td>-0.022</td>
<td>-0.044</td>
<td>-0.066</td>
<td></td>
</tr>
<tr>
<td>2. Auto Terminal</td>
<td></td>
<td>-0.056</td>
<td>-0.112</td>
<td>-0.168</td>
<td>-0.032</td>
<td>-0.064</td>
<td>-0.096</td>
<td>-0.044</td>
<td>-0.088</td>
<td>-0.132</td>
<td></td>
</tr>
<tr>
<td>3. Transit In-Vehicle</td>
<td></td>
<td>-0.028</td>
<td>-0.056</td>
<td>-0.084</td>
<td>-0.016</td>
<td>-0.032</td>
<td>-0.048</td>
<td>-0.022</td>
<td>-0.044</td>
<td>-0.066</td>
<td></td>
</tr>
<tr>
<td>4. Transit First Wait</td>
<td></td>
<td>-0.042</td>
<td>-0.084</td>
<td>-0.126</td>
<td>-0.026</td>
<td>-0.051</td>
<td>-0.077</td>
<td>-0.035</td>
<td>-0.070</td>
<td>-0.106</td>
<td></td>
</tr>
<tr>
<td>5. Transit Transfer Wait</td>
<td></td>
<td>-0.084</td>
<td>-0.168</td>
<td>-0.252</td>
<td>-0.040</td>
<td>-0.080</td>
<td>-0.120</td>
<td>-0.055</td>
<td>-0.110</td>
<td>-0.165</td>
<td></td>
</tr>
<tr>
<td>6. Transit Auto Access</td>
<td></td>
<td>-0.028</td>
<td>-0.056</td>
<td>-0.084</td>
<td>-0.016</td>
<td>-0.032</td>
<td>-0.048</td>
<td>-0.022</td>
<td>-0.044</td>
<td>-0.066</td>
<td></td>
</tr>
<tr>
<td>7. Short Walk</td>
<td></td>
<td>-0.042</td>
<td>-0.084</td>
<td>-0.126</td>
<td>-0.024</td>
<td>-0.048</td>
<td>-0.072</td>
<td>-0.033</td>
<td>-0.066</td>
<td>-0.099</td>
<td></td>
</tr>
<tr>
<td>8. Mid Walk</td>
<td></td>
<td>-0.056</td>
<td>-0.112</td>
<td>-0.168</td>
<td>-0.032</td>
<td>-0.064</td>
<td>-0.096</td>
<td>-0.044</td>
<td>-0.088</td>
<td>-0.132</td>
<td></td>
</tr>
<tr>
<td>9. Long Walk</td>
<td></td>
<td>-0.084</td>
<td>-0.168</td>
<td>-0.252</td>
<td>-0.048</td>
<td>-0.096</td>
<td>-0.144</td>
<td>-0.066</td>
<td>-0.132</td>
<td>-0.198</td>
<td></td>
</tr>
<tr>
<td>10 Bicycle</td>
<td></td>
<td>-0.098</td>
<td>-0.196</td>
<td>-0.294</td>
<td>-0.064</td>
<td>-0.128</td>
<td>-0.192</td>
<td>-0.088</td>
<td>-0.176</td>
<td>-0.264</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.008</td>
<td>-0.003</td>
<td>-0.001</td>
<td>-0.009</td>
<td>-0.004</td>
<td>-0.002</td>
<td>-0.013</td>
</tr>
</tbody>
</table>
Although the form of the equation is the same for all auto modes, in-vehicle times, tolls, and
distances may differ for each mode depending on the highway network being evaluated. For
example in a congested corridor with a freeway HOV lane, the in-vehicle travel time for drive alone
non-toll vehicles would be longer than the time for two person shared-ride HOV/non-toll vehicles
which are allowed to use the less congested HOV lane.

In-vehicle highway times are calculated using procedures described in the next highway assignment
section and include the effects of congestion. Terminal times represent walking time from home to
parking location, walking time from parking location to final destination, and other miscellaneous
time. Terminal times at the residential end are assumed to be one-quarter minute for single family
units and two minutes for multifamily units since higher density developments tend to have less
convenient shared parking. The trip generation step calculates average TDZ residential terminal
times based on the number of units by each type. A one minute terminal time is assumed at most
nonresidential locations. Higher nonresidential terminal times are assumed in Centre City, at
universities, military bases, regional shopping centers, and some older outlying business districts.
These terminal times vary between three and ten minutes depending on the location.

The model considers three types of auto costs: auto operating costs, parking costs, and tolls. Auto
operating costs are assumed to be $0.135 per mile (1999 dollars) and reflect existing fuel costs.
Vehicle depreciation costs are not included since these costs are not usually considered when
making a mode choice decision. While fuel costs are expected to increase over time, the SANDAG
standard forecasts assume constant auto-operating costs. One reason for this assumption is that fuel
cost increases can be offset by use of more fuel efficient vehicles. Because there is no generally
accepted source for future fuel cost and fuel efficiency forecasts, standard modeling practice is to
use base-year auto costs and transit fares for future-year forecasts. It should be noted that cost and
fare assumptions can be varied for scenario testing purposes.

Parking costs are assumed to exist in Centre City San Diego, universities, Lindberg Field, and
business districts in Oceanside, Escondido, La Jolla, and Hillcrest. Although some individual lots
charge more, the highest average parking rates of $8.00 per day are found in Centre San Diego.
These rates are made into a per trip basis by dividing by two.

The RTP contains two types of toll facilities: (1) managed lanes that charge a fee for use by drive
alone vehicles and (2) the SR 125 toll road where tolls will be charged for all vehicles using the
facility. Highway network links are coded with a per mile toll cost that can vary by time period and
location. Data from the existing managed lanes on I-15 were analyzed to determine default
managed lane tolls of $0.26 per mile in peak periods and $0.10 per mile in the off-peak. These
default toll rates can be adjusted to match model-estimated managed lane demand to available
capacity. The proposed toll structure on SR 125 translates into toll rates of $0.33 per mile in peak
periods and $0.27 per mile in the off-peak.

Transit utility computations are more complicated than auto computations because there are more
travel time components associated with transit. These utilities also need to be computed for each
transit access and transit ride mode combination, and for each NMZ pair, time period, and income
group. Walk access computations use the following equation.
where:  
\[ \text{twu}(rm, p, i) = (\text{trivt}(rm, t, ptap, atap) \times \text{ivfac}(rm) \times \text{tcoef}(3, p, i) + (\text{sfw} + \text{lfw}) \times \text{tcoef}(4, p, i) + \text{trxfer}(rm, t, ptap, atap) + \text{xadd}(rm, \text{nx}(rm, t, ptap, atap)) \times \text{tcoef}(5, p, i) + \text{swk} \times \text{tcoef}(7, p, i) + \text{mwk} \times \text{tcoef}(8, p, i) + \text{lwk} \times \text{tcoef}(9, p, i) + \text{fare}(rm, t, ptap, atap) \times \text{fpct}(p, i, rm) \times \text{ccoef}(p, i) + \text{disu}) \div (\text{nctop} \times \text{nctop}) \]

As indicated in Table 20, time coefficients on wait and walk times are higher than in-vehicle time coefficients to reflect the fact that surveys show transit riders perceive these out-of-vehicle time components to be more onerous than time spent riding in a vehicle. An in-vehicle time discount factor further reduces commuter rail in-vehicle time to reflect the fact that commuter rail riders can make more productive use of their time than on other transit modes.

