Davis Travel Demand Model – Development Report

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1. INTRODUCTION

Background

The City of Davis commissioned the development of a travel demand model in 1991 for use in developing the city's General Plan. This model was recalibrated in 1998 using updated data, and was used by the City to evaluate several large land developments that were then under consideration, including Mace Ranch and Wild Horse.

Now that these developments are complete and their traffic impacts are no longer speculative, there is a need to update the model using data that includes these developments. The updating also creates an opportunity to model the traffic generated by UC Davis in a much more detailed and accurate manner than was done previously. Moreover, since the original development of the model in 1991, travel demand forecasting software has become much more powerful. Programs such as TransCAD can now take roadway data directly from the City's GIS and produce outputs that can be directly entered back into the GIS for use by all City departments.

In July 2002 Fehr & Peers Associates, Inc. was engaged to create a new travel demand model using the best available software. This document describes the model development process and presents the validation results, which measure the model's accuracy.

Study Area

Figure 1 shows the study area for the Davis Travel Demand Model. The area encompasses the entire City of Davis and its immediate surroundings, including all of the UC Davis main campus. The roads shown in the figure and described below form the main road network as defined in the General Plan.

Freeways

- Interstate 80 (I-80) is the main access route connecting Davis with Sacramento to the east and the Bay Area to the west. The section in the study area is a 6-8 lane divided freeway.
- State Route 113 (SR-113) runs north through the City of Davis from a "T" interchange with I-80 near UC Davis. SR-113 connects Davis to Woodland and other cities further north. The section in the study area is a 4-lane divided highway.

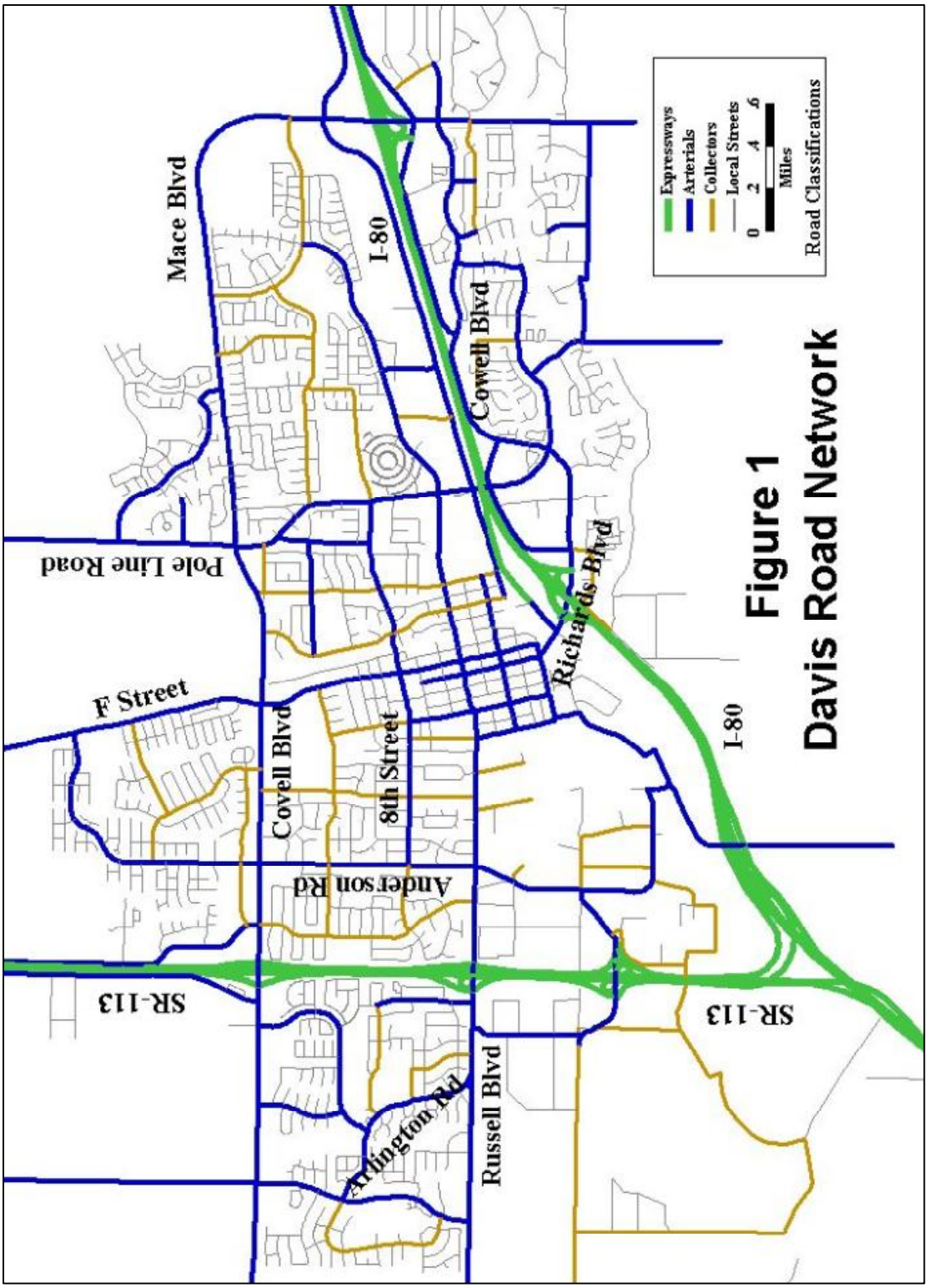


Figure 1
Davis Road Network

Arterials

- Russell Boulevard / Fifth Street is the most important east-west arterial running through Davis. It enters the city from the west, and then forms the border between UC Davis (to its south) and west and central Davis to its north. Russell Boulevard then passes through the central business district, becomes Fifth Street, and serves as a spine for east Davis. Altogether there are fourteen signalized intersections on Russell Boulevard/Fifth Street .
- Covell Boulevard is the second most important east-west arterial, running parallel to Russell Boulevard one mile to the north. Covell Boulevard starts as County Road 31 west of Davis and runs the entire length of the City, with thirteen signalized intersections. Adjacent land uses include three shopping centers, a hospital, and Davis High School. Its eastern end is a curve after which it becomes Mace Boulevard
- Richards Boulevard is a short road connecting Davis' central business district to I-80 and south Davis. The section connecting downtown Davis to I-80 passes through a 2-lane tunnel under a set of railroad tracks. The road then widens to accommodate the turn lanes of the I-80 interchange, and ends in a junction with Cowell Boulevard
- Cowell Boulevard is the east-west spine of south Davis. Adjacent land uses include two shopping centers and a medical center.

Primary Collectors

- Eighth Street runs east-west through the central part of Davis between Covell and Russell. The adjacent land uses are mainly residential.
- Pole Line Road enters the city from the north as County Road 102. The adjacent land uses are mixed, and include apartments, a cemetery, the DMV office, a U.S. Post Office, and some single family dwellings with driveways directly onto Pole Line Road. It has one through lane in each direction, with turn pockets in some locations.
- Anderson Road runs north-south through central Davis and part of north Davis, curving east-west near the city's northern boundary. It has front-on single family dwellings for most of its length, but also has an adjacent school and shopping center.
- F Street enters the city from the north as County Road 101A, passes through a residential area, and becomes the north-south spine of the central business district. It has one through lane in each direction, with turn pockets in some locations.

- Arlington Road is the most important collector in west Davis. Adjacent land uses include a shopping center and a junior high school.

The remaining roads in the City of Davis are considered secondary collectors or local streets.

UC Davis Roadways

- **La Rue Road** is one of the northern gateways to campus. La Rue Road forms the western portion of campus loop roadway between California Avenue and Russell Boulevard. La Rue Road is two lanes in the southern portion of campus and widens to four lanes at Garrod Drive. La Rue Road becomes Anderson Road north of Russell Boulevard and provides access to uses within the northern area of the City of Davis.
- **Hutchison Drive** is the western campus gateway. Hutchison Drive is primarily four lanes east of SR 113 except for a two lane section between Health Sciences Drive and La Rue Road. Hutchison Drive serves vehicles traveling to the core campus and is restricted to campus and emergency vehicles east of California Avenue. West of SR 113, Hutchison Drive is two lanes and serves the agricultural uses and campus facilities between SR 113 and County Road 98.
- **Old Davis Road** is the southern campus gateway and forms the southern portion of the campus loop roadway. Old Davis Road is two lanes and provides access to the South Entry Parking Structure and the Robert and Margrit Mondavi Center for the Performing Arts. The portion of the roadway between California Avenue and Mrak Hall Drive was recently realigned to provide access to the performing arts center and is referred to as New Davis Road.

