CSTDM09 - California Statewide Travel Demand Model

Model Development

Network Preparation and Coding

System Documentation: Technical Note

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May 2011

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1. Introduction

This technical note describes the process used to update the network from the High Speed Rail (HSR) model to generate networks that meet the needs of the California Statewide Travel Demand Model (CSTDM). After developing a new TAZ system that better supports the CSTDM model needs, the HSR network was enhanced through the addition of new links where needed, and through the standardization of link coding across jurisdictional and geographic borders.

In addition, transit services were coded according to a composite methodology. Rail transit is represented directly in the primary network, instead of in a separate rail network, as it was the case in the HSR model. A synthetic methodology is used to represent the many lines of bus local transit, through a numerical approach rather than an explicitly coded network.

2. Description of Existing Network and Editing Process

2.1 The Existing Network

The CSTDM network was developed by enhancing and correcting the HSR model network to address the specific requirements of the CSTDM model. The HSR network is too dense in some locations that were necessary for the high speed rail analysis. It is not dense enough in other locations that are important for the CSTDM. These network density issues were coincident with the similar TAZ issues that were addressed during the TAZ redesign process (please refer to the document describing the CSTDM TAZ system for the details on how the TAZ system was redesigned).

The HSR network was created by splicing together several Metropolitan Planning Organization (MPO) model networks to the Statewide Travel Model (2004) network. These splices, at locations where the source of a link’s “A node” is not the same as the source of the “B node”, were common places to find local inconsistencies. All of these locations were individually reviewed and edited.

To suit the needs of the CSTDM the following issues that needed to be addressed were identified, using both automated and visual methods, then corrected when appropriate:

- Inconsistent capacity and/or lane attribution;
- Incorrect connectivity (mostly at MPO model boundaries);
- Under- and over-specification of roadways;
- High Volume/Capacity(VC) ratios on the loaded network (e.g., >2);
- Zero volumes on major links;
- A_Source <> B_Source (as described in paragraph above);
- Queries for capacity issues (i.e., any capacity > 2200 or < 500);
- Link length compared to straight line length;
- Dangling links (missing connections);
- Incorrect number of lanes;
- Functional class inconsistencies and errors; and
- Under- or over-estimation of speed.

2.2 The New Networks

The new networks were created with the following attributes for the road links. Most of these fields (Table 1) are inherited directly from the HSR network.

Table 1: Network Fields for CSTDM

Field Name	Description	Data source
A	A node for 1-way link	Auto-generated in the Cube Software
B	B node for 1-way link	Auto-generated in the Cube Software
DISTANCE	Link length (miles)	Auto-calculated and checked for accuracy
LANES	Number of lanes (1 direction)	Google Earth version 5.
SPEED	Free flow speed (mph)	ESRI Street Maps 2008, with Street network data redistributed from TeleAtlas 2003
CAPACITY	Vehicles per lane per hour (see Tables 3, 4 and 5)	Tabular entry
FTYPE	Facility type (see Table 2)	GoogleEarth, ESRI 2008, TeleAtlas 2003
AREATYPE	Area type (see Table 5)	Zonal Attribute/Post Process
AREATYPENUM	Area type number (see Table 5)	Zonal Attribute/Post Process
USE	Vehicles allowed (see Table 6)	GoogleEarth
TOLL	Flag for link with toll (see Table 7)	Manual Entry/CalTrans
TIME_INIT	Initial travel times (minutes)	Calculated Distance*60/speed
FACILITY	Type of link (e.g. Walk Links)	n/a
NAME*	Street Name	Other source/TeleAtlas
EDITED	Edit status	Manual Entry
ONRAMP	Flag for link with toll	Manual Entry
OFFRAMP	Flag for link with toll	Manual Entry
SCREENLINE	Flag for identifying links in screenlines	Manual Entry

Table 2: FType Codes

FTYPE	Definition	Sources: TeleAtlas
1	Freeway	A1: All interchanges no signals
2	Expressway	A1-A2: Occasional signals
3	Major arterial	A3: Stoplights present
4	Minor arterial	A3: Stop signs present
5	Collectors	A4: Within a neighbourhood in and urban area.
6	Centroid Connectors	
7	Ramps	A63
8	Freeway - Freeway Connector	Note: not assigned to new links in the CSTDM network
9	Rail Transit Node – Road Network	
10	Air Transit Node – Road Network	
11	Rail Transit Connection	

Table 3: Recommended Capacities by Feature Type

(Number of vehicles per hour per lane. These values are for use when there are no neighboring capacities in use)

Functional Class	Urban	Suburban	Rural
Freeway with no Signal	2,100	2,100	2,100
Expressway with Signal	1,200	1,200	1,400
Major Arterial - Signal	800	800	1,100
Minor Arterial - Signal	650	650	750
Collectors	650	650	650
Ramp	1,250	1,250	1,350
Fwy-Fwy Connector	1,950	1,950	1,950

Table 4: Current Capacity Values in Use

(Number of vehicles per hour per lane. Range of possible capacity values in the model)

Functional Class	Urban	Suburban	Rural
Freeway	1,750-2,100	1,750-2,100	1,950-2,100
Expressway	900-1,800	900-1,900	900-1,900
Major Arterial	800-1,800	800-1,900	800-1,900
Minor Arterial	700-1,800	700-1,800	700-1,800
Collectors	550-1,600	700-1,600	700-1,600
Ramps	500-1,600	600-1,600	1,250-1,600
Fwy-Fwy Connector	1,700-2,000	1,800-2,000	1,800-2,000

Table 5: Area Type Codes and Densities (for use in attributing TAZs)

AREATYPE	Area Type Number	People / Sq. Mile
CBD	1	>20,000
Urban	2	10,001 - 20,000
Small Urban	3	6,001 - 10,000
Suburban	4	1,001 to 6,000
Rural	5	<1,001

Table 6: Use Codes

USE	Definition
1	No restrictions
2	Shared ride - 2 and above
3	Shared ride - 3 and above
4	No trucks
5	Access Link to Transit
6	Rail Link

Table 7: Toll Codes

TOLL	Location
1, 81	Bridge - Benicia / Martinez
2, 82	Bridge - Carquinez
3, 83	Bridge - Richmond - San Rafael
4, 84	Bridge - Golden Gate
5, 85	Bridge - Oakland Bay Bridge
6, 86	Bridge - San Mateo / Hayward
7, 87	Bridge - Dumbarton
8, 88	Bridge - Antioch
10-15	Toll Road – Route 73
20-27	Toll Road – Route 241
30-32	Toll Road – Route 261
40-41	Toll Road – Route 133
50-55	Toll Road – Route 125
60-62	Express Lane – Route 91
70-71	Express Lane – Route 15

The CSTMD network focuses on major roads, i.e. arterial level and above. Collectors are used to ensure connectivity to the TAZs. Therefore, the network does not represent all roads in the state of California.

2.3 Editing Process

Editing the road network required care and tracking of changes. Editing was done in the CUBE binary net format using the Citilabs CUBE software package.

2.3.1 Multiple Editors

Each editor made their own copy of the current master network file and made their edits based on it. At the conclusion of each editing session, the editor saved the edits to a dated and user-identifiable log file. Those log files were then used to apply everyone's changes to a master network on a weekly schedule. The previous master network was backed up prior to each set of changes being applied.

A block of available nodes was assigned to each editor. This was necessary to prevent editors from assigning the same node numbers to different locations. Should this happen, it would have prevented the application of log files to the master network.

Each editor was also assigned a unique numeric identification (ID) and all edits that involved manually changing the contents of a field were tagged with their editor ID in the EDITED field. In cases where we were unable to decide on how to deal with a link or set of links appropriately, we used the EDITED = 2 code, which prompted for further consultation with HBA.

2.3.2 Network Link Specification

The HSR network had inconsistent coding of road densities. Some areas were over-specified while others were under-specified (i.e. there were areas with too many links and areas with too few to meet the needs of the CSTDM). Unless problems occurred in network testing, links were retained in areas that were over-specified. Dangling links were also retained unless they posed a problem when tested. Links were added to places where the network was under-specified.

Links that met the following broad classifications were included in the CSTDM network: freeways, expressways, major arterials. Minor arterials and/or collectors were also included in the network when they were needed to establish suitable connectivity. See Table 2 for appropriate feature types and reference materials for their type.

2.3.3 Incremental Network Testing

After completing the first pass-through of the statewide network, reviewing link properties and enhancing the network to support the new TAZ system, the updated master network was provided to HBA. Once received, HBA loaded the network using an assignable trip table and returned a loaded network to ULTRANS. This permitted incremental testing of the network as it was developed and highlighted problems that were then fixed.

2.3.4 Network Dates

The first network was developed for the year 2008 because it allowed using the most available data from a variety of sources to confirm and update attribution from after 2000. Data sources used in the 2008 network include a 2003 TeleAtlas Road network, obtained through licensing with the ESRI Streetmaps data product, and Google Earth/ Google Maps for confirming the number of lanes and current road layout. The data available from Google Earth/Maps that were used in the process referred to the years 2007 to 2009.

The network for 2000 was generated through the selective removal or down grading of links that were identified as new or enhanced between 2000 and 2008. The HSR Model documentation includes a list of proposed projects from 2000 to 2030. This list was used to confirm the removal of projects that existed in 2008 but did not exist in 2000. A 2001 GDT (now TeleAtlas) dataset and the use of historic aerial imagery from Google Earth were secondary references for identifying links or capacities for removal. No authoritative list of road widening or capacity enhancements was identified.

2.3.5 Link Editing Details

The editing process in CUBE has four primary methods: (1) add link, (2) modify link, (3) split link, or (4) delete link. The editing effort primarily used the add, modify, and split link methods. The editing process was as follows:

1. Select a geographic area to edit and confirm that no one else has already begun to work on the same area.
2. Identify a block of unused node numbers from the editor's assigned range.
3. Make a copy of the master network to use as the base network in the editing process.
4. Add reference data to the CUBE editing view.
5. Identify issue to be edited:
    a. Adding links
        i. Where possible, use the copy function to save time entering attributes.
        ii. Add one or two way links as needed
        iii. Draw nodes from the block of unused nodes
        iv. Code attributes (see Attribute Coding Checklist)
    b. Modifying links
        i. Code attributes (see Attribute Coding Checklist)
    c. Splitting links
        i. Draw nodes form the block of unused nodes
        ii. Code attributes (see Attribute Coding Checklist)
    d. Deleting links (fairly rare)
        i. Delete incorrect links.
6. Save Log File in E:\CSTM2009\Networks\Editlogs\
    a. Make sure that the file is named so that it is identifiable to the editor, date, and order of creation (if there is more than one log per date/editor)
    b. An example naming format is: <initials>_<mmddyyyy>_<#>.log
        i. e.g. ner_08112009_1.log is Nate E. Roth's first log file for August 11th. It is likely that there will be only one log file per day per person.
7. Save changes to the base network so that you can continue on the next day or next editing session.
8. A weekly compilation of all log files from all editors as applied to the master network is created by a designated team member.

2.3.6 Attribute Coding Checklist

1. FType: The road type, see Table 2 for codes.
2. Capacity: Number of vehicles per hour per lane. See Tables 3-4 for recommended values and ranges. When possible maintain consistency with surrounding similar network links. Down coding for flow restrictions apply only to the links affected.
3. Lanes: Review against imagery (Google Earth). Only code the primary portion of the link. Do not code turn lanes separately.
4. Speed: The speed limit.
5. Use: See Table 6 for use restrictions.
6. Distance: The distance code is automatically generated based on the ratio of straight-line distance to the listed distance of a link prior to modification. It can also be edited manually.
7. Toll/OnRamp/OffRamp: If a toll applies to the road section it can be entered. These attributes were used on links that represent toll booths or plazas on the toll roads and bay area bridges.
8. StreetName: Enter the primary street name for ease of reference on links that are edited. This became very time consuming and was omitted for changes that did not involve adding new roads or changing connectivity. However, the StreetName was always included for particular locations, as in the case of the screenline stations, to ease the reference of the links and the identification of the station.
9. Areatype and AreaTypenum: These are properties of the TAZ that were calculated based on the density of the TAZ.
10. Time_init: Calculated automatically after the editing is done.
11. Facility: Is a remnant kept for reference (i.e. SACOG Walk Links).
12. Screenline: Is a number (from 1 to 336) that uniquely identifies each one of the screenline stations used for the validation of the model results with observed traffic counts.