Transit skimming procedures calculate first-wait times based on one-half the headway of coded transit routes. In the mode choice model these wait times are split into short and long first-wait times using the assumptions shown in Table 21. It is assumed that commuter rail, light rail, and BRT modes are sufficiently reliable for transit users to adjust their arrival at transit stops to minimize wait times. Furthermore, it is assumed that the repetitive nature of work trips makes it more likely that arrival times can be more closely matched to transit schedules than more random non-work trips. Long wait times in excess of these thresholds are discounted by 90 percent.
The transit skimming process also calculates transfer wait times, where applicable, based on one-half the headway of coded transit routes. Two adjustments to these standard transfer time calculations are made. First, a small number of stations are assumed to have bus and rail service that will be sufficiently coordinated to replace the standard transfer times with lower timed-transfer times. Next, the transfer times in Table 22 are added to reflect the inconvenience of transferring in addition to actual wait times. These added transfer times are needed so that the model reflects observed transfer rates from transit surveys. Transfer penalties are lower for commuter rail, light rail, and BRT modes than local and express modes, since these stations generally have more amenities and more reliable arrival times. Transit surveys also show that transit riders who use an auto to get to transit are much less likely to transfer so higher transfer penalties are assumed for auto access modes.

### Table 22
**Added Transfer Time (Minutes)**

<table>
<thead>
<tr>
<th>Ride Mode</th>
<th>Access Mode</th>
<th>1</th>
<th>2+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commuter Rail</td>
<td>Walk Access</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Auto Access</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>Trolley/BRT</td>
<td>Walk Access</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Auto Access</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Express/Local Bus</td>
<td>Walk Access</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Auto Access</td>
<td>5</td>
<td>30</td>
</tr>
</tbody>
</table>

Walk time to transit is another important factor in mode choice. Section 5 described how walk distances between NMZs and TAPs are calculated. The following equation is used in the mode choice model to add walk time at the start of a trip, walk time at the end of a trip, and any time spend walking between transit routes when making a transfer.

\[
wktime(rm) = \left( wkdist(pmz, atap) + wkdist(atap, anmz) \right) / wkspd + xfertime(rm, t, atap, atap)
\]

where:
- \( wktime \) = overall walk time between production and attraction zones
- \( wkdist \) = walk distances between NMZs and TAPs
- \( wkspd \) = average walking speed of three MPH
- \( xfertime \) = walk time when transferring between routes.

The model estimation process found that longer distance walk connections are perceived as being more onerous so the combined walk time computed above is segmented into short-walk time (less than 5 minutes), mid-walk time (5 to 20 minutes), and long-walk time (greater than 20 minutes). The transit walk utility equation then applies higher coefficients to longer walk times.

The final component of the transit walk utility equation is the transit fare. TransCAD transit skimming procedures find the cash fare between each TAP pair based on existing fare schedules. In the mode choice model these cash fares are discounted to account for pass usage. Transit surveys show pass usage varies by a number of different factors. For example, commuter rail users are more likely to use passes...
than are local bus riders, incidental nonwork trips are less likely to use passes than work trips, and pass usage declines with higher incomes. Thus cash fare discount factors are computed and applied by ride mode, trip purpose, and income level.

After applying the model and comparing model estimated trip lengths by mode with observed data, it became apparent that the model had a tendency to over estimate short distance trips. The following disutility expression was implemented to correct this problem.

\[
disu = 60 \times tcoef(3, p, i) - 24 \times tcoef(3, p, i) \times d
\]

where:
\[\text{disu} = \text{disutility distance correction value}\]
\[d = \text{trip distance}\]

Transit drive access (park-and-ride) and drop-off access (kiss-and-ride) utilities are computed in a similar manner as the previous transit walk utilities. Times and fares will differ from those for walk access because drive access connections are restricted only to transit stops with formal or informal parking available, and because drive access connections are usually faster than access by feeder bus or long distance walks. Drive access only is allowed at the production end of home-based trips since users generally do not have access to a car at the nonresidential end of a trip.

The transit auto utility equation shown below replaces walk time at the production end with drive time, and adds the cost of driving and a terminal time the end of the auto access leg of the trip.

\[
tau(rm, am, p, i) = (trivt(rm, am, t, ptap, atap) \times ivfac(rm) \times tcoef(3, p, i) + (sfw + lfw) \times tcoef(4, p, i) + (txfer(rm, am, t, ptap, atap) + xadd(rm, nx(rm, am, t, ptap, atap)) \times tcoef(5, p, i) + swk \times tcoef(7, p, i) + mwk \times tcoef(8, p, i) + hwk \times tcoef(9, p, i) + (fare(rm, am, t, ptap, atap) \times fpct(p, i, rm) + dd(rm, am, t, pz, ptap) \times cpm) \times ccoef(p, i) + dt(rm, am, t, pz, ptap) \times tcoef(6, p, i) + term(am, ptap) \times tcoef(2, p, i) + disua - disu) / (ncmid \times nctop)
\]

where:
\[\text{tau(rm,am,p,i)} = \text{transit-walk utility for ride mode “rm”, access mode “am” (drive or drop-off), purpose “p”, and income group “i”}\]
\[dd = \text{drive access distance}\]
\[cpm = \text{drive cost per mile}\]
\[dt = \text{drive access time}\]
\[term = \text{terminal time at the end of the drive access trip}\]

Once the model has computed transit utilities for all three access modes and five-ride modes, the model compares each of the 15 ride-access modes with the best mode. Ride-access modes that fail to offer an advantage in one of five factors (in-vehicle time, wait time, walk time, cost, or number of transfers) are screened out. This screening process prevents the model from calculating trips for irrelevant transit mode alternatives.

The model had a tendency to over-estimate trips where the auto access connection makes up a high proportion of the total trip distance. The following disutility expression was implemented to correct this problem.
where:
\( \text{disua} \) = disutility auto access correction value
\( \text{aarat} \) = ratio of auto access distance to total trip distance

Non-motorized utilities for bike and walk modes are computed by applying a time coefficient to non-motorized travel time. These times are derived from non-motorized distance skims described in Section 6.7 by using an average three MPH speed for walk trips and 12 MPH for bike trips. Walk trip times are categorized into short-walk time, mid-walk time, and long-walk time using the same breakpoints as the transit utility calculations. The model does not consider non-motorized operating costs.

\[
bku(p, i) = \left( \frac{\text{bks} \times \text{coef}(7, p, i) + \text{mwb} \times \text{coef}(8, p, i) + \text{lwb} \times \text{coef}(9, p, i)}{\text{nctop}} \right)
\]

where:
\( \text{bku} \) = bicycle utility
\( \text{dist} \) = distance between zones
\( \text{bks} \) = bicycle speed (12 MPH)
\( \text{wku} \) = walk utility

After computing utilities for each mode, the program then cycles through the six trip purposes and three income levels used in the mode choice model. Exponentiated utilities for each of the 26 lower level modes are calculated using the following equation.