Software

One of the first decisions made in the development process was the selection of travel demand software, which was based on the following criteria:

- It should be a standard, off-the-shelf package so that it is readily available to any potential user;
- The package should be both powerful and flexible;
- Technical support should be readily available; and
- The latest generation of software package is preferable because it will be more powerful and is likely to remain commercially available longer than the older packages.

Of the latest generation of standard packages, TransCAD was selected because of its flexibility and because of its GIS capabilities that make it easy to generate and compare land use scenarios.

2. COMPONENTS OF THE MODEL

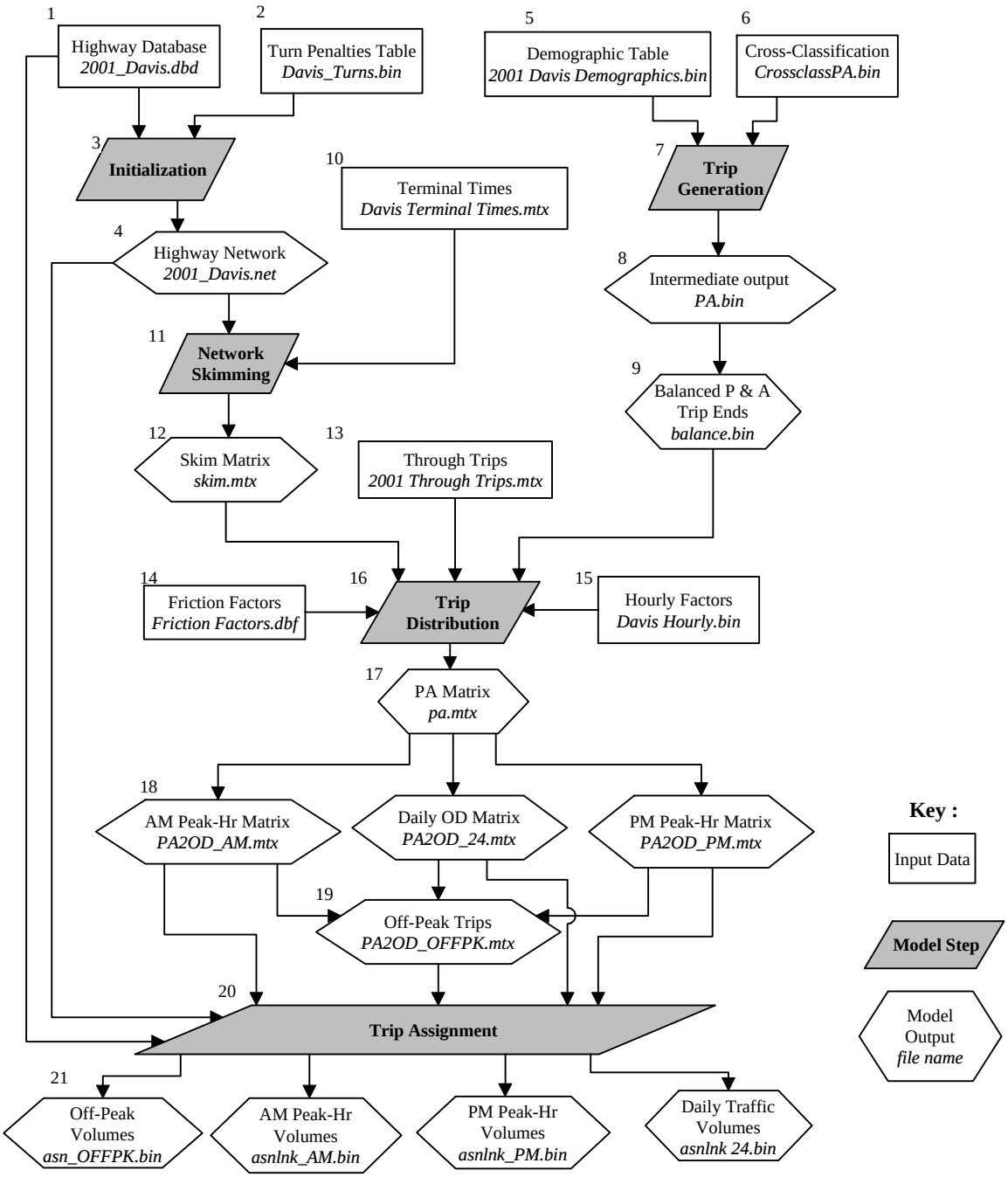
The components of the Davis travel demand model are described in the sections below, and their relationship to each other is shown in Figure 2. The input data is discussed in detail in the next chapter.

Main Model Files and Stages

The model consists of three kinds of components, namely input data, model steps, and model outputs. The input data are files prepared by the modeler to represent different aspects of Davis traffic conditions. The model steps are the five processes that the model goes through in determining traffic flows (see Figure 2). These steps are applicable to most traffic models. The model outputs are data files produced by the model. Some of these files are used as inputs into other steps in the model.

1) Highway Database *(2001_Davis.dbd)*: This is a family of files showing the length, location, free-flow speed, capacity, and other characteristics of the roadways in Davis.
2) Turn Penalty Table (*Davis_Turns.bin*): This file contains information about delays incurred when vehicles make certain movements, such as a left turns across Russell Boulevard. It also contains information on where turns are prohibited.
3) Initialization: In this step the model takes the highway data and converts it into a format used by the computer. Some basic characteristics of the input data are also checked (e.g., no two links can have the same ID number) and an error message may occur if problems are detected.
4) Highway Network *(2001_Davis.net)*: The output from the initialization step is a network file for use in later steps in the model.
5) Demographic Table *(2001 Davis Demographics.bin)*: The travel demand characteristics of the traffic analysis zones (TAZ's) are stored in this file. This includes such things as the number of single- and multi-family dwellings, and the square footage or acreage of commercial, industrial, and other land uses.
6) Cross Classification Table *(CrossclassPA.bin)*: This file contains the daily trip production and attraction rates for each of the land uses listed in the demographic table. These rates are disaggregated by trip purpose. For example, one cell in the table would contain the average daily number of home-based work (HBW) trips per single-family dwelling.

FIGURE 2: COMPONENTS OF THE DAVIS TRAVEL DEMAND MODEL



7) Trip Generation: This step multiplies the demographic and cross classification tables together to produce a first estimate of trip ends, and then balances the production and attraction totals.

8) Intermediate Output *(PA.bin)*: This file contains the model's initial estimate of trips, based on multiplying the demographic data by the cross classification data.

9) Balanced P & A Trip Ends *(balance.bin)*: The model balances the trip production and attraction estimates based on instructions given in the model's resource file. The modeler chooses which estimate is more accurate (productions or attractions). The model then factors the other estimate up or down until it equals the selected estimate.

10) Terminal Times Matrix *(Terminal Times.mtx)*: This file stores the average travel times associated with the start and end of each trip, such as time spent looking for a parking place and parking. The file is in the form of TAZ-TAZ matrix, so each cell contains the sum of the terminal times at the origin TAZ and destination TAZ. External trips do not make use of terminal times[1].

11) Network Skimming: The model examines the travel times for all of the possible routes between each origin TAZ and each destination TAZ, including the terminal times, and stores information on the quickest route.

12) Skim Matrix *(skim.mtx)*: This file stores information on the quickest path between each origin-destination pair. The data is stored in the form of a TAZ-to-TAZ matrix with each cell showing the shortest travel time in minutes.

13) Through Trips *(2001 Through Trips.mtx)*: This file informs the model of the number of through trips, in TAZ-to-TAZ format.

14) Friction Factors *(Friction Factors.dbf)*: This file contains the friction factors that will be used in determining the relative attractiveness of TAZ's based on the travel time from the origin TAZ to the destination TAZ.

15) Hourly Factors *(Davis Hourly.bin)*: This file informs the model of the percentage of trips that take place during the peak hours. The file is in the form of a matrix with one row for each hour of the day and two columns for each trip purpose, one for the initial trip, and the other for the return trip. The Davis model includes an AM peak hour (7:00-8:00) and a PM peak hour (16:00-17:00).