2.3.7 Centroid Connectors

Centroid connectors were created for each TAZ in the system. These were defined based on the following criteria.

1. Connectors should never connect directly to freeways or expressways (expressways might be allowed in very rural areas).
2. Multiple connectors should be used for most zones to avoid overloading the network at the entry point. The default is to have four centroid connectors per TAZ node.

3. Connectors should not connect directly to road network at intersection nodes, instead they should connect to the center of road segments.
4. Where possible, connect centroids to the lowest level roads available in the TAZ.

The first step was an automatic generation of four centroid connectors for each TAZ. In most cases, these connected to road intersections, a violation of criteria number 3 above. Each TAZ was then individually analyzed and the centroids were connected to the road network manually. This centroid connection process was fluid and occurred during the broader context of editing the networks within regions. Attributes for the Centroids were assigned as follows: FType = 6, Capacity = 9999, Lanes = 9, Speed = 15, and Edited = <editor ID>.

3. Transit Coding

The CSTDM employed the following procedure to code the transit network:

- The transit network is built on the latest version of the highway network;
- All nodes representing rail stations or airports are coded in the highway network with their relevant properties (rather than added in a new transit network). Relevant properties are coded into the node attributes and are: node number, x/y coordinates, and fare zone data (optional). Fare zone data was only coded for operators that use either a FROMTO or COUNT fare type;
- All nodes representing rail stations or airports are connected to the nearest "local arterial / collector" node on the highway network via a 2-way link with the following data:
  - Distance = 0.15 miles
  - Lanes = 0
  - Speed = 20mph
  - Capacity = 0
  - FTYPE = 9 for links to Rail Stations
  - FTYPE = 10 for links to Airports
  - AREATYPE = as per original highway coding
  - USE = 5 for Access Link to Transit

- Rail links used by the rail systems are explicitly coded in the highway network with the following data:
  - Distance = default CUBE distance
  - Lanes = 0
  - Speed = see Table 12
  - Capacity = 0
  - FTYPE = 11 for rail line links
  - AREATYPE = as per original highway coding
  - USE = 6 for Rail Link

These rail and transit access links are not used in a normal highway assignment – this is controlled by appropriate use of the "USE" field. These are available for the CUBE Public Transport Program to create walk, auto, park and ride, and drop off / pick up access. They egress "non-transit" links to connect the rail station and airport nodes. The current implementation of the CSTDM does not explicitly extract (and include in assignment) the car mode components of the access and egress choice for air and rail trips. This includes both long distance air and rail, as well as short distance rail transit ("drive access transit"). Due to the nature of the skimming process, loaded networks are needed to do transit skimming which would determine what these car mode components would be. Auto access transit trips are included in the trip list outputs as any other transit trip, and long distance transit (air/rail) trips have the origin and destination stations recorded in the trip list.

Walk and auto travel times are specified to be a function of link distance and rate of travel. The rate of travel is the coded "free flow speed" for auto access and 2.5mph for walk access.

The advantage of this transit access link coding method is that the links and transit nodes are explicitly and transparently associated with the highway network coding. They can be viewed and maintained within the highway network development and maintenance process. A potential drawback is that all rail stations and airports are potentially available for auto access / egress, even though not all locations may have park and ride facilities – this is seen as an acceptable arrangement because stations without park and ride can still legitimately be used for auto drop off and pick up.

3.1 Public Transit Network Inputs: Transit System Data

Transit system data for the CSTDM is input in the System File "System_CSTDM09.pts". Table 8 gives the System File control statements.

Table 8: Control Statements in the CSTDM09 Transit System File

Control Statement	Description	Keywords	Keyword Description	Value
MODE	Defines transit and non-transit modes that the transit system uses. All lines belong to a defined mode.	NUMBER NAME LONGNAME	Unique numeric identifier Unique string identifier 2nd String Identifier	1-999
OPERATOR	Defines the operators in the transit system. All lines and fare systems belong to operators.	NUMBER NAME LONGNAME	Unique numeric identifier Unique string identifier 2nd String Identifier	1-999
WAITCRVDEF	Define wait curves used to compute initial and transfer wait times at stop nodes, based on the frequency of service. The Factors File specifies which wait curve to be applied at each node	NUMBER NAME LONGNAME CURVE	Unique numeric identifier Unique string identifier 2nd String Identifier List of pairs of X-Y coordinates that define curve: X=headway; Y=wait time	1-255

By convention, for CSTDM each transit system is given identical mode and operator numbers in the following ranges:

- 1-9: Non-transit modes
  - 1 : walk access to transit
  - 2 : walk egress from transit
  - 3 : auto access to transit
  - 4 : auto egress from transit
  - 5 : walk transit-transit transfer
- 11-49: light / heavy rail (existing system numbers given in Table 11)
- 50-59: Bus services (not currently used in CSTDM)
- 61: Future High Speed Rail (not currently used in CSTDM)
- 71: Air services

Five wait functions are currently defined in the system file:

- Wait Curve 1 specifies wait time to be 50% of transit service headway, and is for use with initial wait times;
- Wait Curve 2 specifies wait time to be 50% of transit service headway, and is to be used with transfer wait times;
- Wait Curve 3 is a legacy of the HSR model coding, and specifies that the wait time for **rail service** is 50% of the service headway up to a service headway of 28 minutes; for headways > 28 minutes wait time is capped at 14 minutes;
- Wait Curve 4 is also from the HSR model, and specifies that the wait time for **air service** is fixed at 71 minutes for all service headways up to 142 minutes, and 50% of headway for air service with headway exceeding 142 minutes;
- Wait Curve 5 is also a legacy of the HSR model coding, and specifies that the wait time for **High Speed Rail service** is 50% of the service headway up to a service headway of 28 minutes; for headways > 28 minutes wait time is capped at 14 minutes.

The application of these wait curves is defined in the Factors File. Table 9 gives the factors specified in the Factors File. Factors control statements that define the run time parameters controlling Route Enumeration and Evaluation are input in the Factors File "FACT_CSTDM09.DAT".

Table 9: Factors in CSTDM09 Transit Factors File

Factor	Description	Value in CSTDM09
FARESYSTEM	Number of fare model that applies to operators selected with OPERATOR keyword	11-16; 31-35; 41-43; 52; 54
SPREADFUNC	Integer of the function that computes SPREAD in route enumeration – SPREAD defines an upper cost limit for routes between an O-D pair	1 Max of Minimum O-D time * SPREADFACT; minimum O-D time + SPREADCONST
SPREADFACT	Factor that minimum O-D time is multiplied by	1.2
SPREADCONST	Time added to minimum O-D	0.0
MAXCOMPD	# components generated during route enumeration	1,000,000
MAXFERS	Maximum # transfers between O-D	2
AONMAXFERS	Maximum # transfers between O-D for O-D with only one enumerated route	2
EXTRAXFERS1	# of transfers at which program stops exploration less direct routes	2
EXTRAXFERS2	Max # of transfers explored in excess of the # required by minimum cost route	2
RUNFACTOR	Mode specific weighting factors applied to transit in-vehicle times and non-transit leg times in route enumeration	2.89 for modes 1-5 – walk and auto access and egress plus walk transfer
BRDPEN	Mode specific boarding penalty in minutes (for transit modes only)	5 for all transit modes
WAITFACTOR	Node specific wait-time weighting factor	2.89 for all non-TAZ nodes
IWAITCURVE	Wait curve used to calculate initial wait time for nodes specified by NODES keyword	1 for all non-transit nodes except 18501-18520 4 for nodes 18501-18520 (Air)
XWAITCURVE	Wait curve used to calculate transfer wait time at nodes	Same as IWAITCURVE
XFERPEN	Transit mode to transit mode transfer penalty, in minutes.	10, for all transit mode transfers

The IWAITCURVE factor application identified above effectively uses wait time as 50% of headway for calculation of wait times for all rail and air services (with a minimum air wait of 71 minutes). This approach reflects the true "attractiveness" of the service for the user, and reflects the value considered in choice behavior. It ensures that routes with less frequency of service are seen as less attractive than routes with higher frequency. In other models, a cap on waiting time is applied, based on observations of transit passenger behavior that shows a maximum time people actually wait at transit stops. This cap does not reflect the limitations on travel departure / arrival times imposed by less frequent routes.

3.2 Transit Network Inputs: Rail Line Data

Transit line files for 14 different light and heavy rail systems operating in California in the year 2000 were created, using the coding applied in the original HSR model.

Transit line files for 15 different light and heavy rail systems operating in California in the year 2008 were created, using the coding applied in the original HSR model as a template. We began by using the current timetables available on the websites of the operator. Unique lines were determined from the timetables by grouping together the trains that made the same stops. Appendix 1 has all of the line files by operator for 2008 that were developed. Using the tables in Appendix 1, line files were created in CUBE. Table 10 summarizes the transit line files that we created and used for the year 2000 and year 2008. Table 11 gives the CUBE keywords used in the line files.

Table 10: Year 2000 Transit Rail Line Files

Transit Line File	Transit System	Type	Mode / Operator #	# of Lines 2000	# of Lines 2008
BART_CSTDM09_<year>.lin	BART (San Francisco)	Urban Rail	11	9	17
SACOG_LRT_CSTDM09_<year>.lin	Sacramento LRT	LRT	12	1	3
SANDAG_LRT_CSTDM09_<year>.lin	San Diego Trolley	LRT	13	8	10
VTA_LRT_CSTDM09_<year>.lin	Santa Clara Valley LRT	LRT	14	3	3
Muni_Metro_CSTDM09_<year>.lin	Muni Metro (San Francisco)	Metro	15	6	16
SCAG_Urban_Rail_CSTDM09_<year>.lin	Los Angeles Metro	Urban Rail	16	12	15
SANDAG_Sprinter_CSTDM09_<year>.lin	San Diego Sprinter	LRT	17	0	2
SANDAG_Rail_CSTDM09_<year>.lin	San Diego Coaster	Commuter Rail	31	2	2
Metrolink_Orange-CSTDM09_<year>.lin	SCAG Metrolink Orange Line	Commuter Rail	32	2	9

SCAG_Metrolink_Other_CSTDM09_<year>.lin	SCAG Metrolink Other Lines	Commuter Rail	33	20	33
ACE_CSTDM09_<year>.lin	Altamont Commuter Express (Stockton / San Jose)	Commuter Rail	34	1	2
CALTRAIN_CSTDM09_<year>.lin	Caltrain (Gilroy / San Francisco	Regional Rail	35	13	22
Pacsurf_CSTDM09_<year>.lin	Pacific Surfliner	AMTRAK	41	4	10
AMTRAK_Capital_CSTDM09_<year>.lin	Capital Corridor	AMTRAK	42	1	8
AMTRAK_SJQ_CSTDM09_<year>.lin	San Joaquin Valley	AMTRAK	43	4	4

All of these rail services are available in the Short Distance Personal Travel Model, to the extent that they provide a service for trips <100 miles. The Long Distance Personal Travel Model included the operators that are likely to be involved in trips >100 miles. These operators were: Altamont Commuter Express (ACE), AMTRAK Capitol Corridor, San Diego Coaster, San Diego Sprinter (2008 only), LA Metrolink – Orange Line, AMTRAK Pacific Surfliner, and AMTRAK San Joaquin. These operators are represented by 73 stations in 2000 and 87 stations in 2008. These stations were given unique IDs ranging from 1 to 87 and are referred to as CVR stations.