\[
eu(m, i, p) = \exp(u(m, p, i) + cnst(1, p, i) + cnst(2, p, i))
\]

where:
\( \text{eu}(m, i, p) \) = exponentiated utility for mode “m”, income group “i”, and purpose “p”
\( \exp \) = exponential function
\( u(m, p, i) \) = utility for mode, purpose, and income group
\( \text{cnst} \) = modal constant for income group “i”, and purpose “p”

Modal constants (Table 23), calculated during the calibration process, are used to bring model-estimated mode shares into agreement with observed mode shares for each market segment. Market segments for most modes are defined using income group and trip purpose. Federal guidelines prevent income stratification for transit ride modes. Table 24 shows how the 13 modal constants are applied to the 25 submodes.
<table>
<thead>
<tr>
<th>Modal Constant</th>
<th>Income</th>
<th>Purpose</th>
<th>Home-Work</th>
<th>Home-College</th>
<th>Home-School</th>
<th>Home-Other</th>
<th>Other-Other</th>
<th>Serve Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Non-motorized</td>
<td>Low</td>
<td>-0.60</td>
<td>-2.42</td>
<td>2.00</td>
<td>-0.95</td>
<td>-2.68</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-0.57</td>
<td>-2.42</td>
<td>2.26</td>
<td>-1.18</td>
<td>-3.72</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-0.96</td>
<td>-2.42</td>
<td>3.48</td>
<td>-1.13</td>
<td>-2.93</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>2. Transit</td>
<td>Low</td>
<td>2.43</td>
<td>-0.23</td>
<td>1.11</td>
<td>-1.06</td>
<td>-5.17</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>2.53</td>
<td>-0.34</td>
<td>0.26</td>
<td>-2.80</td>
<td>-6.00</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.88</td>
<td>-1.54</td>
<td>-0.24</td>
<td>-4.38</td>
<td>-6.38</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>3. Shared-Ride</td>
<td>Low</td>
<td>-5.20</td>
<td>-3.10</td>
<td>-0.63</td>
<td>-0.64</td>
<td>-0.99</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-5.75</td>
<td>-2.30</td>
<td>1.30</td>
<td>-0.66</td>
<td>-1.81</td>
<td>1.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-6.77</td>
<td>-4.29</td>
<td>2.82</td>
<td>-1.21</td>
<td>-1.89</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>4. Bicycle</td>
<td>Low</td>
<td>-2.75</td>
<td>-0.79</td>
<td>-4.24</td>
<td>-3.25</td>
<td>-3.48</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-2.45</td>
<td>-0.79</td>
<td>-3.24</td>
<td>-3.91</td>
<td>-3.92</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-2.33</td>
<td>-0.79</td>
<td>-5.43</td>
<td>-2.77</td>
<td>-3.92</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>5. 3+ Shared-ride</td>
<td>Low</td>
<td>-1.40</td>
<td>-4.80</td>
<td>1.29</td>
<td>-1.35</td>
<td>-1.00</td>
<td>-0.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-3.16</td>
<td>-3.17</td>
<td>1.57</td>
<td>-1.46</td>
<td>-0.75</td>
<td>-0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-2.84</td>
<td>-2.37</td>
<td>0.90</td>
<td>-0.97</td>
<td>-0.66</td>
<td>-0.19</td>
<td></td>
</tr>
<tr>
<td>6. Toll</td>
<td>Low</td>
<td>-2.42</td>
<td>-3.91</td>
<td>n/a</td>
<td>-3.91</td>
<td>-2.72</td>
<td>-3.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-2.73</td>
<td>-3.91</td>
<td>n/a</td>
<td>-3.67</td>
<td>-3.75</td>
<td>-3.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-0.30</td>
<td>-1.90</td>
<td>n/a</td>
<td>-0.99</td>
<td>-1.81</td>
<td>-3.45</td>
<td></td>
</tr>
<tr>
<td>7. Shared-ride HOV</td>
<td>Low</td>
<td>0.67</td>
<td>-1.65</td>
<td>-2.92</td>
<td>0.87</td>
<td>2.07</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>0.03</td>
<td>-1.17</td>
<td>-3.10</td>
<td>0.43</td>
<td>0.69</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>1.66</td>
<td>-0.19</td>
<td>-2.23</td>
<td>2.37</td>
<td>2.24</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>8. Transit Auto</td>
<td>Low</td>
<td>-5.98</td>
<td>-4.49</td>
<td>-7.12</td>
<td>-5.55</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-5.62</td>
<td>-4.90</td>
<td>-9.13</td>
<td>-4.45</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-3.50</td>
<td>-5.28</td>
<td>-6.00</td>
<td>-4.36</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>9. Transit Drop-off</td>
<td>Low</td>
<td>-1.23</td>
<td>-1.44</td>
<td>1.96</td>
<td>-0.76</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>-2.20</td>
<td>-0.20</td>
<td>3.46</td>
<td>-2.25</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-3.70</td>
<td>-0.36</td>
<td>0.63</td>
<td>-1.32</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>10. Transit BRT</td>
<td>All</td>
<td>0.58</td>
<td>-0.01</td>
<td>0.88</td>
<td>0.28</td>
<td>0.23</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>11. Transit Rail</td>
<td>All</td>
<td>1.15</td>
<td>-0.02</td>
<td>1.76</td>
<td>0.55</td>
<td>0.46</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>12. Transit Auto BRT</td>
<td>All</td>
<td>0.41</td>
<td>-0.33</td>
<td>-0.38</td>
<td>0.52</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>13. Transit Auto Rail</td>
<td>All</td>
<td>0.82</td>
<td>-0.66</td>
<td>-0.75</td>
<td>1.04</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Note: n/a indicates mode not available for purpose.
## Table 24
Application of Modal Constants

<table>
<thead>
<tr>
<th>Mode</th>
<th>Number of Modal Constant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Alone Toll</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive Alone Non-Toll</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Person Shared-ride Non-Toll/Non-HOV</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Person Shared-ride Non-Toll/ HOV</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Person Shared-ride Toll/ HOV</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3+ Person Shared-ride Non-Toll/Non-HOV</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3+ Person Shared-ride Non-Toll/ HOV</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3+ Person Shared-ride Toll/ HOV</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter Rail/Walk Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter Rail/Drive Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter Rail/Drop-Off Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Rail/Walk Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Rail/Drive Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Rail/Drop-Off Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRT/Walk Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRT/Drive Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRT/Drop-Off Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Express Bus/Walk Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Express Bus/Drive Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Express Bus/Drop-Off Access</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Bus/Walk Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Bus/Drive Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Bus/Drop-Off Access</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: + indicates constant is applied to exponentiated utility for mode.
Once exponentiated utilities have been calculated for all submodes upper level modes are obtained by combining utilities from lower level modes as follows.