[1] The travel times for external zones are calculated in a post-processing step external to the TransCAD model. This enables analysts to determine the difference in the regional total VMT when UCD students live in Davis versus the same number of students living elsewhere and commuting to campus.

16) Trip Distribution: The model uses the five input files to determine how trips are distributed among origin-destination pairs and among time periods.

17) Production-Attraction Matrix *(pa.mtx)*: The trip distribution step produces this file as an intermediate product prior to applying hourly factors.

18) Origin-Destination Matrices *(PA20D_24.mtx, A2OD_AM.mtx, PA2OD_PM.mtx)*: The model produces an output file containing the number of trips between each origin-destination pair for the AM peak hour, PM peak hour, and 24-hour periods.

19) Off-Peak Origin-Destination Matrix *(PA20D_OFFPK.mtx)*: The model takes the peak hour trip matrices, multiplies them by a factor so that they represent a 3-hour peak period, and then subtracts this from the 24-hour matrix. The result is a matrix of trips taken during off-peak hours. This is then divided by a factor to produce the loading during the afternoon off-peak period.

20) Trip Assignment: The final step in the model is an iterative process whereby the quickest route is determined for each of the trips in the O-D matrix, taking into account congestion caused by other trips.

21) Hourly Traffic Volumes *(asnlnk_AM.bin, asnlnk_PM.bin, asnlnk_OFFPK.bin, asnlnk24.bin)*: These files store the traffic volumes on each link for the AM peak hour, the PM peak hour, a typical off-peak hour, and for the 2-4 hour period. These volumes are among the main outputs of the model.

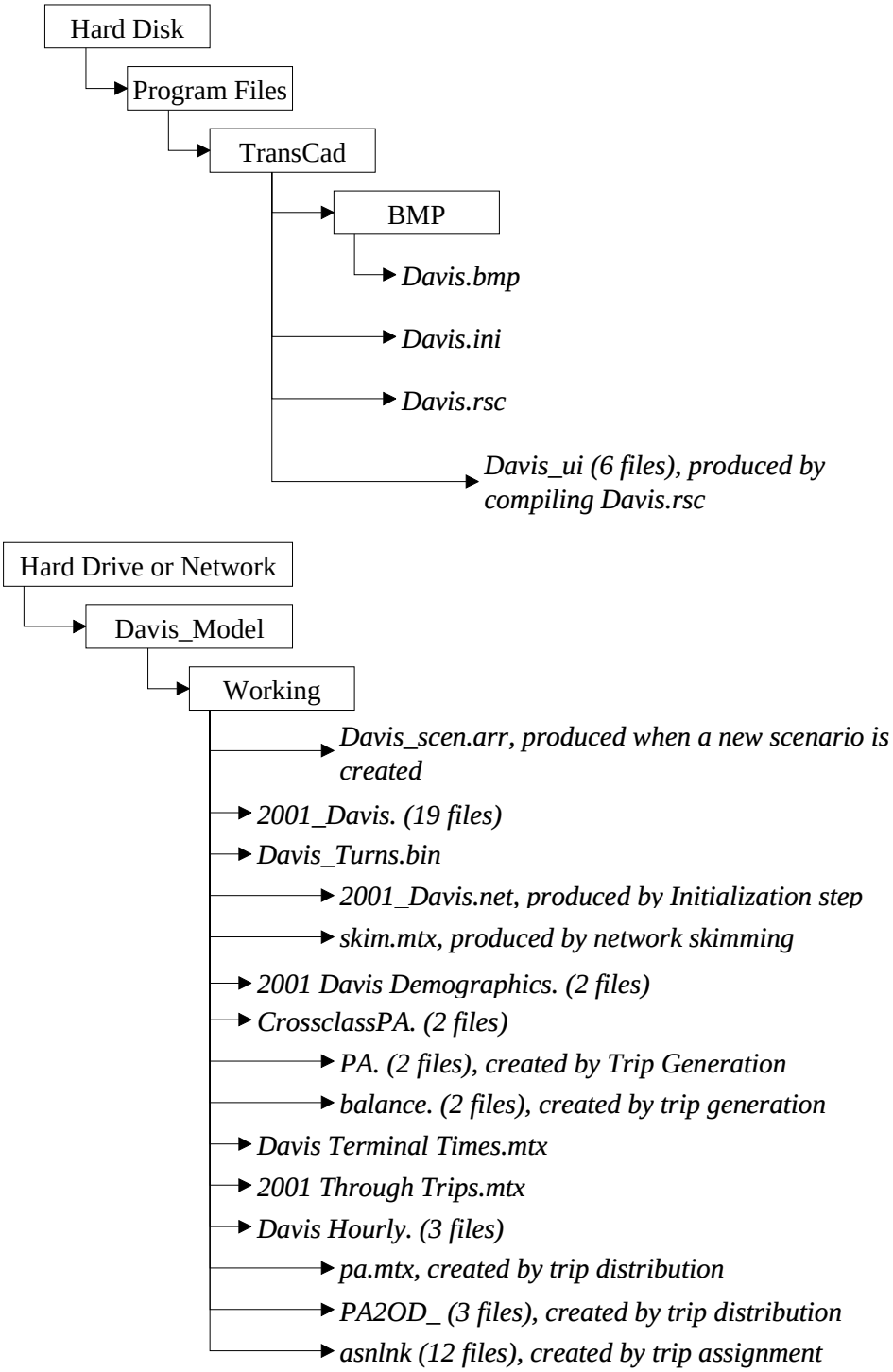
The off-peak trip matrix and assignment were not included in the scope of work for model development. They are somewhat experimental in nature due to the difficulty in defining a "typical" off-peak hour. Users should be cautious when making use of these outputs.

File and Directory Structure

The file structure of the model is shown in Figure 3. The model requires three files (see upper portion of Figure 3) to be stored in the TransCAD directory along with the TransCAD software.

The data files shown in the lower half of Figure 3 can be stored either on the user's hard drive or in a local area network. These files are a mix of inputs supplied by the user and outputs produced by the various steps of the model.

FIGURE 3: FILE STRUCTURE



3. INPUT DATA

As described in the previous chapter, the Davis travel demand model incorporates many types of input data. These are described below.

TAZ System

The 1998 model divided the city into traffic analysis zones (TAZs) which the model uses to connect land uses to the road network. This system was carried over to the new model, with the following improvements (see Figure 4):

- The boundaries of some TAZ were shifted to better reflect the way the neighborhoods connect to the road network. For example, TAZs 230 and 233 had been oriented east-west even though the neighborhood that they represented was split north-south by a greenway. The boundary between these TAZ was re-oriented north-south along the greenway, so that trips to and from these neighborhoods would be assigned to the correct roads.
- The main campus of UC Davis (north of I-80 and east of SR-113) is now represented by seventeen TAZs, with detailed land use data for each one.

The previous system of external zones was carried through to the previous model unchanged, because the city's connections to the regional road network have not changed since the 1998 model was developed.

To make this task easier for future users to add TAZs to the model, 49 "dummy" TAZs were included in the model. These are essentially placeholders that reserve TAZ numbers and ensure that all of the model's data files will be large enough to accommodate any need for additional analysis zones in the future. The dummy TAZs are stored in several clusters on the outskirts of the network, ready to be moved to wherever they are needed.

Land Use Data

The 1998 model included all of the land uses existing at that point in time. The City reviewed and updated this data to include developments that had occurred between 1998 and 2002.

The land use and trip generation rates used in future year scenarios are explained in Appendices C, D, and E.