In addition to rail line data, the Long Distance Personal Travel Model (LDPTM) requires 3 input tables:

1. CVR_Nodes_<year>.DBF
    a. Contains information about the stations and CUBE nodes that are available to the long distance rail model.
        i. Station/Node number, X-Y coordinates, and fare zone number for operators that use a FROMTO fare structure.
    b. Is used by CUBE to create skims
2. CVR_Links_<year>.DBF
    a. Creates a link between the CVR station number and the CUBE node number.
    b. Is used by CUBE to create skims
3. CVR_STATIONS_<year>.DBF
    a. For each CVR station, this table contains the CUBE node number and the TAZ ID it is associated with.
    b. Is used as input file for the LDPTM.

Table 11: Keywords Specified in Year 2000 Transit Rail Line Files

Keyword	Description	Optional?	Possible Values
NAME	Unique string identifier for line	No	MUST be first Keyword
LONGNAME	Second string identifier for line	Yes	String format
MODE	Integer for mode of line	No	1-999; referenced in system, factor, fare files
OPERATOR	Integer for operator of line	Yes	1-999; referenced in system, factor files
ONEWAY	Flag for line 1-way or 2-way	Yes	T (default) =1-way; F=2-way
CIRCULAR	Flag for line circular or linear	Yes	F (default) = linear; F=circular
HEADWAY[1]	Vehicle Interval in minutes for OFFPEAK time period	Yes	1-2,000
HEADWAY[2]	Vehicle Interval in minutes for AM PEAK time period	Yes	1-2,000
HEADWAY[3]	Vehicle Interval in minutes for MIDDAY time period	Yes	1-2,000
HEADWAY[4]	Vehicle Interval in minutes for PM PEAK time period	Yes	1-2,000
XYSPEED	Speed on qualified links on line (mph)	Yes	1-300
RUNTIME	Scheduled time in minutes from first node to last node	Yes	1-30,000
TIMEFAC	Time factor applied to the travel time of all links	Yes	Must be > or = 1
N	List of nodes line traverses (Separated by space, comma or dash);	No	negative # = nonstopping node If TIME,SPEED, ACCESS or TF is used, “N” node keyword needs to be inserted before next node
ALLSTOPS	Flag for all nodes in line are stop nodes	Yes	F (default) = use node designation; T= all nodes are stops (over-writes node designation)
TIME (keyword for Nodes N)	Time in minutes to traverse link between nodes	Yes	Must be > or = 1;
SPEED (keyword for Nodes N)	Speed in mph for all subsequent links in the line, until next SPEED keyword	Yes	Must be > or = 1;
ACCESS (keyword for Nodes N)	Indicator for stop node access	Yes	0 = stop for access and exit 1 = stop for access only 2 = stop for exit only

3.3 Calculation of Line Link Times

The base time for each link is established in a hierarchical process:

1. If the link exists in the network:
   a. Set link time equal to the link variable described by PARAMETERS TRANTIME;
   b. Adjust link time (if required) using the keywords TIMEFAC, SPEED (N) and TIME (N) in the line description.
2. If the link does not exist in the network, but both nodes have coordinates and XYSPEED is coded:
   a. Set link time to the computed X-Y distance divided by XYSPEED, or
   b. Set link time using TIME keyword.

The CUBE program uses a two-part approach to the calculation of final line link times:

1. Establish the base time for each link;
2. Adjust link times based on keywords e.g. if RUNTIME is specified, the program adjusts the time on all links so the total line time sums to the Runtime.

In the original HSR rail transit line coding, rail links were NOT coded. The 2^{nd} method for calculating base times for each link was used, summarized in Table 12.

Table 12: Original HSR Model Link Time Coding Method

Transit Line File	Link Time Method	RUNTIME?	TIMEFAC?	XYSpeeds (mph)
BART_CSTDM09.lin	TIME (N)	Yes	Yes = 1.0	28 - 43
SACOG_LRT_CSTDM09.lin	XYSPEED	No	No	40
SANDAG_LRT_CSTDM09.lin	XYSPEED	No	No	50
VTA_LRT_CSTDM09.lin	TIME (N)	No	Yes = 1.0	28 - 36
Muni_Metro_CSTDM09.lin	TIME (N)	Yes	Yes = 1.0	6 - 18
SCAG_Urban_Rail_CSTDM09.lin	TIME (N)	No	No	50
SANDAG_Rail_CSTDM09.lin	XYSPEED	Yes	No	50
Metrolink_Orange-CSTDM09.lin	TIME (N)	No	No	50
SCAG_Metrolink_Other_CSTDM09.lin	TIME (N)	No	No	50
ACE_CSTDM09.lin	TIME (N)	Yes	Yes	27
CALTRAIN_CSTDM09.lin	TIME (N)	Yes	Yes: 0.89 to 1.07	9 - 39
Pacsurf_CSTDM09.lin	TIME (N)	No	No	30 - 180
AMTRAK_Capital_CSTDM09.lin	TIME (N)	Yes	Yes = 1.0	16
AMTRAK_SJQ_CSTDM09.lin	TIME (N)	No	Yes = 1.0	15

In the CSTDM, all links for the representation of rail lines are explicitly coded. That means that these links are included in the coded network. For 2000 link times are calculated by specifying an appropriate distance and speed for each link. For 2008, link times are determined by the time between stations and the total runtime. Detailed explanations of these processes are outlined below.

For the year 2000, CUBE scripting for transit network creation with the PUBLIC TRANSPORT program is structured as follows:

1. For lines where the HSR coding used TIME(N) for link times:
   a. Code links on each line with SPEED as defined in Table 13;
   b. In the LINKREAD process phase calculate link transit time as:
      LW.TRANTIME = 1.00*(li.distance*60/li.speed)
   c. Set TRANTIME parameter = LW.TRANTIME;
   d. Use TIME (N) function in line coding to specify link times (in practice this over-writes the "TRANTIME" calculated link times;
   e. Do not use TIMEFAC (because the TIME (N) time overwrites any times estimated with TIMEFAC);
   f. Use RUNTIME keyword to get "final" link times.

2. For lines where the HSR coding used XYSPEED for link times:
   a. Code links on each line with SPEED as defined in Table 13;
   b. In the LINKREAD process phase calculate link transit time as:
      LW.TRANTIME = 1.00*(li.distance*60/li.speed)
   c. Set TRANTIME parameter = LW.TRANTIME;
   d. Use XYSPEED in line coding as Table 13 (not really necessary);
   e. Set TIMEFAC as given in Table 13;
   f. Use RUNTIME keyword to get "final" link times.

Table 13: CSTDM09 Link Time Coding Method for Year 2000

Transit Line File	Link Time Method	RUNTIME	TIMEFAC	Speeds (mph)
BART_CSTDM09_2000.lin	TIME (N)	Yes	No	28
SACOG_LRT_CSTDM09_2000.lin	TIME (N)	Yes	No	40
SANDAG_LRT_CSTDM09_2000.lin	TIME (N)	Yes	No	50
VTA_LRT_CSTDM09_2000.lin	TIME (N)	No	No	28
Muni_Metro_CSTDM09_2000.lin	TIME (N)	Yes	No	18
SCAG_Urban_Rail_CSTDM09_2000.lin	TIME (N)	No	No	50
SANDAG_Rail_CSTDM09_2000.lin	TIME (N)	Yes	No	50
Metrolink_Orange-CSTDM09_2000.lin	TIME (N)	No	No	50
SCAG_Metrolink_Other_CSTDM09_2000.lin	TIME (N)	No	No	50
ACE_CSTDM09_2000.lin	TIME (N)	Yes	No	27
CALTRAIN_CSTDM09_2000.lin	TIME (N)	Yes	No	39
Pacsurf_CSTDM09_2000.lin	TIME (N)	No	No	30
AMTRAK_Capital_CSTDM09_2000.lin	TIME (N)	Yes	No	16
AMTRAK_SJQ_CSTDM09_2000.lin	TIME (N)	No	No	15

For the year 2008, the time between stations and the total runtime were used. Time between stations and total runtime were determined using the timetables on the operators' websites. We did not use speed and distance between stations, because we represented the rail tracks as the straight line distance.

3.4 Rail Line Fare Data

Fare information for each rail transit system is entered in the "farein_CSTDM09_<year>.far" file, as summarized in Tables 14a and 14b:

Table 14a: Transit Line Year 2000 Fare Information

Transit Line File	Fare Structure Type	Fare Zone Node Parameter	Initial Fare (2000$)	Transfer Fare (2000$)
BART_CSTDM09_2000.lin	FROMTO	BARTZ	n/a	n/a
SACOG_LRT_CSTDM09_2000.lin	FLAT	n/a	$1.10	$1.10
SANDAG_LRT_CSTDM09_2000.lin	FLAT	n/a	$1.25	$0.20
VTA_LRT_CSTDM09_2000.lin	FLAT	n/a	$0.90	$0.90
Muni_Metro_CSTDM09_2000.lin	FLAT	n/a	$0.70	$0.70
SCAG_Urban_Rail_CSTDM09_2000.lin	FLAT	n/a	$0.58	$0.20
SANDAG_Rail_CSTDM09_2000.lin	COUNT	CTRZ	n/a	n/a
Metrolink_Orange-CSTDM09_2000.lin	FROMTO	MLKZ	n/a	n/a
SCAG_Metrolink_Other_CSTDM09_2000.lin	FLAT	n/a	$2.29	$0.20
ACE_CSTDM09_2000.lin	FROMTO	ACEZ	n/a	n/a
CALTRAIN_CSTDM09_2000.lin	COUNT	CALTZ	n/a	n/a
Pacsurf_CSTDM09_2000.lin	FROMTO	PACZ	n/a	n/a

AMTRAK_Capital_CSTDM09_2000.lin	FROMTO	CAPZ	n/a	n/a
AMTRAK_SJQ_CSTDM09_2000.lin	FROMTO	SJQZ	n/a	n/a

Table 14b: Transit Line Year 2008 Fare Information

Transit Line File	Fare Structure Type	Fare Zone Node Parameter	Initial Fare 2008$/2000$	Transfer Fare 2008$/2000$
BART_CSTDM09_2008.lin	FROMTO	BARTZ	n/a	n/a
SACOG_LRT_CSTDM09_2008.lin	FLAT	n/a	$2.50/$1.87	$2.50/$1.87
SANDAG_LRT_CSTDM09_2008.lin	FLAT	n/a	$2.50/$1.87	$2.50/$1.87
VTA_LRT_CSTDM09_2008.lin	FLAT	n/a	$2.00/$1.50	$2.00/$1.50
Muni_Metro_CSTDM09_2008.lin	FLAT	n/a	$2.00/$1.50	$0.00/$0.00
SCAG_Urban_Rail_CSTDM09_2008.lin	FLAT	n/a	$1.25/$0.94	$1.25/$0.94
SANDAG_Sprinter_CSTDM09_2008.lin	FLAT	n/a	$2.00/$1.50	$2.00/$1.50
SANDAG_Rail_CSTDM09_2008.lin	COUNT	CTRZ	n/a	n/a
Metrolink_Orange-CSTDM09_2008.lin	FROMTO	MLKZ	n/a	n/a
SCAG_Metrolink_Other_CSTDM09_2008.lin	FROMTO	MLKZ	n/a	n/a
ACE_CSTDM09_2008.lin	FROMTO	ACEZ	n/a	n/a
CALTRAIN_CSTDM09_2008.lin	COUNT	CALTZ	n/a	n/a
Pacsurf_CSTDM09_2008.lin	FROMTO	PACZ	n/a	n/a
AMTRAK_Capital_CSTDM09_2008.lin	FROMTO	CAPZ	n/a	n/a
AMTRAK_SJQ_CSTDM09_2008.lin	FROMTO	SJQZ	n/a	n/a

The following fare structure types are used:

- FROMTO: Fare is an attribute of the boarding and disembarking fare zones;
- FLAT: Fare calculated from Initial / Transfer fares;
- COUNT: Fare is a measure of the number of fare zones crossed;

For transit lines with the FROMTO fare system, a fare zone-to-fare zone fare table is externally inputted, with each rail station having a node attribute (identified in the second column of Tables 14a and14b) giving the fare zone in which the station is located. Transit lines with the COUNT fare system also use a node attribute giving the fare zone.