\[
\begin{align*}
\text{dae}u &= \exp(\ln(\text{dane}u + \text{date}u) \times n\text{clow}) \\
\text{sr}2\text{e}u &= \exp(\ln(\text{sr}2\text{nn} + \text{sr}2\text{nh} + \text{sr}2\text{th}) \times n\text{clow}) \\
\text{sr}3\text{eu} &= \exp(\ln(\text{sr}3\text{nn} + \text{sr}3\text{nh} + \text{sr}3\text{th}) \times n\text{clow}) \\
\text{d}r\text{eu} &= \exp(\ln(\text{dae}u) \times n\text{cmid}) \\
\text{s}r\text{eu} &= \exp(\ln(\text{sr}2\text{eu} + \text{sr}3\text{eu}) \times n\text{cmid}) \\
\text{a}ue\text{u} &= \exp(\ln(\text{d}r\text{eu} + \text{sr}\text{eu}) \times n\text{ctop}) \\
\text{n}n\text{eu} &= \exp(\ln(\text{wke}u + \text{bke}u) \times n\text{ctop}) \\
\text{twke}u &= \exp(\ln(\text{crwke}u + \text{lrwke}u + \text{brtwke}u + \text{ebwke}u + \text{lbwke}u) \times n\text{cmid}) \\
\text{taueu} &= \exp\left(\ln\left(\frac{\text{crre}u + \text{lrre}u + \text{brtre}u + \text{ebre}u + \text{lbre}u}{\text{crke}u + \text{lrke}u + \text{brtkre}u + \text{ebkre}u + \text{lkre}u}\right) \times n\text{cmid}\right) \\
\text{tre}u &= \exp(\ln(\text{twke}u + \text{taueu}) \times n\text{ctop})
\end{align*}
\]

where:
ln = natural log function
eu = exponentiated utility
da = drive alone
dan = non-toll
dat = toll
sr2 = 2 person shared-ride
sr2nn = non-toll/non-hov
sr2nh = non-toll/hov
sr2th = toll/hov
sr3 = 3+ person shared-ride toll/hov
dr = drive
au = auto
sr = shared-ride
nm = non-motorized
wk = walk
bk = bicycle
twk = transit-walk
cr = commuter rail
lr = light rail
brt = bus rapid transit
eb = express bus
lb = local bus
tau = transit auto access
pr = park-ride access (drive)
kr = kiss-ride access (drop-off)
tr = transit
nclow = nested logit coefficient for low nest
ncmid = nested logit coefficient for middle nest
nctop = nested logit coefficient for top nest
The ratio of exponentiated utilities, shown in the equation, below computes mode shares. Trips by mode then are obtained by applying mode shares to total person trips in each market segment. The resulting trips are accumulated and output in summary reports and as trip tables for the highway and transit assignment process:

\[
ms(ma) = \frac{eu(ma)}{(eu(ma) + eu(mb))}
\]

where:

- \(ms(ma)\) = mode share for mode “a”
- \(eu(ma)\) = utility for mode “a”
- \(eu(mb)\) = utility for mode “b”

### 6.9.3 Model Calibration

A major project to recalibrate the mode choice model was completed in 2006 and is documented in a report Mode Choice Model Improvements, November 2006. Results from the 1995 Travel Behavior Survey, 2000 Market Research Survey, and 2001 Caltrans Statewide Survey, and 2001-2003 Transit Ridership Survey were analyzed to estimate time and cost coefficients and determine a nesting structure.

After model estimation, observed base year mode shares were tabulated from the Travel Behavior Survey and Transit Ridership Survey which were used to calibrate modal constants so that model-estimated mode shares agree with observed mode shares by market segment.

Transit ridership forecasts from the transit assignment model were extensively evaluated to determine the accuracy of mode choice estimates and adjust model parameters to correct problem areas. Regional level Census 2000 work-trip mode shares also were used to fine-tune mode share estimates.

### 6.9.4 Mode choice variations

A number of different applications are derived from the mode choice procedures described above including:

- Creating input files to the Federal Transit Administration’s (FTA) Summit program
- Computing composite utilities for the feedback loop trip distribution model
- Calculating and applying person trip to vehicle trip conversion factors

**Summit Input Files.** FTA requires a rigorous cost effectiveness analysis when applying for federal funding for major transit investments under the New Starts program. A special version of the mode choice program creates an output file for each time period and purpose, which contains trips and exponentiated utilities for each TAZ pair and income group. These files then are used by the FTA Summit program to calculate and summarize user benefits that are used in a subsequent measure of cost effectiveness.
**Composite Utilities.** The utility calculations described above can be used to provide a trip distribution impedance measure that factors in times and costs by all modes of transportation. A special version of the mode choice model cycles through each time period, zone pair, purpose, and income group and calculates average utilities for three major modes: automobile, transit, and non-motorized. The lowest utility value then is used to compute a daily composite utility for each TDZ pair by three generalized purposes: home-work/college, home-other, and non-home based.

**Person Trip to Vehicle Trip Factoring.** First stage and feedback loop model applications use a person trip to vehicle trip conversion program to obtain vehicle trip tables for input to the highway assignment process. This conversion process is intended to reflect the effects of smart growth, transit improvements, and other conditions that are forecasted by the mode choice model, while avoiding the time and complexity of transit network modeling and applying the standard mode choice model.

Vehicle factors are obtained from a previous final stage mode choice model which computes vehicle fractions for four highway modes (non-toll/non-HOV, drive alone toll, person shared-ride non-toll/HOV, and shared-ride toll/HOV) by time period (peak period and off-peak period), mode choice purpose (home-work, home-college, home-school, home-other, serve passenger, and non-home based), TDZ pair, and forecast year (for example 2004, 2010, or 2030).

### 6.10 HIGHWAY ASSIGNMENT

Highway assignment is the process of loading vehicle trips between zones onto specific segments of highway. Trips are apportioned to links based on the generalized cost and capacity associated with each link from the highway network coding process described earlier. Major inputs and outputs are listed below in Tables 25 and 26.

As congestion builds over time, the highway assignment model shifts traffic to adjacent facilities having excess capacity. Similarly, corridors where new roadways or roadway improvements are planned will see traffic diversions to the new facilities from parallel facilities having slower speeds or higher congestion. These shifts in traffic between facilities are a major component of what is perceived as induced demand.

Table 25

<table>
<thead>
<tr>
<th>Input</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle trips between zones</td>
<td>Mode choice model</td>
</tr>
<tr>
<td>Highway network</td>
<td>Network coding</td>
</tr>
<tr>
<td>Volume-delay functions</td>
<td>Highway Capacity Manual</td>
</tr>
<tr>
<td>Traffic counts</td>
<td>Caltrans and local jurisdictions</td>
</tr>
</tbody>
</table>
### Table 26
Highway Assignment Model Outputs

<table>
<thead>
<tr>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily and peak hour traffic volumes by highway segment</td>
</tr>
<tr>
<td>Congested highway times and speeds by segment and time period</td>
</tr>
<tr>
<td>Level-of-service by segment and time period</td>
</tr>
<tr>
<td>Air pollution emission model inputs</td>
</tr>
<tr>
<td>Summary reports and plots</td>
</tr>
</tbody>
</table>

#### 6.10.1 Model Structure

SANDAG loads traffic using the TransCAD “Multi-Modal Multi-Class Assignment” function. This is an iterative technique for balancing estimated link volumes with available capacity by minimizing an overall congestion index. The model first finds minimum paths between zones based on input generalized cost assumptions for each roadway segment. Trips between zones are accumulated on links making up the minimum time path between each zone pair. Once all trips have been assigned, congestion levels are determined by computing mid-link and intersection volume-to-capacity (V/C) ratios. Input link times are revised using a volume delay function that adjusts speeds based on the mid-link V/C ratio and an intersection delay function that adjusts intersection delays based on the intersection V/C. Additional assignment iterations are performed making use of revised link speeds from the previous iteration until equilibrium is reached.