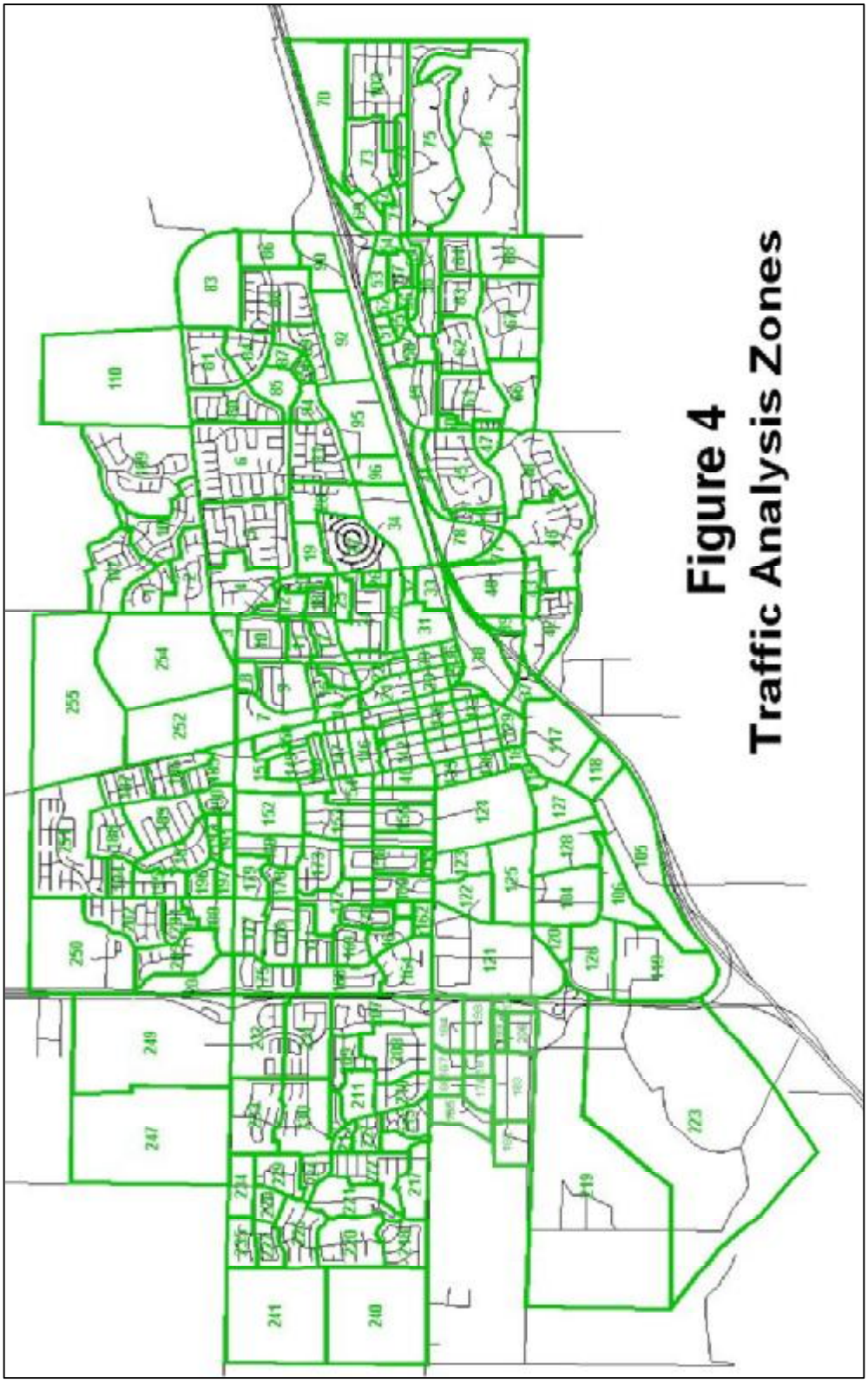


Figure 4
Traffic Analysis Zones

Trip Generation Rates

Trip generation rates relate the number of vehicle trips going to and from a site to some measure of the intensity of use at the site. Trip generation rates must be defined for each end of each trip. For example, by convention all trips with one end at a residence is defined as being "produced" by the residence and "attracted" to the other use (job, school, shop, etc.), and so a trip generation rate is needed for both land use types.

The usual source for vehicle trip generation rates is *Trip Generation*, by the Institute of Transportation Engineers (ITE), 6th Edition, 1997. The trip generation rates used in the Davis model were all based on this source except where modified as described below.

Home Based Trips: Given that primary land uses in Davis are single-family detached houses and apartments, and that Davis is generally viewed as being less car-oriented than most cities in the Sacramento region, it was important to develop locally valid trip generation rates for these two categories of land use rather than rely on the ITE trip generation rate. 24-hour traffic counts were therefore conducted at the access points to three neighborhoods of single family dwellings and two apartment complexes[2] (see Figure 5). By comparing the ITE rates to the traffic counts, it was found that the ITE rate underestimated vehicle trips from single-family dwellings by 34 percent and over-estimated vehicle trips from multi-family dwellings by 10% (See Table 1).

Table 1: Results of Trip Generation Surveys

Survey Location	DUs	Trips/Day	Trips/Day/DU
Single Family Dwellings			
Montgomery Ave.	134	1,703	
Catalina Drive	431	6,523	
Marina Circle	510	5,610	
Total	1,075	13,836	12.87
ITE Rate for SFD			9.57
Ratio Local/ITE			**1.34**
Multi-Family Dwellings			
Bidwell Street	252	1,372	
Cranbrook Apts	216	1,420	
Total	468	2,792	5.97
ITE Rate for MFD			6.63
Ratio Local/ITE			**0.90**

[2] A fourth neighborhood of single-family dwellings was also counted, but the results were rejected when it was discovered that some of the units were still under construction and generating large amounts of construction traffic. A third apartment complex was counted, but the results were rejected when it was found that the cobblestone surface of the driveway affected the reliability of the hose counts. The remaining count sites were mature communities with reliable hose counts and little if any cut-through traffic. Two of the communities were counted a second time to double-check the results.