The externally input fare table files are listed below. The row of the matrix represents the boarding fare zone traversed, and the column the alighting fare zone traversed. They are currently read into the model in standard CUBE Voyager binary matrix format (having been created in previous work), with the following names:

- For BART: "BART_<year>.mat"
- For Metrolink Orange: "Metrolink_<year>.mat"
- For ACE: "ACE_<year>.mat"
- For Pacific Surfliner: "Pacsurf_<year>.mat"
- For AMTRAK Capitol Corridor: "Capitol_<year>.mat"
- For Amtrak San Joaquin Valley: "SJQ.fare_<year>.mat"
- For Metrolink – Other: "MetrolinkOther_<year>.mat"

In the CUBE script these fare matrices are specified using the FAREMATI keyword with the FILEI input method. Each input fare matrix is given an index number i.e. FAREMAT[1] = BART.mat; FAREMAT[2] = Metrolink.mat; etc.

In the "farein_CSTDM09.far" fare system input file, these fare matrix input files are referenced using the FAREMATRIX keyword with the format FAREMATRIX=FMI.x.1, where x = fare matrix index number (from FAREMAT[x]), and ".1" references the first table in this file (by convention, each fare matrix file has a single table).

It is very important to note that different .far input files are required for each CUBE script referencing different fare input matrices, with the correct correspondence between the CUBE script and the FAREMAT / FMI index numbers.

For transit lines with the COUNT fare system, a FARETABLE is entered in the Fare input file. Table 15 (below) displays the values from the fare tables.

Table 15: Fare Table Values for Transit Lines Using COUNT Fare System

	2000 Fare (2000$)	2008 Fare (2008$)	2008 Fare (2000$)
Coaster 1 Zone	$3.60	$4.50	$3.37
Coaster 2 Zones	$4.05	$5.00	$3.75
Coaster 3 Zones	$4.50	$5.50	$4.12
Coaster 4 Zones	$5.00	$6.00	$4.50
Caltrain 1 Zone	$0.95	$2.50	$1.87

Caltrain 2 Zones	$1.47	$4.25	$3.19
Caltrain 3 Zones	$2.02	$6.00	$4.50
Caltrain 4 Zones	$2.38	$7.75	$5.81
Caltrain 5 Zones	$2.93	$9.50	$7.12
Caltrain 6 Zones	$3.48	$11.25	$8.43
Caltrain 7 Zones	$3.85	n/a	n/a
Caltrain 8 Zones	$4.40	n/a	n/a
Caltrain 9 Zones	$4.95	n/a	n/a

The Caltrain Zone system changed from 2000 to 2008, going from 9 to 6 zones. These differences are reflected in the respective time period's network.

3.5 Non-Transit Legs

Non-transit legs are generated by the Public Transport Program in the DATAPREP phase to represent access, egress and transfer for either walk and auto links between zones and nodes served by transit, plus walk transfer links between transit nodes.

The following keywords are used to specify the type and characteristics of the non-transit (nt) legs:

- NTLEGMODE: Non-transit mode assigned to the nt leg;
- FROMNODE: List of nodes from which nt legs generated;
- TONODE: List of nodes to which nt legs generated;
- MAXNTLEGS: Maximum # of nt legs generated for a particular transit mode from a FROMNODE to a TONODE;
- DIRECTION: Integer indicating direction of the generated nt leg:
    - 1: Forward direction (FROMNODE to TONODE)
    - 2: Reverse direction (TONODE to FROMNODE)
    - 3: Both Directions
- COST: Expression to compute link costs in generation nt legs;
- MAXCOST: maximum cost for nt leg allowed for a particular mode;
- EXTRACTCOST: Expression that computes the skimmed costs from the nt leg

Table 16 describes how these keywords are specified in the CSTDM09, for the generation of nt legs for the extraction of “short distance” transit trip transit skims. Table 16b describes how these keywords are specified for the generation of nt legs for the extraction of “long distance” transit trip transit skims.

Table 16: Nontransit Leg Keywords for Short Distance Transit Trips in CSTDM09

GENERATE Keyword for nt legs	Walk Access Leg	Walk Egress Leg	Auto Access Leg	Auto Egress Leg	Walk Transfer Leg
NTLEGMODE	1	2	3	4	5
FROMNODE	1-6999	7000-206000	1-6999	7000-206000	7000-206000
TONODE	7000-206000	1-6999	7000-206000	1-6999	7000-206000
MAXNTLEGS	2	2	2	2	2
DIRECTION	1	1	1	1	3
COST	WALKTIME	WALKTIME	AUTOTIME	AUTOTIME	WALKTIME
MAXCOST	30	30	15 / 30	15 / 30	15
EXTRACTCOST	WALKTIME	WALKTIME	AUTOTIME	AUTOTIME	WALKTIME

For long distance transit travel, two transit modes are included: Air travel AND Conventional Rail (CVR) travel (The Pacific Surfliner, Amtrak Capitol and Amtrak San Joaquin lines); and High Speed Rail. The nt legs” for these modes were specified as:

- Walk Access – up to 45 minutes
- Walk Egress and Walk Transfer – up to 15 minutes
- Drive Access to Airport Node – up to 100 miles
- Drive Access to CVR Station Node – up to 50 miles
- Drive Egress from Airport Node – up to 100 miles
- Drive Egress from CVR Station Node – up to 50 miles

It is important point to note that the nt leg cost is derived from data for actual links in the base highway network. Auto times are specified in the CUBE script to be the “loaded” times generated from a vehicle assignment to the road network.

3.6 Representation of Air Travel Services

Air travel is coded in a similar way to the method used for rail services. The HSR model analyzed the calculated average input data from the Federal Aviation Administration (FTA) 10 percent ticket sample data for the year 2000 to establish the amount and detail of air service existing for travel within California in the year 2000. Eighteen airports providing intra-state air service were identified for the year 2000, and node numbers were assigned to these 18 airports. A total of 57 airport to airport pairs having non-stop or connecting commercial intra-state air traffic service in the year 2000 were identified. These 57 air routes are represented as individual air “lines” in an input CUBE transit line file, with headways and travel times for each route. An input air line file ***“Air_2000_CSTDM09.lin”*** contains this headway and gate-to-gate time data for each of these 114 routes, with Mode and Operator number 71 (Air). A FROMTO fare system is used to describe the fare matrix for these routes, with an AIRZ fare zone node attribute and an air fare external fare matrix file ***“airfare2000.mat***”.

The air network was updated for the year 2008 using a similar methodology to the one used for 2000. Data from the U.S. Department of Transportation Research and Innovative Technology Administration (RITA) and Federal Aviation Administration (FAA) database for air passenger services in 2008 were used to update the air network. The full database containing passenger data for domestic air services in the USA was analyzed to identify the major routes offering regular scheduled commercial passenger services across California. All airports that had an average of 4000 or more monthly passengers during 2008 were included in the model. The remaining airports were only added to the 2008 air network if they were included in the HSR model (and in the CSTDM 2000 air network). Using these criteria, 20 airports were included in the 2008 air network.

Table 17 presents the list of the airports included in the 2008 air network (airports from 1 to 18 are also present in the 2000 air network).

Table 17: Airports Included in the CSTDM Air Network

Airport Number	Node Number	Airport	2000 Air Network	2008 Air Network
1	18501	SAN - San Diego	Yes	Yes
2	18502	SNA - Santa Ana	Yes	Yes
3	18503	LGB - Long Beach	Yes	Yes
4	18504	LAX - Los Angeles	Yes	Yes
5	18505	ONT - Ontario	Yes	Yes
6	18506	BUR - Burbank	Yes	Yes
7	18507	SJC - San Jose	Yes	Yes
8	18508	SFO - San Francisco	Yes	Yes
9	18509	OAK - Oakland	Yes	Yes
10	18510	SMF - Sacramento	Yes	Yes
11	18511	MRY - Monterrey	Yes	Yes
12	18512	OXR - Oxnard	Yes	Yes
13	18513	PSP - Palm Springs	Yes	Yes
14	18514	SBA - Santa Barbara	Yes	Yes
15	18515	ACV - Arcata/Eureka	Yes	Yes
16	18516	BFL - Bakersfield	Yes	Yes
17	18517	FAT - Fresno	Yes	Yes
18	18518	MOD - Modesto	Yes	Yes
19	18519	RDD - Redding	No	Yes
20	18520	SBP - San Luis Obispo	No	Yes

The 2008 air network was generated in a similar way to the 2000 network. The ***Air_2008_CSTDM09.lin*** file was created including all routes on which direct commercial passenger air services were provided during 2008. In addition, all indirect routes (with one connection, usually either in LAX or SFO) that generated an average number of trips of at least 1 passenger per day (about 400 passengers per year) were included in the air network.

Data for travel times from gate to gate and headways were estimated for each route included in the model. This estimation was based on an analysis of the data from the RITA/FAA database. The fare matrix ***airfare2008.mat*** was created from an analysis of the 10% ticket sample data from RITA/FAA. An average fare was estimated for each route on which a direct flight was available. For routes that had no direct flights, the average fare was estimated based on the data from the 10% ticket sample for trips with one connection.

Two aspects of the air service coding differ from the approach used for rail coding:

- Links representing paths between two airport nodes are not coded in the highway network. The TIME keyword is used to represent time on the transit link identified for each route.
- The HSR model used only one headway and time period for air service to represent peak and off-peak travel. This approach is preserved in the CSTDM, with time period 2 (AM Peak) being specified for the headway data.

3.7 Transit and Road Reliability Indices

In the HSR model, reliability indices were used as explanatory parameters to explain long distance trip mode choice for air, conventional rail and auto modes.

- For **Air**, reliability was defined as the percentage of flights arriving within one hour of scheduled arrival time. Data for each of the 114 routes was obtained from the RITA/FAA 10% ticket sample data. Values ranged from 88% (San Francisco / Los Angeles) to 95% (Oakland / Santa Ana).
- For **Conventional Rail**, reliability was defined as the percentage of services arriving at the destination station within one hour of scheduled arrival time. Values were estimated from information provided by the train operators:
    - 94% for Pacific Surfliner;
    - 94% for Amtrak Capital Corridor;
    - 89% for Amtrak San Joaquin Valley;
    - 99% for High Speed Rail.
- For **Auto,** a reliability measure developed by Cambridge Systematics, representing the probability that an auto traveller arrives within 60 minutes of the congested travel time, based on non-recurrent incident delay concepts, was applied for each O-D pair for peak and off-peak travel times:

$$P = \left(\frac{(TC + 60)}{TC + 0.0073^{*} \left[\frac{(TC / TO - 1)}{0.18}^{0.117647} \right]^{5.2695} {}^{*}60^{*} TO} \right)$$

Where:

TO = Free-flow (off-peak) travel time in minutes

TC = Congested (peak) travel time in minutes

The resulting percent reliability estimates for a trip from Los Angeles to San Francisco are in the range of 67 to 92 percent, depending on the specific details of a trip. Trips with no congestion have 100 percent reliability.

4. Local Bus Transit

4.1. Introduction

A hybrid method is used to represent short distance (under 100 mi) transit in the California Statewide Travel Demand Model (CSTDM). Local bus service is represented indirectly through a model relating bus times to auto time in CUBE, which is different than rail services that are explicitly coded into the CUBE network.