A.M. peak period, P.M. peak period, and off-peak trip tables are loaded separately since motorists may choose different travel paths during different time periods. For example, heavily-congested facilities and metered ramps would tend to be avoided during peak periods, but not during off-peak hours. Daily volumes are obtained by adding together assignments for the three time periods.

TransCAD ability to perform simultaneous assignments for multiple assignment modes also is used. As indicated above, the mode choice model outputs up to eight separate vehicle trip tables. Highway networks include existing and proposed HOV lanes as separate facilities. During the assignment process trips by the eight modes are matched with facilities that are available for use by each mode.

#### 6.10.2 Post-assignment Processing

After completing the highway assignments, additional processing is needed to produce reports, data files, and plots tailored to SANDAG needs. Some of the major functions of this post-assignment processing are described below.

**Calibration Error Volume Adjustment.** Base year model-estimated link volumes for individual links differ from ground counts, even after model calibration is complete. An automated adjustment procedure has been developed to adjust future year traffic volumes to compensate for calibration errors.
Managed Lane Volume Adjustments. The 2030 RTP proposes managed lanes on many freeways. Managed lanes allow solo drivers who pay a toll to make use of HOV lanes. However, traffic on managed lanes would be controlled so that level-of-service “D” is maintained. Post-assignment procedures simulate optimal managed lane operation by: (1) shifting traffic from over-capacity main freeway lanes to adjacent managed lanes that have excess capacity; and (2) shifting traffic from over-capacity managed lanes to adjacent freeway main lanes.

Bus Volume Adjustment. Public transit bus volumes are determined in the transit network coding process. These volumes are added to private vehicle traffic volumes from the highway assignment model.

Hourly Distribution Factors. The TransCAD assignment process outputs A.M. peak period, P.M. peak period, and off-peak period traffic volumes, while many applications need hourly traffic volumes. Caltrans collects hourly traffic counts at its permanent count stations. These counts are used to compute the fraction of traffic in each hour of a time period for each direction and count station. Resulting hourly distribution factors are applied to freeway segments after assigning freeway segments to the closest count station.

Level-of-Service Computations. Highway Capacity Manual procedures are used to compute the level-of-service (LOS) for each highway segment based on a V/C ratio using coded capacities and volumes from the adjustment process described above. LOS computations differ by type of facility. On freeways, an LOS rating “A” through “F” is assigned based on the hour with the highest V/C ratio within each time period. When a V/C ratio exceeds 1.0, the hours at LOS “F” are accumulated. While sophisticated traffic queuing procedures do not now exist as a part of long range transportation models, an attempt is made to account for some queuing impacts in the post-assignment process by assigning freeway links up to one mile in back of chokepoints the chokepoint LOS. This results in somewhat higher levels of freeway congestion and lower freeway speeds which should better reflect reality.

LOS computations on surface streets also are based on volume to capacity ratios. Street segments between major intersections are grouped into sections. The highest V/C on any segment within a section determines LOS for the entire section.

Travel Time Computations. Link travel times are re-computed based on adjusted link volumes using Highway Capacity Manual procedures. The same V/C calculations used to assign LOS also are used to look up speeds and intersection delay times associated with VC ratios.

Freeway speeds vary between three MPH and 75 MPH depending on the V/C ratio. Link travel times are recomputed for each hour and an average travel time for each time period is calculated by weighting the hourly travel time by the hourly volume. Again, freeway HOV lane LOS is assumed to be no worse than LOS “D,” so HOV speeds vary between 62 MPH and 75 MPH.

Travel times on surface streets consider both mid-block congestion and delays at signals and stop signs. Mid-block speeds vary between three MPH and the posted speed, depending on the V/C ratio. Intersection delays vary between ten seconds and two minutes and are added to the link travel time computed from mid-block speed. Delays at ramp meters ramp meters range between one minute and 15 minutes. HOV times on ramp meters with HOV bypass ramps are assumed to be one-third of SOV delays.
**Emission Model Inputs.** The California Air Resources Board’s Burden model is used to estimate on-road motor vehicle emissions and fuel consumption. This model requires as input the vehicle miles of travel in each hour by 13 vehicle types (light-duty automobiles, light-duty trucks, heavy-heavy duty trucks, etc.) by 18 speed ranges. Link level traffic volumes are split into vehicle types by applying vehicle type percentages that vary by facility type and hour of the day. These percentages were obtained from the 2000 Vehicle Classification and Occupancy Study. Resulting vehicle type volumes are multiplied by link distances and accumulated by speed range to produce Burden inputs.

**Reporting and Plotting.** Summary statistics such as vehicle miles of travel (VMT), vehicle hours of travel (VHT), and average speeds are computed which are key performance indicators for transportation and land use alternatives. Model outputs also are linked with GIS coverages to produced computer plots and data sets used to display traffic volumes on the Internet.

**6.10.3 Model Calibration**

Comparisons of base year traffic volumes from the highway assignment model with observed traffic counts provide key measures of the model accuracy. Differences between model-estimated and observed VMT at the regional level indicate whether the overall amount of travel in the region is correct. VMT comparisons by facility type may indicate problems with speed assumptions between facility types. Traffic estimates on individual links also are compared with traffic counts. Large discrepancies may indicate network coding errors, miscoding of access opportunities, land use coding errors, or inappropriate trip generation rates.

**6.11 TRANSIT ASSIGNMENT**

The transit assignment step determines route, link, and stop level ridership using inputs listed in Table 27. These transit assignment results, as shown in Table 28, are important when evaluating model accuracy and the effectiveness of proposed transit improvements.

<table>
<thead>
<tr>
<th>Table 27</th>
<th>Transit Assignment Model Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Source</td>
</tr>
<tr>
<td>Transit trips between TAPs by time period</td>
<td>Mode choice model</td>
</tr>
<tr>
<td>External transit trips</td>
<td>Transit Ridership Surveys</td>
</tr>
<tr>
<td>Transit network</td>
<td>Network coding</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 28</th>
<th>Transit Assignment Model Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
</tr>
<tr>
<td>Daily and peak period boardings by route, link, and stop</td>
<td>Summary reports and plots</td>
</tr>
</tbody>
</table>
6.11.1  Model Structure

TransCAD software assigns TAP-to-TAP transit trips to the network. Eight separate transit assignments are produced for peak and off-peak periods; walk and auto access; and local bus and premium service. These individual assignments are summed to obtain total transit ridership forecasts.

Before assigning transit trips, external transit trips coming into San Diego from outside the region need to be added to the internal transit trips estimated by the mode choice model. Currently few transit trips enter from the north or east, however, over 20,000 transit trips cross the Mexican border each day. An external transit trip table for the base year is developed from on-board transit ridership surveys and factored to future years based on border crossing trends to account for these trips.

6.11.2  Model Calibration

Transit ridership forecasts from the transit assignment model are compared with transit counts from the SANDAG transit passenger counting program to determine whether transit modeling parameters need to be adjusted. The transit assignment model itself has few parameters so the calibration process is primarily a check on transit network coding and mode choice procedures.