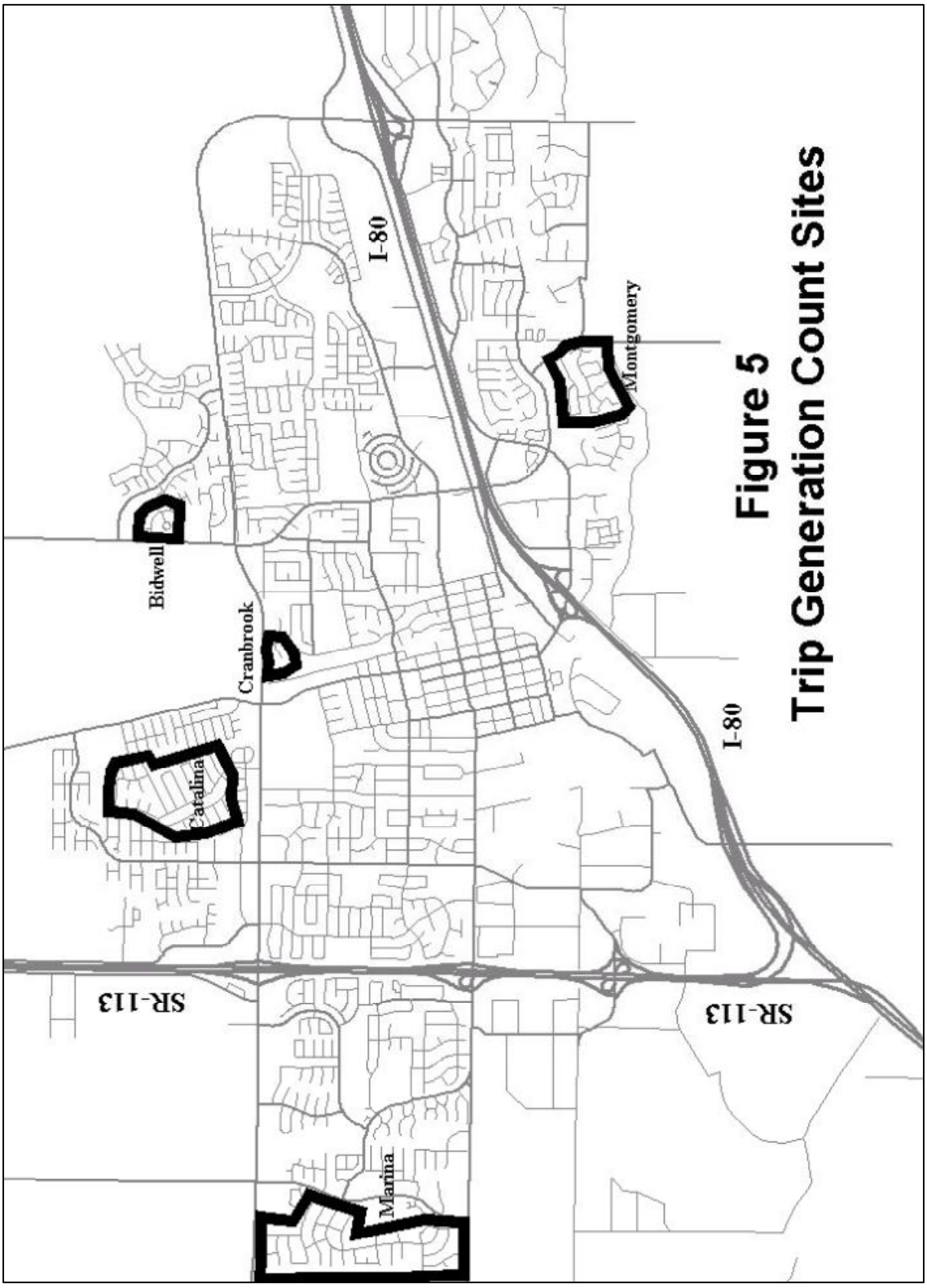


Figure 5
Trip Generation Count Sites

The result for single-family dwellings may surprise some Davis residents that view their city as being very bicycle and pedestrian-friendly, and so deserves some explanation. First, the rates in Davis may be lower than those of other cities in the state which form the basis for most residents' comparison. Nevertheless, car use is so prevalent in California compared to elsewhere in the country that the region as a whole tends to be much higher than the national average represented in the ITE rates. So Davis may be one of the least car-oriented cities in a very car-oriented region.

Also, the ITE rates are based on data that has accumulated since the 1960's. Trip generation rates seem to have risen over this period due to the increasing number of two-job households and income growth in general. It is quite possible that the inclusion of older data has made the ITE rate too low.

Finally, a distinction needs to be made between those bicycle and pedestrian trips with a clear purpose and destination (such as to buy milk at the supermarket) and those that are taken for recreation and exercise. The former could substitute for car trips and thus reduce the overall rate of traffic generation (which seems to be the case for multi-family dwellings) while the latter have no effect on the rate of trip-making by car trips but instead serve primarily to improve the quality of life of Davis residents. It appears likely that many of the bicycle and pedestrian trips that one sees in Davis are "quality of life" trips rather than transportation in the usual sense of the term.

Home Based Work (HBW) Trips: The production rate for home-based work trips was computed by taking the overall vehicle trip-generation rate for each housing type and multiplying it by the percent of work trips found in SACOG's 2000 household survey[3] (see Table 2). The HBW attraction rates were computed by taking the overall trip attraction rate for each land use type[4] and multiplying this by the percent work trips found in NCHRP 365[5].

School Trips: The production rate for home-based school trips was found by taking the overall vehicle trip-generation rate for each housing type and multiplying it by the percent of school trips found in SACOG's 2000 household survey. A reduction factor was applied to the school trips generated by multi-family dwellings to account for the fact that most apartments in Davis are rented by students without children. School trip attractions were computed by multiplying the number of K-8 and high school students by their respective ITE trip generation rates.

[3] *2000 Sacramento Area Household Travel Survey - Final Report*, SACOG, November 2000

[4] For several of the non-residential land uses (e.g. public/quasi-public, neighborhood commercial) no directly corresponding ITE category exists, and so a mixture of several rates was used.

[5] *National Cooperative Highway Research Program Report 365 – Travel Estimation Techniques for Urban Planning*, Transportation Research Board, 1998

UC Davis (UCD) Trips: The new model considers the trips associated with UC Davis in a separate category from other trips. It further disaggregates UC Davis as producing three kinds of trips, namely trips associated with UC Davis employees, those associated with students living on campus, and those associated with off-campus students. The first two groups were assumed to produce UCD trips, which are trips with one end at an off-campus residence and the other end on the UC Davis campus. On-campus students were assumed to make no UCD trips (vehicle trips to campus locations), but to instead generate home-based other trips (shopping, dining out, etc.).

The number of UC employees residing in Davis was computed by taking the total number of UC Davis employees and multiplying this by the percent that are Davis residents taken from the *UC Davis Long-Range Development Plan*[6]. The number of off-campus students in Davis was similarly found by taking the number of off-campus students and multiplying this by the percent resident found in the *UC Davis Long Range Development Plan*. Unfortunately, no information was available on how the resident employees and students are distributed within Davis. Therefore the simplifying assumption was made that the employees are spread evenly among the city's single-family dwellings and that the students are spread evenly among the city's multi-family dwellings. This enabled us to produce a trip generation rate for UCD trips for both housing types.

The trip attraction rate for UCD trips was taken from surveys done for the *UC Davis Long Range Development Plan*.

Home Based Other (HBO) Trips: Home-based work trips, school trips, and UCD trips were subtracted from the total trip generation rate for households, leaving as a residual the production rate of home-based other trips. The HBO attraction rates were computed by taking the overall trip attraction rate for each land use type and multiplying this by the percent HBO trips found in NCHRP 365.

Non-Home Based (NHB) Trips: For retail, industrial, and office land uses, HBW and HBO trips were subtracted from the overall trip generation rate, leaving NHB trips as the residual.

The trip generation rates described above produce results that correspond well to actual conditions, as will be discussed in the later section on model validation. Further details of the methodology can be found in Appendices C, D, and E.

[6] *Data Collection and Intersection Analysis for the University of California, Davis Long Range Development Plan*, Fehr & Peers Associates, Fall 2001.

Table 2: Daily Trip Vehicle Generation Rates Used in the Davis Model

Land Use Category	Unit	Code	Production Or Attraction	Home-Based Work	School	Home-Based Other	Non-Home Based[7]	UCD Trips	Research Park Trips	Total Daily Trips
Single-Family or Duplex										
West & Central Davis	DU	R1,R2	Production	2.532	0.629	8.531	0.000	1.127	0.000	12.819
North & East Davis				2.532	0.629	8.389	0.000	1.268	0.000	12.819
South Davis				2.532	0.629	8.274	0.000	1.384	0.000	12.819
Apartments										
West & Central Davis	DU	R3	Production	1.240	0.109	4.153	0.000	0.459	0.000	5.961
North & East Davis				1.240	0.109	4.374	0.000	0.238	0.000	5.961
South Davis				1.240	0.109	4.120	0.000	0.492	0.000	5.961
Mobile Homes	DU	R4	Production	1.240	0.109	4.154	0.000	0.000	0.000	5.502
Central Business District	1,000sq.ft.	CBD	Attraction	6.029	0.000	37.423	8.524	0.000	0.000	60.500
Neighborhood Commercial	1,000sq.ft.	NC	Attraction	16.643	0.000	103.299	23.529	0.000	0.000	167.000
Community Center Retail	1,000sq.ft.	CC	Attraction	16.643	0.000	103.299	23.529	0.000	0.000	167.000
Auto Sales	1.000sq.ft.	AS	Attraction	3.737	0.000	23.196	5.284	0.000	0.000	37.500
Light Industrial	Acre	M1	Attraction	30.657	0.000	10.571	5.286	0.000	0.000	51.800
Heavy Industrial	Acre	M2	Attraction	3.995	0.000	1.378	0.689	0.000	0.000	6.750
Business Park, R&D	Acre	BP	Attraction	88.657	0.000	30.571	15.286	0.000	0.000	149.800
Office	1,000sq.ft.	OF	Attraction	10.357	0.000	3.571	1.786	0.000	0.000	17.500
Parks	Acre	PR	Attraction	0.000	0.000	4.570	0.000	0.000	0.000	4.570
Elementary School	Student	Elem	Attraction	0.000	1.020	0.000	0.000	0.000	0.000	1.020
High School	Student	High	Attraction	0.000	1.790	0.000	0.000	0.000	0.000	1.790

[7] Non-home based trip generation rates applied twice, once for productions and once for attractions for the same non-residential land use.