Using a hybrid approach provides an appropriate level of detail for a statewide model such as the CSTDM. The high cost, long-term capital rail projects can be created explicitly because the coding burden for these is relatively low, and their impact high. In 2009, there were 39 lines of rail transit in California, with average weekday ridership of approximately 1.12 million. By comparison, the Los Angeles Metro bus system had a daily ridership of 1.18 million, but 191 bus routes. Similarly, the three major Bay agencies (Muni, AC Transit and VTA) combined for daily bus ridership of 0.84 million, but across 262 bus routes. In the entire state of California, bus services are provided through more than 50 local transit operators. These operators provide transit services on more than 1500 local bus routes, with varying levels of service. Densely populated urban areas have frequent service while remote areas have rather limited service.

Local bus services are clearly important, and in many areas are the only form of public transit provided. However, coding these networks in detail is beyond the scope of the CSTDM. Moreover, the characteristics of local bus services change frequently to adapt to modifications in travel demand, changes in the land use and the urban form of cities, and funding for public transportation.

The detailed description of the development of the local bus transit model is documented in the separate document “Local Transit Functions” in the interest of space.

4.2. Local Transit Model Inputs

The local transit functions use four key inputs:

1. Transfer areas: the areas within which a person can travel (they include the possibilities of transfers among different operators in a region);
2. Service areas: the areas within which transit service is generally provided by a single operator (they are subdivisions of the larger transfer areas served by multiple transit operators);
3. Level of Service: a single number representing the quantity of local bus service provided by the transit operator; and
4. Fare: a composite value, expressed in year 2000 US dollars, indicating the typical fare paid by a customer.

Transfer and Service Areas concur to the definition of the catchment areas for transit. A transfer area measures the accessibility to transit services in a region. It is a measure of the portion of a region in which transit trips are possible (using any of the operators that offer local transit services). A service area is a smaller region that is usually served by only one operator. The characteristics of the transit services and the level of service are considered homogenous inside each service area.

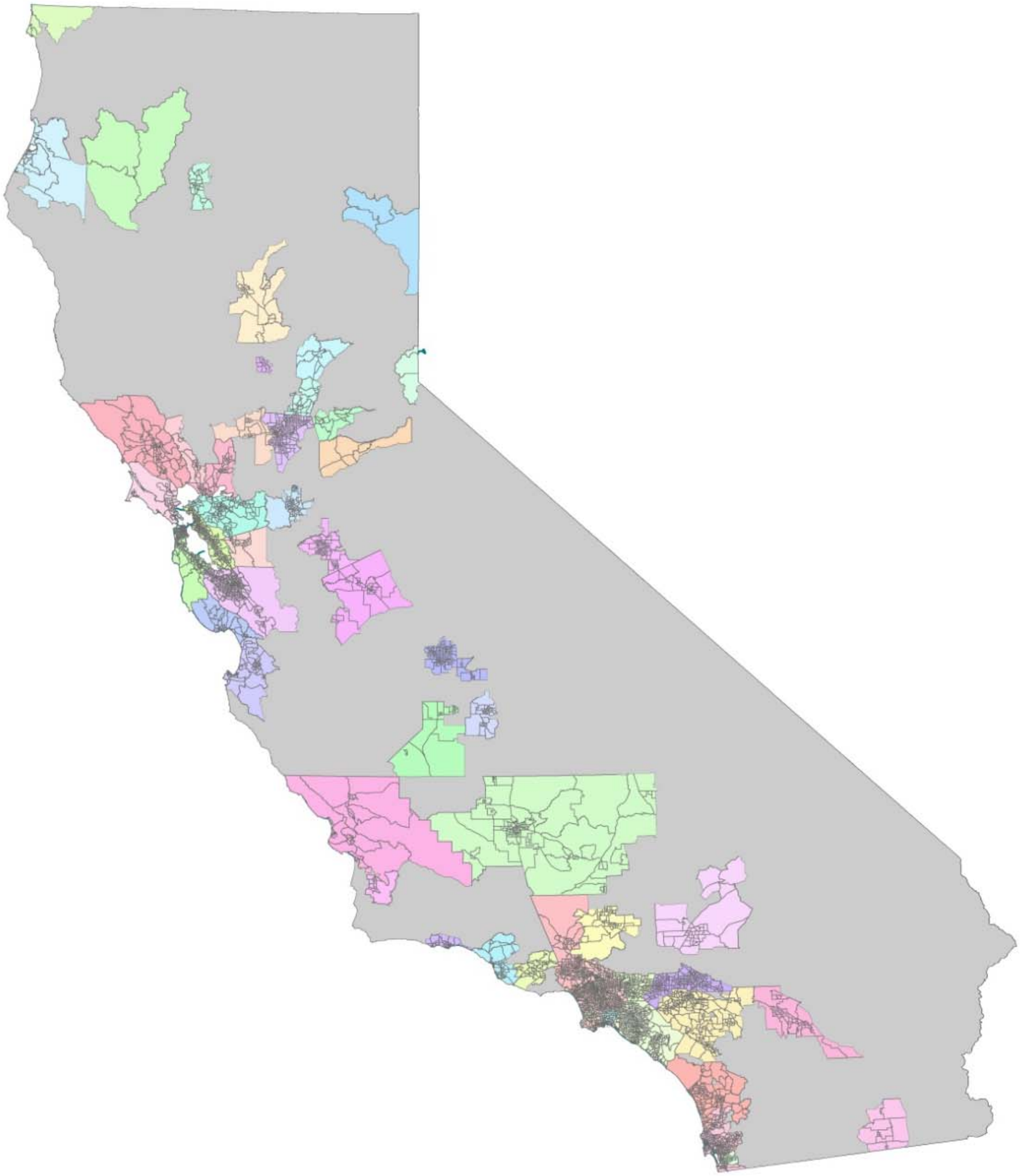

Figure 1: Transfer Areas for local bus transit in CSTDM

Multiple service areas are sometimes found in large transfer areas, as a result of multiple operators providing services in a geographically vast area. Service areas are indicated through the addition of a digit to the number of the transfer areas they belong to (for example, service areas 7.0, 7.1, 7.2 and 7.3 form the transfer area no. 7 in the “Sacramento region”).

A GIS shapefile of transit lines provided by the California Department of Transportation was used to develop the transfer and service areas. Each of the 5191 TAZs in the CSTDM framework is eventually assigned to a catchment area, based on the proximity from the TAZ centroid to the closest bus lines. The TAZ is assigned to the corresponding service and transfer area of the operator that runs the transit lines within three miles of the TAZ centroid. If no lines is available in a three mile range from the TAZ centroid, but at least one bus line crosses the TAZ, then the TAZ is also included in the corresponding transfer and service areas. Otherwise, the TAZ is not included in any catchment area (no transit services).

A total of 32 Transfer Areas and 55 Service Areas were identified in California.

Two different functions, using the input variables reported above, are used to express the travel attributes for local bus transit. The first local transit function allows computing in-vehicle time (IVT), and the second represents out of vehicle time (OVT). The two were separated because OVT is considered more onerous than IVT because it includes walking to and from the bus, waiting for the bus, and waiting at any transfer points.

Detailed information on the assumptions used for the development of the local transit functions, the data collection and the estimation of the econometric models used to express transit attributes are reported in the “Local Transit Functions” documentation.

5. Other Roadway Properties

5.1 On-Peak/Off-Peak Changes

Some parts of the network change throughout the day to accommodate heavy traffic flow in one direction during the AM or PM peak time periods (Table 18). These changes were saved into log files which are applied to the master network to ensure that the correct number of lanes is available during each time period that the model is run.

Table 18: On-Peak/Off-Peak Changes

	6 am - 10 am	**10 am - 3 pm**	**3 pm - 7 pm**	**7 pm - 6 am**
San Diego - Coronado Bridge	3 lanes westbound 2 lanes eastbound	2 lanes westbound 3 lanes eastbound	2 lanes westbound 3 lanes eastbound	2 lanes westbound 3 lanes eastbound
Caldecott Tunnel	4 lanes westbound 2 lanes eastbound	2 lanes westbound 4 lanes eastbound	2 lanes westbound 4 lanes eastbound	2 lanes westbound 4 lanes eastbound
Golden Gate Bridge	4 lanes southbound 2 lanes northbound	3 lanes southbound 3lanes northbound	2 lanes southbound 4 lanes northbound	2 lanes southbound 2 lanes northbound (2 lane buffer)
Bay Bridge Tolls	HOVs exempt from tolls	HOVs pay tolls	HOVs exempt from tolls	HOVs pay tolls

5.2 Reversible Lanes

Reversible lanes were coded into the network in three locations:

1. San Diego - Coronado Bridge
2. Caldecott Tunnel
3. Golden Gate Bridge

See Table 18 for detailed lane configurations.

Additional reversible lanes were identified at three other locations:

- Lafayette St - from Lewis St to E Homestead Rd in Santa Clara
- E 4th St - from Hewitt St to I-5 in Los Angeles

- I-15 - from Hwy 163 to Hwy 56 in San Diego (2 HOT Lanes change direction)

These locations are not coded as reversible lanes in the network. Instead, they are coded to have their full capacity running in both directions at all times. They were not coded for a variety of reasons. These links were generally not a bottleneck in the counter commute direction and were dominated by flow in one direction at a time so reverse flows were unlikely to be constrained. Also, the original network coding from the MPOs included full capacity in both directions. In interest of simplicity these links were not coded with reversible lanes and instead had full capacity in both directions.

5.3 Toll Roads and Bridges

Toll roads and bridges are represented by a set of unique codes in the ONRAMP, OFFRAMP, and TOLL attribute of the link. The link that represents the location of a toll booth or plaza has this unique TOLL code, the approach and departure links are coded with an identical value in the ONRAMP and OFFRAMP fields. 2008 toll rates were determined using the appropriate transit authority website or by requesting rates directly from the transit authority.

Interstate 15 North of San Diego and State Route 91 have Congestion pricing schemes. Computing tolls for these was more complicated and was done as shown in Tables 19 and 20.

Table 19: Interstate 15 Tolls

	2000*	2008	2008**
Off peak	$0.63	$0.45	$0.34
AM	$1.29	$0.92	$0.69
Midday	$0.60	$0.43	$0.32
PM	$1.89	$1.35	$1.01

The interstate 15 tolls were calculated based on known revenues for 2000 and 2008, known traffic counts for 2000 and 2008, and known tolls for 2008. This data was provided by Chris Burke, Project Manager for the San Diego Association of Governments I-15 Project Management Committee. The 2008 tolls were averaged for weekdays across the four time periods. Average revenue per car was calculated for 2000 and 2008 using the known traffic counts and revenue: $1.79/car in 2000 and $1.28/car in 2008. This relationship was then used to rescale the 2008 known tolls by time period to 2000. The 2008 tolls were then separately converted to 2000 dollars (**) with an assumed inflation of 33.4% between 2000 and 2008.

State Route 91 with current tolls determined by the level of congestion required estimation of tolls. The 91 Express Lanes General Manager, Kirk Avila, provided toll schedules for fall 2000 and fall 2008. We then averaged the tolls Monday through Friday across the four time periods of the day. The 2008 toll values were then converted to year 2000 dollar equivalents (Table 20).

Table 20: State Route 91 Tolls

	Actual Dollars				Converted to 2000 dollars			
	Off peak 1	Peak 2	Midday 3	PM 4	Off peak 1	Peak 2	Midday 3	PM 4
60 - East (2000)	$1.13	$3.44	$2.02	$3.44				
61 - West (2000)	$1.04	$2.87	$1.50	$1.56				
East HOV3 express lane (2000)	$0.57	$1.72	$1.01	$1.72				
60 - East (2008)	$1.68	$7.10	$2.68	$7.10	$1.26	$5.32	$2.01	$5.32
61 - West (2008)	$1.59	$3.81	$1.95	$2.07	$1.19	$2.86	$1.46	$1.55
East HOV3 express lane (2008)	$0.84	$0.98	$1.34	$3.55	$0.63	$0.73	$1.00	$2.66

Table 21 provides the first and last node of each toll zone (toll zones include the on-ramp, off-ramp, and tolling station), the toll id,, the sources of toll data used in this model, and the toll status for HOV traffic. Table 21a provides the translation for the toll sources.