Some of these comparisons of model-estimated boardings with actual boardings include:

- system level boardings, which may reveal transfer rate problems and lead to changes to the transfer wait time factor in the mode choice model
- boardings by mode, which may reveal modal biases and lead to changes in mode choice modal constants
- boardings by frequency of service, which may show biases that lead to changes in the first wait factor in the mode choice model
- Centre City screenline crossings, which may lead to changes in parking costs
- boardings by stop location, which may indicate problems which specific generators such as a university
CHAPTER 7: COMPARING THE FORECASTS

This section contrasts the primary assumptions and results of the 2030 Cities/County Forecast and the 2030 Regional Growth Forecast Update. For the most part, the differences in assumptions reflect revised data that were available for the latter effort.

7.1 REGIONAL FORECAST ASSUMPTIONS

The two regional forecasts vary in several areas, including changes to land use plans, national and state economic drivers, and current economic conditions. The results of these differences are illustrated in Table 29 which summarizes some key forecast indicators for the year 2030: population, housing, and employment. The year 2030 was the last time point for the 2030 Forecast. The specific differences in the key assumptions are discussed below.

<table>
<thead>
<tr>
<th>Table 29</th>
<th>Population, Housing, and Employment in the Year 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030 Cities/County Forecast</td>
<td>3,855,085</td>
</tr>
<tr>
<td>2030 Regional Growth Forecast Update</td>
<td>3,984,753</td>
</tr>
<tr>
<td>Difference</td>
<td>129,688</td>
</tr>
</tbody>
</table>

7.1.1 Base Year Data

The 2030 Regional Growth Forecast Update is based on 2004 population estimates produced by the California Department of Finance. The 2030 Regional Growth Forecast Update also is based on detailed housing unit estimates that SANDAG compiled from a combination of County Assessor Records, the 2000 Census, and aerial imagery. The Cities/County Forecast was based almost exclusively on the 2000 Census.

7.1.2 Demographic Parameters

Fertility Rates. Table 30 illustrates the differences in the fertility rates used in the 2030 Cities/County Forecast and the 2030 Regional Growth Forecast Update. Regional fertility rates for each ethnic group in the 2030 Regional Growth Forecast Update are slightly lower than those used in the 2030 Cities/County Forecast. The Hispanic fertility rate, in particular, is 16 percent lower in 2030. Fertility rates were lowered primarily because during the 1990s birth rates declined faster than expected in the San Diego region. During that ten-year period the fertility rates for Hispanics and non-Hispanic Whites, Blacks, and Asian and Others declined by 18 percent, 8 percent, 8 percent,
and 11 percent respectively. These more rapid declines and updated U.S. projections by the Census Bureau indicated that our previous assumptions about fertility were too high.

**Table 30**

Total Fertility Rates in the Year 2030*

2030 Cities/County Forecast and 2030 Regional Growth Forecast Update
San Diego Region

<table>
<thead>
<tr>
<th></th>
<th>Hispanic</th>
<th>White</th>
<th>Black</th>
<th>Am Indian</th>
<th>Asian &amp; Other</th>
<th>Hawaii &amp; Pac Island</th>
<th>Other</th>
<th>Two or More Races</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030 Cities/County Forecast</td>
<td>2.51</td>
<td>1.71</td>
<td>2.15</td>
<td></td>
<td></td>
<td></td>
<td>1.86</td>
<td></td>
</tr>
<tr>
<td>2030 Regional Growth Forecast Update</td>
<td>2.12</td>
<td>1.67</td>
<td>2.12</td>
<td></td>
<td></td>
<td></td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-16%</td>
<td>-2%</td>
<td>-1%</td>
<td></td>
<td></td>
<td></td>
<td>-1%</td>
<td></td>
</tr>
</tbody>
</table>

* The total fertility rate is the average number of children a woman will have during her lifetime.

**Household Size.** The differences in household size to the year 2030 for the two forecasts are presented in Table 31. The two forecasts also show very similar trends in household size between 2000 and 2030. Household size is inversely related to household formations in that, for example, lower household formations for the same population mean that on average more persons will live in each house. Future household formation rates decline in both forecasts over time, based on the assumption that our household size will move toward that of Orange County, which had a household size of 3.0 in the year 2000.

**Table 31**

Household Size

2030 Cities/County Forecast and 2030 Regional Growth Forecast Update
San Diego Region

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2004</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030 Cities/County Forecast</td>
<td>2.73</td>
<td>2.79</td>
<td>2.78</td>
<td>2.86</td>
<td>2.88</td>
</tr>
<tr>
<td>2030 Regional Growth Forecast Update</td>
<td>2.73</td>
<td>2.77</td>
<td>2.76</td>
<td>2.80</td>
<td>2.87</td>
</tr>
<tr>
<td>Difference</td>
<td>0%</td>
<td>-1%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Labor Force Participation.** Labor force participation rates determine the age, sex, and ethnic composition of the labor market from a given population mix. Higher participation rates mean that more local residents will be in the local labor market, reducing the need for migration to fill jobs. In the 2030 Regional Growth Forecast Update, labor force participation rates generally were similar to those used in the Cities/County Forecast, based on recent U.S. projections by the Department of Labor.
7.1.3 Economic Drivers

National and state economic data are principal drivers (independent variables) in the DEFM economic equations. The 2030 Regional Growth Forecast Update and the 2030 Cities/County Forecast were based on different long-term national trends. The national economy's underlying growth was slightly lower in the 2030 Regional Growth Forecast Update, particularly toward the end of the forecast horizon. The 2030 Regional Growth Forecast Update also had the benefit of four more years of data for estimating equations. Those years, 2000 to 2004, reflected a period of slower economic growth for the national and local economies and were influential in the resulting equation coefficients. As a result, the growth rates in output for nearly every regional economic sector were higher in the Final 2030 Forecast.

7.2 LAND USE POLICIES

When developing housing unit and employment capacities (the potential for new housing units and jobs), we begin with current land use plans and policies. In the 2030 Regional Growth Forecast Update SANDAG used the current plans and policies of the incorporated jurisdictions and the June 2005 land use plans and the population and housing unit targets. The inputs for the unincorporated areas were used at the request of the County.

Under existing plans and policies housing capacity was lower regionally by 22,800 units in the 2004-base compared to the 2000 base. The decline occurred in slightly more than half of the MSAs. Areas showing an increase in housing capacity include the Central, South Suburban, and East Suburban MSAs. The declines resulted primarily from actual development that occurred between 2000 and 2004. The increase in housing capacity occurring within the Central MSA represented increases in housing densities in the Centre City Planning Area of the City of San Diego. These are illustrated in Table 32.

The shares of the region’s housing unit capacities also changed between the two forecasts. The greatest change in shares occurred in the Central MSA which increased from 22.4 percent to 27.6 percent. North City and North County West MSAs saw the biggest decreases in shares, falling from 19.3 percent to 14.8 percent, and 11.3 percent to 7.9 percent, respectively. All other MSAs had minimal differences in share between the two forecasts.

Overall, employment capacity under existing plans and policies increased in the region by 62,200 jobs between the two forecast base years. In the South Suburban MSA, there were over 45,000 more potential jobs in the 2004 base year. Only the Central and East Suburban MSAs decreased in employment capacity between the 2000 and 2004 forecasting bases. These are seen in Table 33.