Table 2: Daily Vehicle Trip Generation Rates Used in the Davis Model (continued)

Land Use Category	Unit	Code	Production Or Attraction	Home-Based Work	School	Home-Based Other	Non-Home Based[8]	UCD Trips	Research Park Trips	Total Daily Trips
UC Davis Employees	position	UCDE	Attraction	0.000	0.000	0.000	0.000	4.490	0.000	4.490
UCD Off-Campus Students	student	UCDOS	Attraction	0.000	0.000	0.000	0.000	0.509	0.000	0.509
UC Davis Resident Students	student	UCDRS	Production	0.000	0.000	2.383	0.000	0.000	0.000	2.383
Public/Quasi-Public	1,000sq.ft.	PQP	Attraction	3.015	0.000	18.711	4.262	0.000	0.000	30.250
UCD Faculty/Staff Housing	DU	UCDFS	Production	0.979	0.509	4.302	0.000	4.000	0.000	9.790
UCD External Trips	Trip	UCDX	Production	0.000	0.000	0.000	0.000	1.000	0.000	1.000
Research Park Attraction	Trip	UCDRPA	Attraction	0.000	0.000	0.000	0.000	1.000	0.000	1.000
Research Park Production	Trip	UCDRPP	Production	0.000	0.000	0.000	0.000	1.000	0.000	1.000
Spare 1[9]		Spare 1		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spare 2		Spare 2		0.000	0.000	0.000	0.000	0.000	0.000	0.000

[8] Non-home based trip generation rates apply for both productions and attractions to the same land use.
[9] Two spare trip purposes are incorporated into the model to facilitate its use in later studies.

2002 Roadway Network

The City's GIS street centerline file was the starting point for the model's roadway network. This included all of the existing roads in the city. The information from the centerline file was stored for each link in the roadway network. In addition to roadway characteristics, the model requires information on roadway capacities and speeds. The roadway classification system was taken from the General Plan. For each classification, the roadway capacity was based on the regional SACMET travel demand model and other local models, while the free-flow speeds were set at the posted speed limit[10]. Table 3 shows the standard speeds and capacities used for each road class in the model.

Table 3: Roadway Speeds and Capacities

Roadway Classification	Speed (mph)	Hourly Capacity (PC/Hr/Lane)
Freeway	65	1,800
Freeway Ramp	40	1,500
Arterial	40	800
Collector	30	600
Local Street	25	400
Centroid Connector[11]	25	10,000

The speed and capacity characteristics were modified for some links during calibration in order to better fit the conditions in individual sites.

Turn Penalties

Drivers encounter delays when making certain movements at congested intersections. These delays are incorporated into the model in the form of turn penalties. In the Davis model, turn penalties or prohibitions were used in sixty-one places (see Figure 6) where traffic signals exist or where turn prohibitions apply. The model includes standard turn penalties at signalized intersections as shown in Table 4.

Table 4: Initial Turn Penalties at Signalized Intersections (in minutes)

Movement	Intersection of Major & Minor Roads		Intersection of Roads of Equal Size
	Major Rd.	Minor Rd.	
Right Turn	0.0	0.1	0.0
Through	0.1	0.5	0.3
Left Turn	0.3	0.7	0.5

[10] In some case this speed was changed during model calibration.
[11] Centroid connectors are abstract representations of the starting and ending points of each trip.

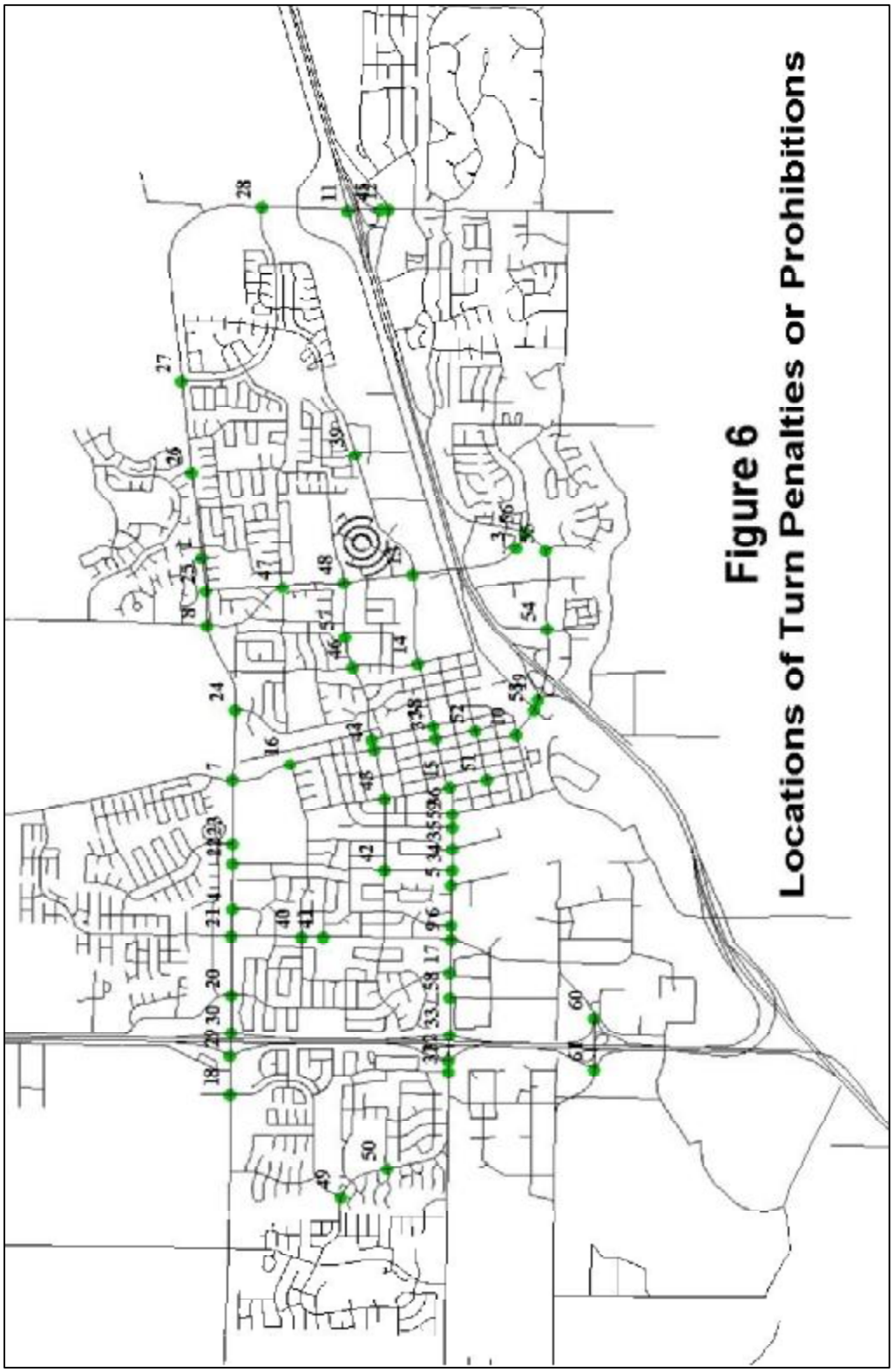


Figure 6
Locations of Turn Penalties or Prohibitions

During calibration some locations, such as the Richards Boulevard/First Street intersection, were given higher turn penalties to reflect the additional delays actually experienced in the field.

Terminal Times

The model requires an estimate of terminal times, which is the amount of time at the origin used in traveling from the starting place to the point where the vehicle enters the road network and the amount of time at the destination finding a parking place and traveling from there to the actual endpoint of the trip. For Davis, the terminal times shown in Table 5 were used.

Table 5: Terminal Times

Area	Destination Terminal Time (minutes)	Origin Terminal Time (minutes)
North Davis	1	1
South Davis	1	1
East Davis	1	1
West Davis	1	1
Central Davis	1	1
CBD	3	1
UC Davis	5	3
External Zones	0	0

Friction Factors

Friction factors, also know as travel time factors, are used in the trip distribution stage of the model to compare the relative attractiveness of destinations that differ in terms of travel time from the trip origin. Friction factors developed by MTC and Caltrans, and tested in the City of Dixon model, were used in the Davis model.

Trips Between Davis and External Areas

Journey-to-work information from the 1990 census[12] was used to estimate the percent of work trips to Davis from places outside the city. These were then assigned to the appropriate external TAZs. A similar exercise was done for work trips leaving Davis residences for other localities. The results are summarized below:

[12] Journey to work data from the 200o census was not available at the time of this report.