Table 21: Toll Nodes, IDs, HOV Status and Data Sources

Toll Nodes	Route	TOLLID	HOV Status	Toll Source 2000	Toll Source 2008
20535-20530	680	1	HOV3 free AM/PM peak	A	B
20580-20606	80	2	HOV3 free AM/PM peak	A	B
20642-20758	580	3	HOV3 free AM/PM peak	A	B
25739-25722	101/1	4	HOV3 free AM/PM peak	C	C
21186-21203	80	5	HOV3 free AM/PM peak	A	B
22063-22050	92	6	HOV2 free AM/PM peak	A	B
22265-22280	84	7	HOV2 free AM/PM peak	A	B
20079-20022	160	8	HOV3 free AM/PM peak	A	B
112185-112186	73	10	No HOV discount	D	D
114773-114774	73	11	No HOV discount	D	D
97603-97604	73	12	No HOV discount	D	D
97601-97602	73	121	No HOV discount	D	D
115074-121121	73	13	No HOV discount	D	D
53967-114574	73	14	No HOV discount	D	D
54120-154506	73	15	No HOV discount	D	D
98545-151535	241	20	No HOV discount	D	D
151536-68542	241	201	No HOV discount	D	D
151553-98558	241	21	No HOV discount	D	D
151551-98562	241	211	No HOV discount	D	D
116300-116301	241	22	No HOV discount	D	D
113298-117041	241	221	No HOV discount	D	D
114748-114749	241	23	No HOV discount	D	D
113262-113261	241	231	No HOV discount	D	D
115181-115182	241	24	No HOV discount	D	D
113086-113087	241	241	No HOV discount	D	D
112638-114579	241	25	No HOV discount	D	D
114710-117048	241	251	No HOV discount	D	D
151557-114648	241	26	No HOV discount	D	D
115332-115333	241	261	No HOV discount	D	D
117090-115547	241	27	No HOV discount	D	D

115598-117086	241	271	No HOV discount	D	D
117099-117098	261	30	No HOV discount	D	D
116286-117096	261	301	No HOV discount	D	D
98550-57563	261	31	No HOV discount	D	D
57564-98554	261	311	No HOV discount	D	D
116291-117103	261	32	No HOV discount	D	D
117102-117101	261	321	No HOV discount	D	D
110141-98570	133	40	No HOV discount	D	D
98565-98566	133	401	No HOV discount	D	D
154742-154743	133	41	No HOV discount	D	D
117110-117109	133	411	No HOV discount	D	D
36526-38050	125	51	No HOV discount	N/A	E
38051-38032	125	511	No HOV discount	N/A	E
38030-38044	125	52	No HOV discount	N/A	E
38045-38028	125	521	No HOV discount	N/A	E
38026-38038	125	53	No HOV discount	N/A	E
38039-38025	125	531	No HOV discount	N/A	E
37415-13115	125	55	No HOV discount	N/A	E
13115-37415	125	551	No HOV discount	N/A	E
54888-38052	91	60	HOV 50%, 3+ *	F	F
122514-38055	91	61	HOV free, 3+	F	F
166444-65043	15	70	HOV free, 2+	G	G
65039-35095	15	71	HOV free, 2+	G	G
29997-30083	680	81	HOV3 free AM/PM peak	A	B
30043-30067	80	82	HOV3 free AM/PM peak	A	B
26253-45652	580	83	HOV3 free AM/PM peak	A	B
25718-25716	101/1	84	HOV3 free AM/PM peak	C	C
25369-25373	80	85	HOV3 free AM/PM peak	A	B
22042-22049	92	86	HOV2 free AM/PM peak	A	B
22295-22296	84	87	HOV2 free AM/PM peak	A	B
20021-20074	160	88	HOV3 free AM/PM peak	A	B

Table 21a: Lookup Table for the Toll Sources in Table 21

Code	Description
A	Toll Bridge Report to the CA Legislature FY 2000-01; then verified with the MTC librarian http://bata.mtc.ca.gov/reports.htm
B	Bay Area Toll Authority Website http://bata.mtc.ca.gov/tolls/index.htm
C	Golden Gate Bridge Authority - Phone call 3/11/10
D	Jennifer Seaton - Communications and Public Affairs - The Toll Roads
E	South Bay Expressway Toll Wizard http://www.southbayexpressway.com/tollwiz/
F	Kirk Avila - 91 Express Lanes' General Manager
G	Chris Burke - SANDAG's Project Manager for the I-15 Project Management Committee
N/A	Not applicable because these roads did not exist in 2000

The final tolls for year 2000 (Table 22), and year 2008 in 2008 dollars (Table 23) and 2000 dollars (Table 24) are provided below.

5.3.1 Year 2000 Tolls

Table 22: 2000 Tolls in US Dollars

				2000 (2000 dollars)							
				2-axle auto, truck, or motorcycle		HOV2		HOV3+		4 axles	
TOLLID	**Route**	**Direction**	**Toll Exit/Plaza/Bridge**	**Peak Cost (Cash)**	**Off-Peak Cost (Cash)**	**Peak Cost (Cash)**	**Off-Peak Cost (Cash)**	**Peak Cost (Cash)**	**Off-Peak Cost (Cash)**	**Peak Cost (Cash)**	**Off-Peak Cost (Cash)**
1/81*	680	North	Bridge - Benicia/Martinez	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
2/82*	80	East	Bridge - Carquinez	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
3/83*	580	West	Bridge - Richmond/San Rafael	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
4/84*	101/1	South	Bridge - Golden Gate	5.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00
5/85*	80	West	Bridge - Oakland Bay Bridge	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
6/86*	92	West	Bridge - San Mateo/Hayward	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
7/87*	84	West	Bridge - Dumbarton	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
8/88*	160	North	Bridge - Antioch	2.00	2.00	2.00	2.00	2.00	2.00	6.25	6.25
10	73	South	Exit - Bonita Canyon	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
11	73	South	Exit - Newport Coast	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	73	South	Plaza - Catalina View Mainline	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50
121	73	North	Plaza - Catalina View Mainline	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50
13	73	North	Exit - El Toro/Laguna Canyon Rd	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
14	73	North	Exit - Aliso Creek Rd	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
15	73	North	Exit - La Paz Rd/Moulton Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
20	241	North	Plaza - Windy Ridge Mainline	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50
201	241	South	Plaza - Windy Ridge Mainline	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50
21	241	North	Plaza - Tomato Springs Mainline	1.50	1.50	1.50	1.50	1.50	1.50	3.00	3.00
211	241	South	Plaza - Tomato Springs Mainline	1.50	1.50	1.50	1.50	1.50	1.50	3.00	3.00
22	241	North	Exit - Portola Parkway-North	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

221	241	South	Exit - Portola Parkway-North	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
23	241	North	Exit - Alton Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
231	241	South	Exit - Alton Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
24	241	North	Exit - Portola Parkway-South	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
241	241	South	Exit - Portola Parkway-South	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
25	241	North	Exit - Los Alisos Parkway	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
251	241	South	Exit - Los Alisos Parkway	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
26	241	North	Exit - Antonio Parkway	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
261	241	South	Exit - Antonio Parkway	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
27	241	North	Exit - Oso Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
271	241	South	Exit - Oso Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
30	261	North	Exit - Portola Parkway-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
301	261	South	Exit - Portola Parkway-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
31	261	South	Plaza - Irvine Ranch Mainline	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
311	261	North	Plaza - Irvine Ranch Mainline	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
32	261	North	Exit - Irvine Blvd-West	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
321	261	South	Exit - Irvine Blvd-West	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
40	133	North	Plaza - Orange Grove Mainline	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
401	133	South	Plaza - Orange Grove Mainline	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
41	133	North	Exit - Irvine Blvd-East	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
411	133	South	Exit - Irvine Blvd-East	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
51	125	North	Exit - East H St	not a road in 2000, built in 2005, opened in 2007							
511	125	South	Exit - East H St	not a road in 2000, built in 2005, opened in 2007							
52	125	North	Exit - Otay Lakes/Telegraph Canyon Rd	not a road in 2000, built in 2005, opened in 2007							
521	125	South	Exit - Otay Lakes/Telegraph Canyon Rd	not a road in 2000, built in 2005, opened in 2007							
53	125	North	Exit - Olympic Parkway	not a road in 2000, built in 2005, opened in 2007							
531	125	South	Exit - Olympic Parkway	not a road in 2000, built in 2005, opened in 2007							

55	125	South	Plaza - Otay Mesa Rd/ 905	not a road in 2000, built in 2005, opened in 2007	
551	125	North	Plaza - Otay Mesa Rd/ 905	not a road in 2000, built in 2005, opened in 2007	
60	91	East	91 express lanes	*(See table 20)*	NA
61	91	West	91 express lanes	*(See table 20)*	NA
70	15	North	15 express lanes	*(See table 19)*	
71	15	South	15 express lanes	*(See table 19)*	

*Toll IDs 1-8 are bridges in the bay area. For CSTDM, these rates were divided in half and assigned to both directions on the bridges. See section 5.3.5.

5.3.2 Year 2008 Tolls

Table 23: 2008 Tolls in 2008 US Dollars

				2008 (2008 dollars)							
				2-axle auto, truck, or motorcycle		HOV2		HOV3+		4 axles	
TOLLID	Route	Direction	Toll Exit/Plaza/Bridge	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)
1/81*	680	North	Bridge - Benicia/Martinez	4.00	4.00	4.00	4.00	0.00	4.00	8.25	8.25
2/82*	80	East	Bridge - Carquinez	4.00	4.00	4.00	4.00	0.00	4.00	8.25	8.25
3/83*	580	West	Bridge - Richmond/San Rafael	4.00	4.00	4.00	4.00	0.00	4.00	8.25	8.25
4/84*	101/1	South	Bridge - Golden Gate	6.00	6.00	6.00	6.00	0.00	6.00	12.00	12.00
5/85*	80	West	Bridge - Oakland Bay Bridge	4.00	4.00	4.00	4.00	0.00	4.00	8.25	8.25
6/86*	92	West	Bridge - San Mateo/Hayward	4.00	4.00	0.00	4.00	0.00	4.00	8.25	8.25
7/87*	84	West	Bridge - Dumbarton	4.00	4.00	0.00	4.00	0.00	4.00	8.25	8.25
8/88*	160	North	Bridge - Antioch	4.00	4.00	4.00	4.00	0.00	4.00	8.25	8.25
10	73	South	Exit - Bonita Canyon	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
11	73	South	Exit - Newport Coast	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
12	73	South	Plaza - Catalina View Mainline	5.00	4.25	5.00	4.25	5.00	4.25	10.00	8.50
121	73	North	Plaza - Catalina View Mainline	5.00	4.25	5.00	4.25	5.00	4.25	10.00	8.50
13	73	North	Exit - El Toro/Laguna Canyon Rd	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
14	73	North	Exit - Aliso Creek Rd	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
15	73	North	Exit - La Paz Rd/Moulton Parkway	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
20	241	North	Plaza - Windy Ridge Mainline	2.75	2.75	2.75	2.75	2.75	2.75	5.50	5.50
201	241	South	Plaza - Windy Ridge Mainline	2.75	2.75	2.75	2.75	2.75	2.75	5.50	5.50
21	241	North	Plaza - Tomato Springs Mainline	2.50	2.25	2.50	2.25	2.50	2.25	5.00	4.50
211	241	South	Plaza - Tomato Springs Mainline	2.50	2.25	2.50	2.25	2.50	2.25	5.00	4.50
22	241	North	Exit - Portola Parkway-North	1.50	1.25	1.50	1.25	1.50	1.25	1.50	1.25
221	241	South	Exit - Portola Parkway-North	1.50	1.25	1.50	1.25	1.50	1.25	1.50	1.25
23	241	North	Exit - Alton Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
231	241	South	Exit - Alton Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
24	241	North	Exit - Portola Parkway-South	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
241	241	South	Exit - Portola Parkway-South	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
25	241	North	Exit - Los Alisos Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
251	241	South	Exit - Los Alisos Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