Changes in the shares of the region’s employment capacity under current plans and policies were less pronounced than the changes in the shares of housing capacity. The largest change in employment shares occurred in the South Suburban MSA. This magnitude (4.1 percentage points) of the change is not surprising given planned development in that area.
### Table 32
**Housing Unit Capacity Under Existing Plans and Policies**
2000 and 2004
by Major Statistical Area

<table>
<thead>
<tr>
<th>MSA</th>
<th>Base Year</th>
<th></th>
<th></th>
<th>Difference (2004-2000)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td></td>
<td>2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>70,188</td>
<td>22.4%</td>
<td></td>
<td>80,485</td>
<td>27.6%</td>
<td>10,297</td>
</tr>
<tr>
<td>North City</td>
<td>60,524</td>
<td>19.3%</td>
<td></td>
<td>43,185</td>
<td>14.8%</td>
<td>-17,339</td>
</tr>
<tr>
<td>South Suburban</td>
<td>46,664</td>
<td>14.9%</td>
<td></td>
<td>47,500</td>
<td>16.3%</td>
<td>836</td>
</tr>
<tr>
<td>East Suburban</td>
<td>34,056</td>
<td>10.8%</td>
<td></td>
<td>34,308</td>
<td>11.8%</td>
<td>252</td>
</tr>
<tr>
<td>North County West</td>
<td>35,564</td>
<td>11.3%</td>
<td></td>
<td>23,082</td>
<td>7.9%</td>
<td>-12,482</td>
</tr>
<tr>
<td>North County East</td>
<td>52,753</td>
<td>16.8%</td>
<td></td>
<td>48,024</td>
<td>16.5%</td>
<td>-4,729</td>
</tr>
<tr>
<td>East County</td>
<td>14,238</td>
<td>4.5%</td>
<td></td>
<td>14,566</td>
<td>5.0%</td>
<td>-328</td>
</tr>
<tr>
<td>Region</td>
<td>313,987</td>
<td>100.0%</td>
<td></td>
<td>291,150</td>
<td>100.0%</td>
<td>-22,837</td>
</tr>
</tbody>
</table>

* Potential new housing units.

### Table 33
**Employment Capacity Under Existing Plans and Policies**
2000 and 2004
by Major Statistical Area

<table>
<thead>
<tr>
<th>MSA</th>
<th>Base Year</th>
<th></th>
<th></th>
<th>Difference (2004-2000)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td></td>
<td>2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>79,951</td>
<td>12.5%</td>
<td></td>
<td>67,349</td>
<td>9.6%</td>
<td>-12,602</td>
</tr>
<tr>
<td>North City</td>
<td>122,506</td>
<td>19.2%</td>
<td></td>
<td>137,599</td>
<td>19.6%</td>
<td>15,093</td>
</tr>
<tr>
<td>South Suburban</td>
<td>167,579</td>
<td>26.3%</td>
<td></td>
<td>212,722</td>
<td>30.4%</td>
<td>45,143</td>
</tr>
<tr>
<td>East Suburban</td>
<td>65,222</td>
<td>10.2%</td>
<td></td>
<td>47,408</td>
<td>6.8%</td>
<td>-17,814</td>
</tr>
<tr>
<td>North County West</td>
<td>81,337</td>
<td>12.7%</td>
<td></td>
<td>98,387</td>
<td>14.0%</td>
<td>17,050</td>
</tr>
<tr>
<td>North County East</td>
<td>95,040</td>
<td>14.9%</td>
<td></td>
<td>109,619</td>
<td>15.7%</td>
<td>14,579</td>
</tr>
<tr>
<td>East County</td>
<td>26,461</td>
<td>4.1%</td>
<td></td>
<td>27,212</td>
<td>3.9%</td>
<td>751</td>
</tr>
<tr>
<td>Region</td>
<td>638,096</td>
<td>100.0%</td>
<td></td>
<td>700,296</td>
<td>100.0%</td>
<td>62,200</td>
</tr>
</tbody>
</table>

* Potential new jobs.
7.3 SUBREGIONAL FORECAST

The Urban Development Model (UDM) is used to produce the subregional forecast. Most of the differences in the assumptions are due to different results from calibrating the various distribution algorithms for employment, housing stock, households, and income. For the 2030 Regional Growth Forecast Update, each of the UDM components was recalibrated using 2004 base-year data. These calibrations included establishing new parameters and error term adjustments for the employment gravity model, the commute time curve, and the income distribution curve.

The remaining differences in UDM between the 2030 Cities/County Forecast and 2030 Regional Growth Forecast Update are the result of land use assumptions and how they translate into housing stock and employment allocations. To compare the 2030 Cities/County Forecast to the 2030 Regional Growth Forecast Update, we focused on the year 2030, because it was the terminal year of both forecasts.

The differences in housing unit forecasts for MSAs in the year 2030 are presented in Table 34. Regionally there were more than 129,100 more housing units in the 2030 Regional Growth Forecast Update and these additional units are evident in all MSAs. However, there are only minor differences in the shares of the region’s housing units between the two forecasts, with the greatest difference in share of forecasted housing stock occurring in the North City MSA.

Table 35 presents a similar comparison for employment. In the 2030 Regional Growth Forecast Update, higher employment was forecast for South Suburban MSA. This trend is consistent with planned development in that region. Conversely, the Central MSA share of employment decreased from 21.3 percent to 18.4 percent, which is consistent with employment changes that occurred in the Central MSA between 2000 and 2004.

Table 34

<table>
<thead>
<tr>
<th></th>
<th>Forecast Series</th>
<th>Difference (RGFU-C/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2030 Cities/County Forecast Update</td>
<td></td>
</tr>
<tr>
<td>MSA</td>
<td>Number</td>
<td>Share</td>
</tr>
<tr>
<td>Central</td>
<td>294,342</td>
<td>21.7%</td>
</tr>
<tr>
<td>North City</td>
<td>328,630</td>
<td>24.3%</td>
</tr>
<tr>
<td>South Suburban</td>
<td>144,689</td>
<td>10.7%</td>
</tr>
<tr>
<td>East Suburban</td>
<td>205,826</td>
<td>15.2%</td>
</tr>
<tr>
<td>North County West</td>
<td>172,640</td>
<td>12.7%</td>
</tr>
<tr>
<td>North County East</td>
<td>185,352</td>
<td>13.7%</td>
</tr>
<tr>
<td>East County</td>
<td>22,609</td>
<td>1.7%</td>
</tr>
<tr>
<td>Region</td>
<td>1,354,088</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Table 35
Civilian Employment in the Year 2030
2030 Regional Growth Forecast Update and 2030 Cities/County Forecast
by Major Statistical Area

<table>
<thead>
<tr>
<th>MSA</th>
<th>2030 Cities/County</th>
<th>2030 Forecast Update</th>
<th>Difference (RGFU-C/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
</tr>
<tr>
<td>Central</td>
<td>373,402</td>
<td>20.5%</td>
<td>383,989</td>
</tr>
<tr>
<td>North City</td>
<td>646,005</td>
<td>35.4%</td>
<td>678,975</td>
</tr>
<tr>
<td>South Suburban</td>
<td>167,253</td>
<td>9.2%</td>
<td>190,974</td>
</tr>
<tr>
<td>East Suburban</td>
<td>184,778</td>
<td>10.1%</td>
<td>191,514</td>
</tr>
<tr>
<td>North County West</td>
<td>228,395</td>
<td>12.5%</td>
<td>230,103</td>
</tr>
<tr>
<td>North County East</td>
<td>210,820</td>
<td>11.6%</td>
<td>221,684</td>
</tr>
<tr>
<td>East County</td>
<td>13,377</td>
<td>0.7%</td>
<td>16,443</td>
</tr>
<tr>
<td>Region</td>
<td>1,824,030</td>
<td>100.0%</td>
<td>1,913,682</td>
</tr>
</tbody>
</table>

7.4 TRANSPORTATION MODEL

In June 2005 SANDAG conducted a Peer Review of the transportation models with modeling professionals from major metropolitan areas around the country. A 2006 Independent Transit Review Panel further evaluated transit patronage forecasts as a part of the broader objective of improving San Diego transit service. These model reviews concluded that the SANDAG model procedures were basically sound, but recommended a number of near-term improvements.