Table 6: Work Trips to and from Davis from 1990 Census

Road/Direction	Expressed as Trips		Expressed as %	
	To Davis	From Davis	To Davis	From Davis
External				
SR113 to/from North	1,936	1,501	14.7%	10.1%
I80 to/from East	3,373	5,572	25.6%	37.3%
I80 to/from West	1,319	1,463	10.0%	9.8%
Russell to/from West	278	131	2.1%	0.9%
Total External	6,906	8,667	52.4%	58.0%
Internal	6,269	6,269	47.6%	42.0%
Total Work Trips	13,175	14,936	100.0%	100.0%

As indicated in the tables above, approximately 58% of the employed people living in Davis work outside the city, while 52% of the jobs in Davis are filled by people living elsewhere.

The census covers only work trips, so another source of information was needed to estimate the percentage of HBO and NHB trips going outside the city. Information from the 2000 SACOG household survey was used to estimate the percent of HBO and NHB between Davis and other cities. The 2002 UC Davis Travel Survey was used to estimate the percentage of UCD trips with one endpoint outside the model area.

Through Trips

The major flows of through traffic in the study area use I-80 and SR-113. The size of these flows was estimated based on Caltrans traffic counts.

4.0 MODEL VALIDATION

Model validation is the term used to describe the model's performance in terms of how closely the model's output matches existing travel data for the study area in the base year. Caltrans has established certain guidelines for models to be deemed acceptable for forecasting future year traffic. This section describes the model performance in comparison to the standards discussed in ***Travel Forecasting Guidelines*** (California Department of Transportation, November, 1992).

Trip Generation

One of the basic assumptions of any traffic model is that the total number of local trips (internal-to-internal, or I-I) produced is equal to the total number of local trips attracted. If the totals are not equal, the model will automatically adjust the attractions to match the productions. For this reason, the trip generation component of the model should generate similar totals of trips produced to trips attracted.

Table 7 summarizes the I-I productions and attractions of the Davis traffic model for each trip purpose. The results indicate a close correlation between computed productions and attractions.

Table 7: Internal-Internal Daily Trip Generation Summary

Trip Purpose	Computed Productions (Trips/Day)	Computed Attractions (Trips/Day)	Ratio
Home-based Work	32,319	32,338	0.96
Home-based School	10,170	10,969	0.93
Home-based Other	162,682	153,330	1.06
Non-home Based	38,521	38,521	1.00
UCD Trips	21,696	28,219	0.77
Total	264,001	263,376	1.00

Trip Assignment

The most critical measurement of the accuracy of any traffic model is the degree to which it can approximate actual traffic counts in the base year. The validity of the Davis traffic model was tested for daily, a.m. peak hour, and p.m. peak hour conditions. Model volumes were compared to existing traffic counts for the thirty-eight count sites and the eight screenlines shown in Figure 7. The remainder of this section contains a summary of the validation results while Appendix G contains a detailed summary report of all validation comparisons.

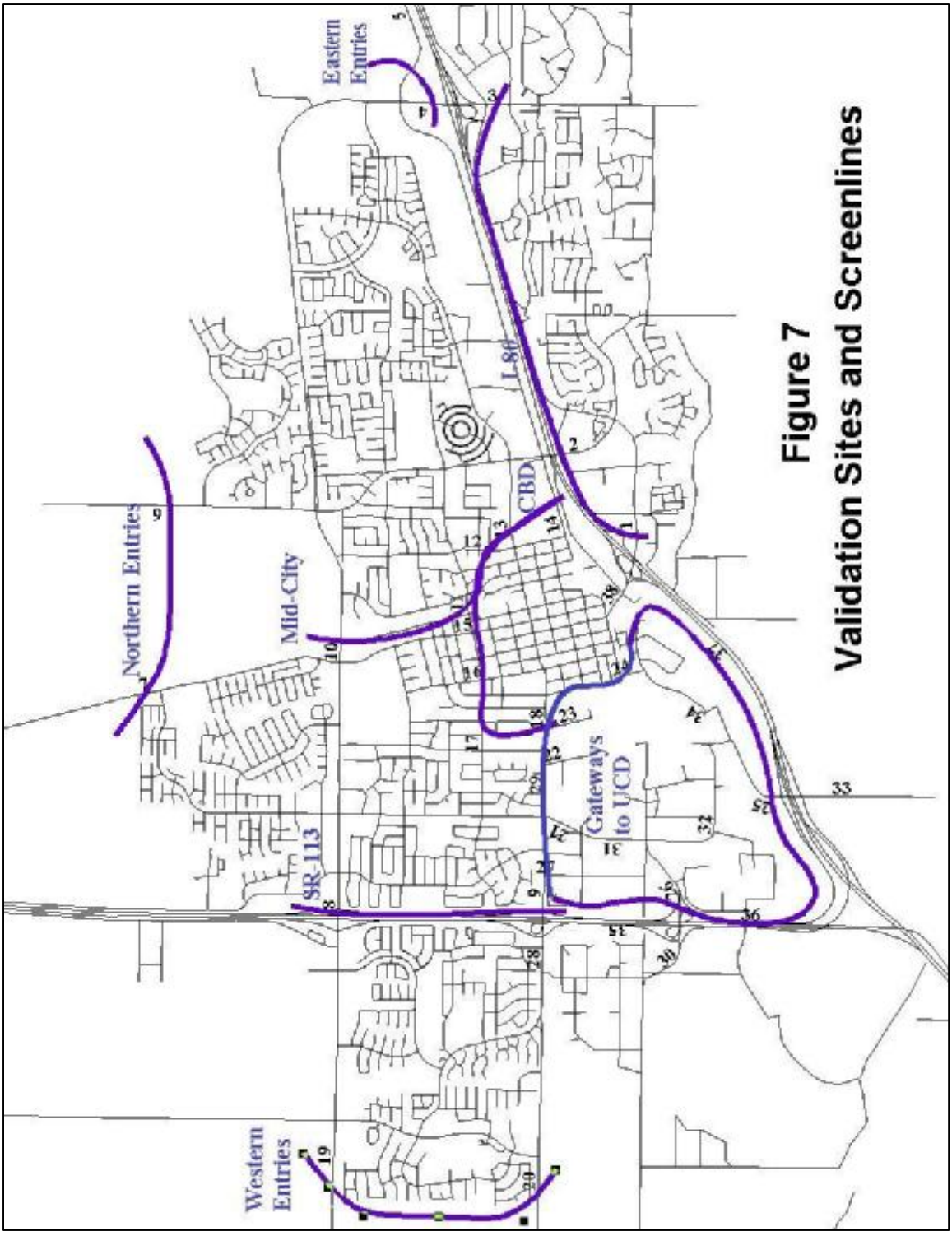


Figure 7
Validation Sites and Screenlines

Comparison Techniques

Traffic model accuracy is usually tested using two comparison techniques:

- The volume-to-count ratio is computed by dividing the traffic volume forecast from the model by the actual traffic volume counted on various road segments. The deviation is the difference between the model volume and the actual count divided by the actual count.
- The percent root mean squared error (RMSE) is the square root of the model volume minus the actual count squared, divided by the number of counts. It is a measure similar to standard deviation in that it assesses the accuracy of the entire model.

Validation Guidelines

For a model to be considered accurate and appropriate for use in traffic forecasting, it must replicate actual conditions to within a certain level of accuracy. Since it would be impossible for any model to precisely replicate all counts, validation guidelines have been established in ***Travel Forecasting Guidelines*** (California Department of Transportation, November, 1992). Key validation standards based on the Caltrans guidelines for the Davis traffic model are summarized below:

- A minimum of 75 percent of the roadway links should be within the maximum desirable deviation, which ranges from approximately 15 to 60 percent depending on total volume (the larger the volume, the less deviation is permitted); and
- The two-way sum of the volumes on all roadway links in which counts are available should be within 10 percent of the counts.

Although not stated in the Caltrans standards, another validation standard was applied to the Davis traffic model:

- The maximum acceptable root mean squared error should not exceed 40 percent.

A summary of the validation results is provided below.