26	241	North	Exit - Antonio Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
261	241	South	Exit - Antonio Parkway	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
27	241	North	Exit - Oso Parkway	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
271	241	South	Exit - Oso Parkway	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
30	261	North	Exit - Portola Parkway-West	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
301	261	South	Exit - Portola Parkway-West	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
31	261	South	Plaza - Irvine Ranch Mainline	1.75	1.50	1.75	1.50	1.75	1.50	3.50	3.00
311	261	North	Plaza - Irvine Ranch Mainline	1.75	1.50	1.75	1.50	1.75	1.50	3.50	3.00
32	261	North	Exit - Irvine Blvd-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
321	261	South	Exit - Irvine Blvd-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
40	133	North	Plaza - Orange Grove Mainline	1.75	1.75	1.75	1.75	1.75	1.75	3.50	3.50
401	133	South	Plaza - Orange Grove Mainline	1.75	1.75	1.75	1.75	1.75	1.75	3.50	3.50
41	133	North	Exit - Irvine Blvd-East	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
411	133	South	Exit - Irvine Blvd-East	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
51	125	North	Exit - East H St	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
511	125	South	Exit - East H St	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
52	125	North	Exit - Otay Lakes/Telegraph Canyon Rd	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
521	125	South	Exit - Otay Lakes/Telegraph Canyon Rd	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
53	125	North	Exit - Olympic Parkway	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
531	125	South	Exit - Olympic Parkway	3.00	3.00	3.00	3.00	3.00	3.00	6.00	6.00
55	125	South	Plaza - Otay Mesa Rd/ 905	4.50	4.50	4.50	4.50	4.50	4.50	9.00	9.00
551	125	North	Plaza - Otay Mesa Rd/ 905	4.50	4.50	4.50	4.50	4.50	4.50	9.00	9.00
60	91	East	91 express lanes	*(See Table 20)*						NA	
61	91	West	91 express lanes	*(See Table 20)*						NA	
70	15	North	15 express lanes	*(See Table 19)*							
71	15	South	15 express lanes	*(See Table 19)*							

*Toll IDs 1-8 are bridges in the bay area. For CSTDM, these rates were divided in half and assigned to both directions on the bridges. See section 5.3.5

Table 24: 2008 Tolls in 2000 US Dollars

				2008 (2000 dollars)							
				2-axle auto, truck, or motorcycle		HOV2		HOV3+		4 axles	
TOLL	Route	Direction	Toll Exit/Plaza/Bridge	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)	Peak Cost (Cash)	Off-Peak Cost (Cash)
1/81*	680	North	Bridge - Benicia/Martinez	3.00	3.00	3.00	3.00	0.00	3.00	6.18	6.18
2/82*	80	East	Bridge - Carquinez	3.00	3.00	3.00	3.00	0.00	3.00	6.18	6.18
3/83*	580	West	Bridge - Richmond/San Rafael	3.00	3.00	3.00	3.00	0.00	3.00	6.18	6.18
4/84*	101/1	South	Bridge - Golden Gate	4.50	4.50	4.50	4.50	0.00	4.50	9.00	9.00
5/85*	80	West	Bridge - Oakland Bay Bridge	3.00	3.00	3.00	3.00	0.00	3.00	6.18	6.18
6/86*	92	West	Bridge - San Mateo/Hayward	3.00	3.00	0.00	3.00	0.00	3.00	6.18	6.18
7/87*	84	West	Bridge - Dumbarton	3.00	3.00	0.00	3.00	0.00	3.00	6.18	6.18
8/88*	160	North	Bridge - Antioch	3.00	3.00	3.00	3.00	0.00	3.00	6.18	6.18
10	73	South	Exit - Bonita Canyon	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
11	73	South	Exit - Newport Coast	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
12	73	South	Plaza - Catalina View Mainline	4.12	3.56	4.12	3.56	4.12	3.56	8.25	7.12
121	73	North	Plaza - Catalina View Mainline	4.12	3.56	4.12	3.56	4.12	3.56	8.25	7.12
13	73	North	Exit - El Toro/Laguna Canyon Rd	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
14	73	North	Exit - Aliso Creek Rd	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
15	73	North	Exit - La Paz Rd/Moulton Parkway	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
20	241	North	Plaza - Windy Ridge Mainline	2.06	2.06	2.06	2.06	2.06	2.06	4.12	4.12
201	241	South	Plaza - Windy Ridge Mainline	2.06	2.06	2.06	2.06	2.06	2.06	4.12	4.12
21	241	North	Plaza - Tomato Springs Mainline	2.06	1.87	2.06	1.87	2.06	1.87	4.12	3.75
211	241	South	Plaza - Tomato Springs Mainline	2.06	1.87	2.06	1.87	2.06	1.87	4.12	3.75
22	241	North	Exit - Portola Parkway-North	1.31	1.12	1.31	1.12	1.31	1.12	1.31	1.12
221	241	South	Exit - Portola Parkway-North	1.31	1.12	1.31	1.12	1.31	1.12	1.31	1.12
23	241	North	Exit - Alton Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
231	241	South	Exit - Alton Parkway	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
24	241	North	Exit - Portola Parkway-South	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
241	241	South	Exit - Portola Parkway-South	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
25	241	North	Exit - Los Alisos Parkway	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
251	241	South	Exit - Los Alisos Parkway	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
26	241	North	Exit - Antonio Parkway	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
261	241	South	Exit - Antonio Parkway	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56

27	241	North	Exit - Oso Parkway	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	
271	241	South	Exit - Oso Parkway	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	
30	261	North	Exit - Portola Parkway-West	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	
301	261	South	Exit - Portola Parkway-West	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	
31	261	South	Plaza - Irvine Ranch Mainline	1.50	1.31	1.50	1.31	1.50	1.31	3.00	2.62	
311	261	North	Plaza - Irvine Ranch Mainline	1.50	1.31	1.50	1.31	1.50	1.31	3.00	2.62	
32	261	North	Exit - Irvine Blvd-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
321	261	South	Exit - Irvine Blvd-West	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
40	133	North	Plaza - Orange Grove Mainline	1.50	1.50	1.50	1.50	1.50	1.50	3.00	3.00	
401	133	South	Plaza - Orange Grove Mainline	1.50	1.50	1.50	1.50	1.50	1.50	3.00	3.00	
41	133	North	Exit - Irvine Blvd-East	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
411	133	South	Exit - Irvine Blvd-East	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
51	125	North	Exit - East H St	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
511	125	South	Exit - East H St	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
52	125	North	Exit - Otay Lakes/Telegraph Canyon Rd	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
521	125	South	Exit - Otay Lakes/Telegraph Canyon Rd	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
53	125	North	Exit - Olympic Parkway	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
531	125	South	Exit - Olympic Parkway	2.25	2.25	2.25	2.25	2.25	2.25	4.50	4.50	
55	125	South	Plaza - Otay Mesa Rd/ 905	3.37	3.37	3.37	3.37	3.37	3.37	6.75	6.75	
551	125	North	Plaza - Otay Mesa Rd/ 905	3.37	3.37	3.37	3.37	3.37	3.37	6.75	6.75	
60	91	East	91 express lanes	*(See Table 20)*								not allowed on road
61	91	West	91 express lanes	*(See Table 20)*								not allowed on road
70	15	North	15 express lanes	*(See Table 19)*								
71	15	South	15 express lanes	*(See Table 19)*								

*Toll IDs 1-8 are bridges in the bay area. For CSTDM, these rates were divided in half and assigned to both directions on the bridges. See section 5.3.5

5.3.4 HOV Toll Exemptions

HOV vehicles are exempt from paying tolls on the Bay Area Bridges during the AM and PM peak time periods.

5.3.5 Bay Area Bridge Tolls

Tolls are charged to motorists in only one direction on the 8 Bay Area Bridges. However, consistent with the procedure applied in similar models, the tolls charged on the bridges were divided in half and assigned to trips going in both directions. This approach allowed obtaining more realistic results in the assignment of vehicles to the road network.

6. Network Checks

After the initial alpha network was created, it was submitted to HBA Specto for testing. Identified problems were fixed and the network was tested again. The fixing of errors in the network is an ongoing process and is on an "as identified" basis. Checking has continued throughout the network creation, calibration, and validation stages of the model.

The checks that were run included:

1. Full connectivity: make sure all TAZs are connected to the network
2. Appropriate connectivity: make sure TAZs are connected to the network through nodes that do not include freeways
3. Network Connectivity: make sure that road segments are appropriately connected (largely visual)
4. Appropriate attribute coding: check for speed, lane and capacity values that are outside of expected bounds (attribute testing and visual)
5. Post assignment (Volume to Capacity) VC ratio checks: Check for high VC ratio (>1.5), and review surrounding links
6. Post assignment volume checks: volume >8,000 or zero on freeways/expressways, and review surrounding links
7. Post assignment speed checks: speed >70mph or < 10mph
8. OD Distance checks: ensure that TAZ-TAZ distances on network are > euclidean distances

6.1 SCAG Capacity Changes

The SCAG portion of the network, which was inherited as part of the original HSR network, had link capacity values that were significantly lower in many places than the rest of the statewide network. This was causing high VC ratios in many of these links. To address this problem, link capacity values were raised to bring them closer to our recommended values. SCAG links were raised to the following minimum values:

- Ftype 1: 2000
- Ftype 2: no change
- Ftype 3: 800
- Ftype 4: 650
- Ftype 5: 650
- Ftype 7: 720

Any existing values that were higher than these minimum values were retained, unless we had reasons to believe that they were incorrect.

7. Results

The modification and enhancement of the HSR statewide network to support the larger number of TAZs and to sufficiently represent the network in locations distant from proposed high speed rail stops has resulted in significant changes to the network. The CSTDM networks for 2000 and 2008 are more similar to each other than either is to the original network.

Throughout the state the road network has become denser, and the capacities and speeds of the links have been brought into better agreement across jurisdictional and geographic boundaries. The networks for rail have been added to the base network instead of residing in a separate network, requiring the run of two networks in parallel to represent road and rail.

Table 25 reports the counts and distances of links in the HSR network and in the CSTDM networks (note that the table reports the total length of links and not the lane miles).

Table 25: Link and Link Distance Totals

	HSR		2000		2008	
FType	**Count**	**Distance (mi)**	**Count**	**Distance (mi)**	**Count**	**Distance (mi)**
Freeway	11,480	10,469	12,521	10,462	12,935	10,743
Expressway	4,204	11,804	6,666	13,141	6,690	13,168
Major Arterial	41,568	23,609	66,117	31,547	66,129	31,548
Minor Arterial	41,561	16,059	52,668	18,235	52,650	18,231
Collector	36,879	18,692	40,777	17,701	40,777	17,701
Centroid Connector	19,864	9,423	39,266	32,665	39,266	32,665
Ramp	13,749	2,500	15,208	2,337	15,346	2,360
Freeway-Freeway Connector			12	2	12	2
Rail to Network Connector			798	119	798	119
Air Terminal to Network Connector			36	5	36	5
Rail Network Link			824	2,952	824	2,952
	169,305	92,556	234,893	129,166	235,463	129,494

7.1 2008 Network

Editing on the 2008 Network began in late September 2009, and an alpha version was submitted to HBA Specto for testing under load in late November 2009. Initial results from loading the alpha network revealed that many links had volume/capacity ratio greater than 1.5, some links received no traffic assignment in unexpected locations, and a few link had connection problems. Staff at ULTRANS continued to refine the 2008 network through early March 2010. Further changes were made as necessary throughout the duration of the project. Figure 2 presents the 2008 network.