The most significant change to transportation model procedures since the last documentation published in 2003 was the estimation of a new mode choice model based on San Diego survey data. Other major modifications include an enhanced trip distribution feedback loop process, school trip generation based on population by age category, and an update of the calibration base year from 2000 to 2004.

One of the new features of the revised mode choice model is the ability to forecast trips on toll facilities based on cost of the toll and the time savings offered by the facility. The previous RTP was the first to propose construction of a network of freeway managed lanes that would allow toll paying single occupant vehicles to use HOV lanes with excess capacity. The new toll procedures estimate in a more rigorous manner the traffic volumes and toll revenues on these managed lanes and other toll facilities such as the soon to open SR 125 Toll Road.

Federal Transit Agency (FTA) approval of transit forecasting procedures is required before model results can be used to justify federal funding for major transit investments. The new mode choice model has modified transit patronage forecasting procedures to comply with FTA guidelines. As a result the new model yields somewhat lower light rail ridership forecasts. Lower ridership also is forecast on proposed bus rapid transit (BRT) service in response to peer review comments on BRT forecasts in the last RTP.
The enhanced feedback loop process was another major revision to previous modeling procedures. First, a zone system with 2,000 zones was developed that aggregates the 4,605 traffic assignment zones for trip distribution purposes. The smaller number of TDZs enables the feedback loop process to run in a reasonable length of time. Gamma function parameters were then re-estimated to make use of TDZ level composite utilities that account for travel time and cost by mode and time period.

Another fundamental change that affected the entire transportation modeling process was to calibrate the model to year 2004 base year conditions, whereas the previous models had a 2000 base year. During the calibration process model parameters are adjusted as necessary to bring model results into agreement with observed data. The recalibrated models reflect the drop-off in transit ridership that has occurred over the several years, which results in somewhat lower transit forecasts.

7.4.1 Highway Network Inputs

The model uses highway facilities proposed in the 2030 RTP, which has more freeway HOV lanes and fewer general purpose lanes than the 2020 RTP. An assumption in the 2020 RTP that Intelligent Transportation Systems (ITS) improvements would yield a 10 percent increase in freeway capacity by 2020 was modified. A 10 percent increase in freeway capacity now is assumed only for freeway segments that are currently not ramp metered, but are planned for metering in the future. TransCAD is able to deal discretely with mid-link and intersection conditions. Procedures were modified to make use of this feature and the TransCAD generalized cost concept was used to create a composite time and cost measure.

7.4.2 Trip Generation

A new trip rate was added for Indian gaming casinos and unique generators were located at existing and proposed casinos. Trips at external zones were updated with year 2000 traffic counts and higher forecasts of external-internal trips were input to reflect increasing interregional commuting. Regional control totals for some trip purposes were linked to different regional variables to correspond better with activity changes. Trip rates were adjusted slightly in the year 2000 calibration process to bring model-estimated travel in agreement with observed counts. Trip rates were also adjusted downward to correct a tendency of the 2020 models to overestimate inter-zonal nonhome based trips.

7.4.3 Trip Distribution

The TransCAD gamma function is used to generate friction factors based on generalized costs, replacing TRANPLAN friction factors. A post gravity model step was added that adjusts home-work and home-college trips to match the zip code distribution from a survey of University of California San Diego students and faculty. A tendency of the 2020 distribution model to overestimate inter-zonal trips was corrected. The gravity model now distributes internal-external trips. External trips were previously obtained by factoring a base-year trip table.

7.4.4 Highway Assignment

The TransCAD highway assignment procedures replace TRANPLAN procedures used previously. Additional assignment iterations are performed using separate link and intersection delay functions to better reflect congestion effects. The post-assignment process also was modified substantially. A
technique for identifying a one mile queue in back of over-capacity freeway links was added. A procedure was developed for reflecting the effects of HOV lanes and managed lanes by shifting traffic from overcapacity main lanes to adjacent underused managed lanes and for shifting traffic from overcapacity HOV lanes to main lanes. Hourly traffic distribution factors were added to determine the length of traffic congestion, reflect the effects of Travel Demand Management programs, and more accurately calculate average speeds for A.M. peak, P.M. peak, and off-peak periods. Procedures for outputting 2030 RTP performance measures and inputs to the Burden air pollution emissions model were added.

7.4.5 Transit Network Inputs

A greatly expanded transit system is proposed in the 2030 RTP with regional (yellow car) and corridor (red car) bus rapid transit (BRT) service serving many parts of the region. This is a new type of transit service that would have stations and operating characteristics similar to commuter rail and light rail, but service would be provided by buses operating on HOV lanes, some grade-separated transit ways, and surface streets. Two new transit modes were introduced to accommodate the proposed regional and corridor BRT service. Transit-ways, routes, stations, and operating characteristics were added to the network based on maps developed by transit planners.

In addition to coding the expanded transit network, transit network analysis procedures were modified to accommodate the new service modes. Congested speeds were replaced with free-flow speeds on surface streets used by BRTs to simulate the effects of priority treatments planned for BRT routes. Fares were computed for the new service, which match current trolley and commuter rail fares.

Finally, transit walk access procedures were upgraded. A walkability factor was added to reflect the fact that traditional neighborhoods with grid pattern streets tend to have more direct walk connections than suburban areas with curvilinear street patterns. Walk distances from individual MGRAs within TAZs to transit stops are now calculated, replacing a simplified approach that aggregated MGRAs and used a standard walk access distance of one-eighth mile for short walk connections of ¼ mile or less and a ½ mile distance for long walk connections of one-quarter mile to one-half mile. The maximum walk distance for rail and BRT stops was increased from one-half mile to three-quarter mile.

7.4.6 Mode Choice Model

Mode choice model equations and parameters were restructured to incorporate a different value of time for low income households and higher income households. The objective was to reflect the fact that very few high income households now use transit, but not bias the model against future transit alternatives where transit travel times more closely match highway times. A ten-minute transfer penalty was replaced with a higher transfer wait factor in order to correctly estimate existing transfer rates without biasing the model against transit alternatives with improved service frequencies. A factor on congested highway time was added to reflect the perception that travel in congested conditions is more onerous than travel in free-flow conditions. Mode choice parameters were adjusted to match regional level Census 2000 work mode shares and 2000 transit passenger counts. Procedures to compute 21 performance measures for the 2030 RTP also were added.