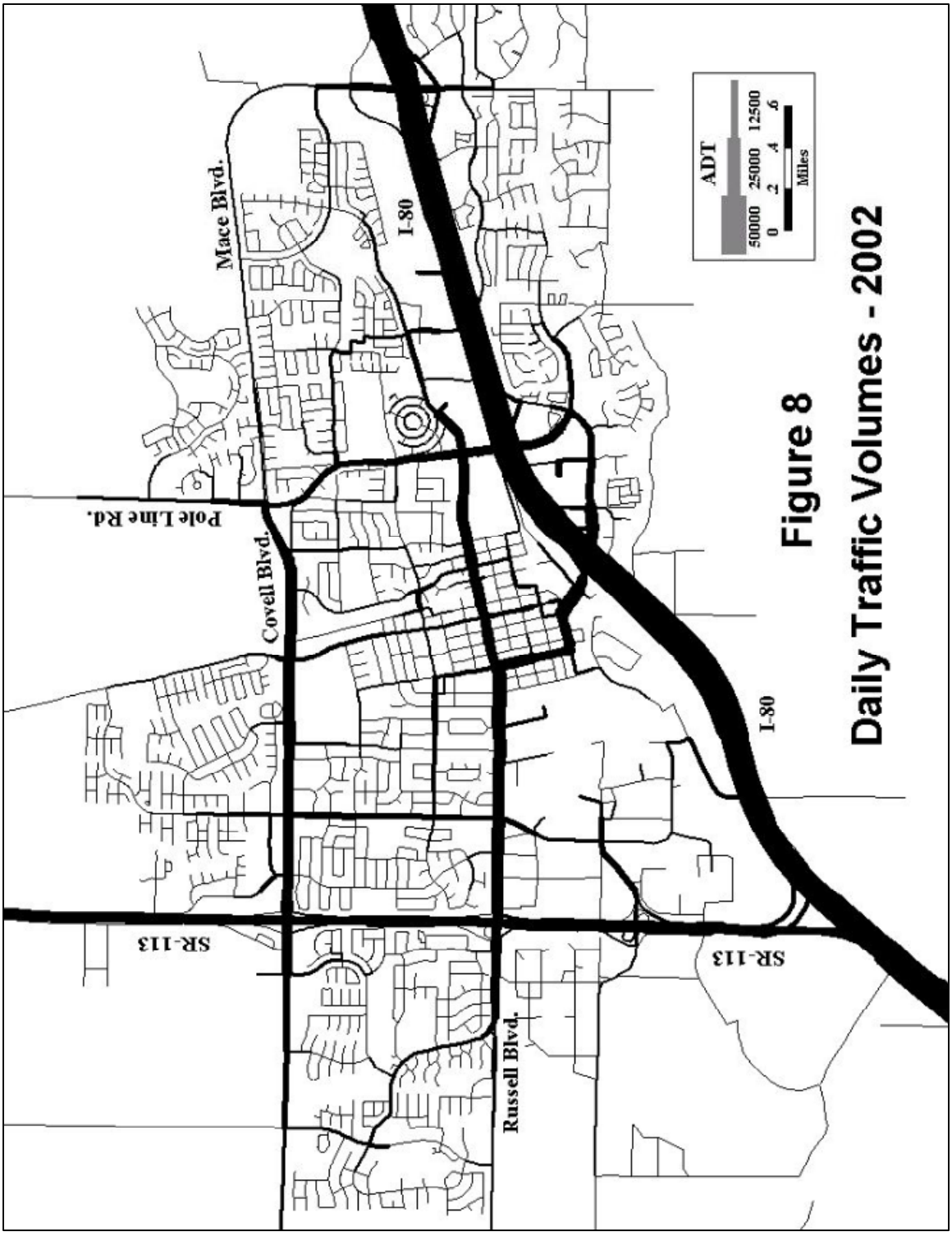
Validation Results

A spreadsheet was created to compute the validation results for roadway links in the Davis traffic model. The results for daily, a.m. peak hour, and p.m. peak hour conditions are summarized in Table 8 below, while the detailed spreadsheets are presented in Appendix G.

Table 8: Results of Model Validation

Period Validation Item	Criterion for Acceptance	Model Results
Daily		
% of Links Within Caltrans Deviation Standard	At Least 75%	89%
% of Screenlines Within Caltrans Deviation Standard	At Least 75%	94%
2-Way sum of All Links Counted	Within 10% of actual	+5%
RMSE	Below 40%	20%
AM Peak		
% of Links Within Caltrans Deviation Standard	At Least 75%	79%
% of Screenlines Within Caltrans Deviation Standard	At Least 75%	81%
2-Way sum of All Links Counted	Within 10% of actual	+5%
RMSE	Below 40%	30%
PM Peak		
% of Links Within Caltrans Deviation Standard	At Least 75%	89%
% of Screenlines Within Caltrans Deviation Standard	At Least 75%	100%
2-Way sum of All Links Counted	Within 10% of actual	-2%
RMSE	Below 40%	23%

As shown in Table 8, the model exceeds all Caltrans guidelines for model accuracy. The forecast traffic volumes replicate 2002 travel patterns quite well, as can be seen in Figure 8. This is a result of the high quality of the inputs, including a complete data base of 2002 land use, travel characteristics data from the 2000 SACOG household survey, locally-validated trip generation rates, and special surveys for the UC Davis campus.


Daily Traffic Volumes - 2002
Figure 8
ADT
50000 25000 12500
0 2 4 6
Miles
Mace Blvd.
I-80
Pole Line Rd.
Covell Blvd.
I-80
SR-113
SR-113
Russell Blvd.

5.0 FORECASTS OF TRAFFIC CONDITIONS

One of the main purposes of the model is to provide an indication of what traffic conditions will be like in the future for different set of land use assumptions. This chapter reports the forecasts for three future scenarios.

Traffic by Scenario

Table 9 shows a comparison of traffic across the eight screenlines for different scenarios. As can be seen from the table, traffic in Davis is expected to increase significantly by 2015. Table 10 shows some of the sources of this traffic growth. Population increase appears to account for perhaps one third to one half of the forecast traffic growth. Most of the growth appears to come from growth in non-residential land uses, especially retail and office space.

The growth in traffic to UC Davis is forecast to be higher than the growth in the number of students, especially for the with-project scenario. This is because a greater proportion of students will live on-campus and will generate HBO trips.

Table 9: Comparison of Screenline Traffic Volumes for Different Scenarios

Screenline	Direction	2002 Count	2010 Forecast	Forecast /Existing	2015 No Project Forecast	Forecast /Existing	2015 With Project Forecast	Forecast /Existing
I-80 Screenline	Northbound	26,378	40,737	1.54	41,058	1.56	43,850	1.66
	Southbound	26,895	35,659	1.33	36,040	1.34	38,767	1.44
Eastern Entries to Davis	Inbound	11,116	14,114	1.27	14,642	1.32	16,410	1.48
	Outbound	10,669	14,035	1.32	14,509	1.36	15,151	1.42
Northern Entries to Davis	Inbound	3,954	5,957	1.51	5,950	1.50	6,095	1.54
	Outbound	4,036	5,597	1.48	5,950	1.47	6,095	1.51
SR-1113 Screenline	Eastbound	22,355	33,672	1.51	31,395	1.40	36,125	1.62
	Westbound	23,278	32,288	1.39	31,331	1.35	36,050	1.55
Mid-City E-W Screenline	Eastbound	27,092	44,053	1.63	43,118	1.59	46,465	1.72
	Westbound	26,526	45,220	1.70	45,799	1.73	48,608	1.83
CBD Screenline	Inbound	23,034	30,214	1.31	28,882	1.25	30,913	1.34
	Outbound	22,885	27,918	1.22	29,025	1.27	32,517	1.42
Western Entries to Davis	Inbound	4,654	7,396	1.59	7,474	1.61	8,119	1.74
	Outbound	4,294	7,607	1.77	7,602	1.77	8,114	1.89
Gateways to UCD	Inbound	29,696	37,201	1.25	35,426	1.19	42,046	1.42
	Outbound	30,481	36,903	1.21	35,393	1.16	41,966	1.38

Table 10: Sources of Traffic Growth

Land Use Type	Existing in 2002	2010 Forecast	Forecast /Existing	2015 No Project Forecast	Forecast /Existing	2015 with Project Forecast	Forecast /Existing
Number of Dwelling Units[13]	24,457	29,095	1.19	29,632	1.21	30,212	1.24
Retail Area (KSF)	1,975	3,283	1.66	3,246	1.64	3,304	1.67
Industrial & BP (acres)	335	338	1.01	338	1.01	338	1.01
Office (KSF)	1,580	2,411	1.52	2,411	1.52	2,411	1.52
UC Davis Students	26,153	29,310	1.12	28,133	1.08	31,283	1.20

[13] Includes UC Davis on-campus housing for faculty and staff