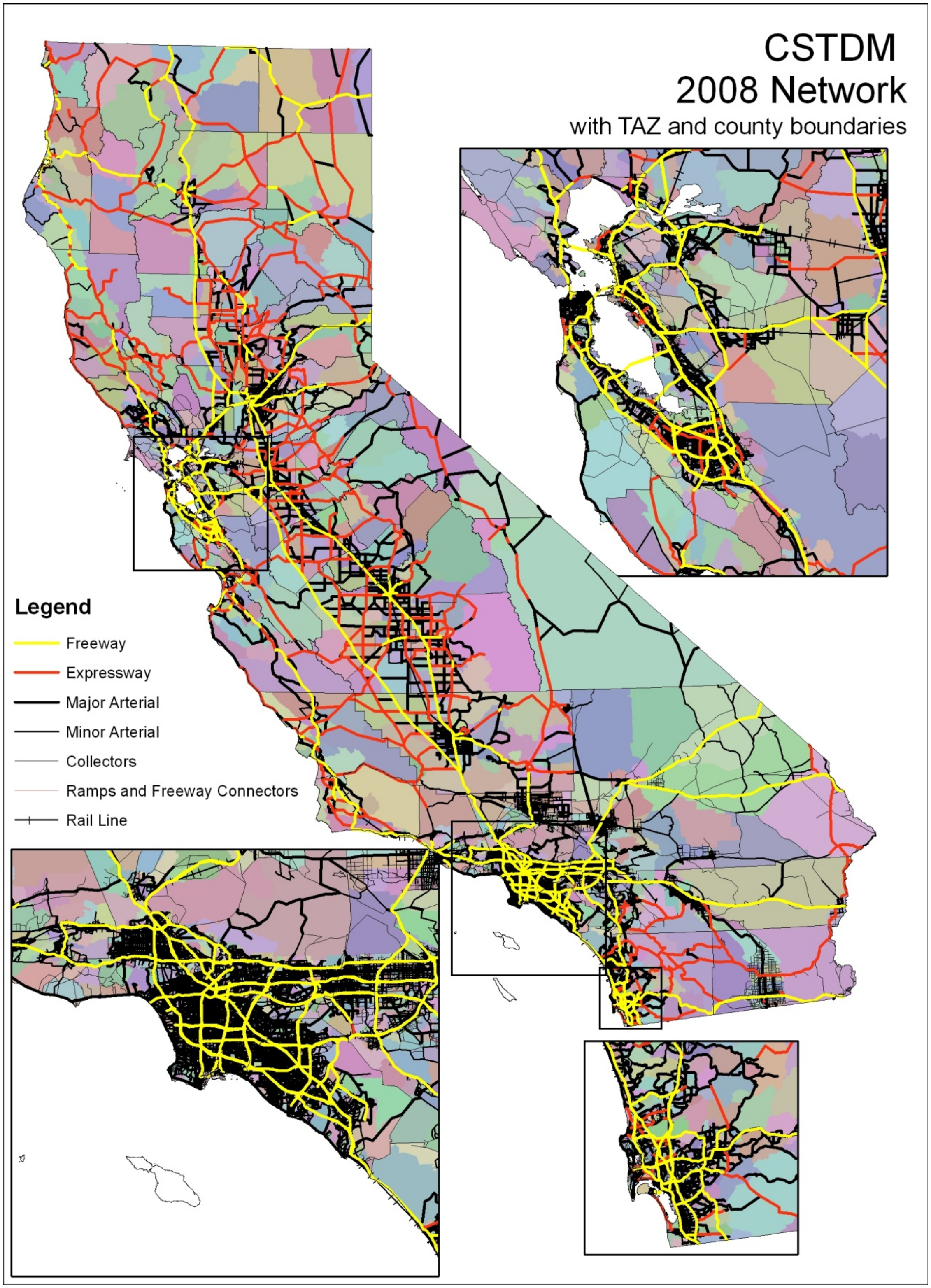

Figure 2: The 2008 network

7.2 2000 Network

The year 2000 network was created by taking the 2008 network and removing links or changing capacity as needed to replicate the conditions in 2000. The High Speed Rail Authority identified in their documentation many projects slated for completion between 2000 and 2030. Using this information we identified those projects that had been completed between 2000 and 2008 and modified the network to represent the earlier condition (see Table 26). Other edits were made based on notes and observations recorded during the initial preparation of the 2008 network where we observed the presence of recently constructed or enlarged portions of the system.

Figure 3 presents the 2000 network, Figure 4 the rail network for 2008, and Figure 5 a detailed view of changes between the HSR network and the 2008 CSTDM network.

Table 26: Network links edited based on the HSRA Identified Changes

Location (County)	Route	Changed Section	Change made
San Mateo	92	San Mateo Hay ward Bridge	added a lane
San Mateo	280	Edgewood to 92	added a lane
Santa Clara	101	85 to Cochrane	added a lane
Santa Clara	87	101 to 85	added a HOV lane
Santa Clara	880	Trimble to 101	added a lane
Santa Clara	880	Dixon to 237	added a lane, also added HOV lane
Santa Clara/Alameda	680	Vallecitos to 237	added HOV lane
Santa Clara	85	101 to Middlefield	added HOV lane
Alameda	880	Stevenson to Mission	added a lane
Alameda	92	880 to San Mateo County Line	added a lane
Conta Costa	580	Central to Marin County Line	added a lane
Conta Costa	4	Cummings to 80	added 2 lanes
Conta Costa	680	Main St to Solano County Line	added HOV lane
Sonoma	101	12 to Rohnert Park	added HOV lane
Orange	133	73 to 405	added a lane
Riverside	71	Near Corona/Chino Hills	added a lane
Riverside	74	15 to 7th st	added a lane
San Bernardino	10	Orange St to Ford St (Redlands)	added a lane
San Bernardino	15	Mojave Dr to Stoddard Wells Rd	added a lane
San Bernardino	15	138 to Oak Hill Rd (Cajon Pass)	added a lane

Location (County)	Route	Changed Section	Change made
Sacramento	65	Industrial Blvd to south Yuba co Line (Near Lincoln)	added a lane
Sacramento	5	80 to Sacramento International Airport	added a lane
Fresno	180	East of 168	added the new highway
Fresno	168	North of Herndon Ave	added the new highway
Los Angeles	2	Sepulveda to Moreno	changed to a divided parkway
Los Angeles	10	Baldwin Ave to Rte 605	added HOV lanes
Los Angeles	14	Rte 5 to San Fernando Rd	added HOV lanes
Los Angeles	14	Vincent Ramp UC to Ave P-8	added HOV lanes
Los Angeles	138	Co Hwy N6 to 165th St	added a lane in each direction
Los Angeles/San Bernardino	210	Foothill Blvd to Rte 215	added 8 lane freeway including HOV lanes
Los Angeles	405	Waterford Ave to Rte 10	added SB lane and SB HOV lane
Los Angeles	405	Rte 90 to Rte 10	added HOV lane
Los Angeles	405	Rte 105 to Rte 90	added HOV lanes
San Diego	52	I-15 to Mast Blvd	added a lane in each direction
San Diego	56	Carmel Valley Rd to Black Mountain Rd	added 4 lane freeway
San Diego	125	SR 905 to San Miguel Rd	added 4 lane freeway
San Diego	125	San Miguel Rd to SR 54	added 4 lane freeway
San Diego	125	Jamacha Rd to SR 94	added 6 lane freeway
San Diego	905	I-805 to SR 125	added a lane in each direction
San Diego	5	I-805 to SR 56	added 4 lane local bypass in each direction
San Diego	94	SR 125 Junction	added freeway connectors
San Benito	25	Southside Rd to Bolsa Rd	added 4 lane bypass
Kern	58	Altus Ave to Randsburg Cutoff Rd	added 4 lane bypass

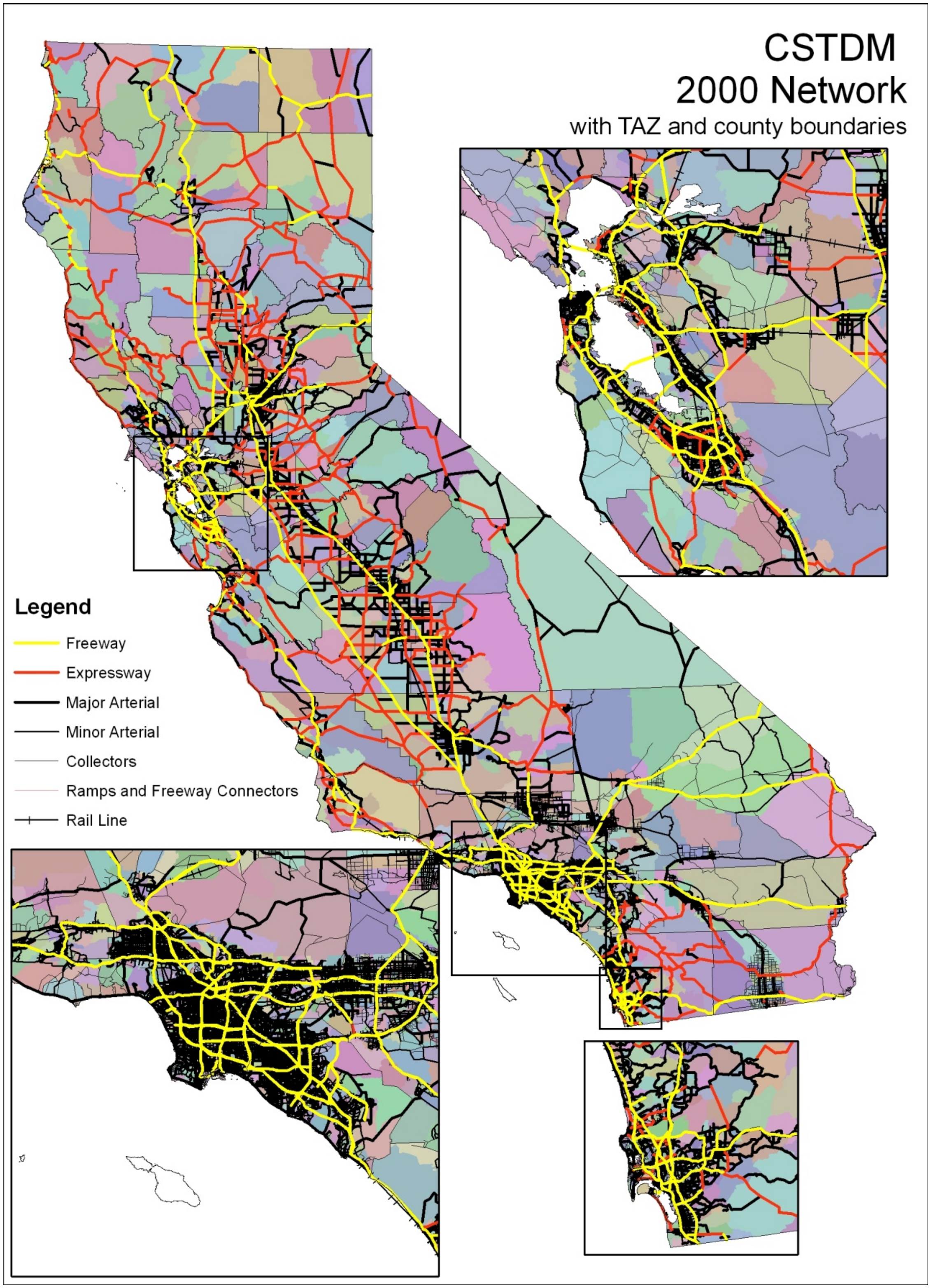

Figure 3: The 2000 network

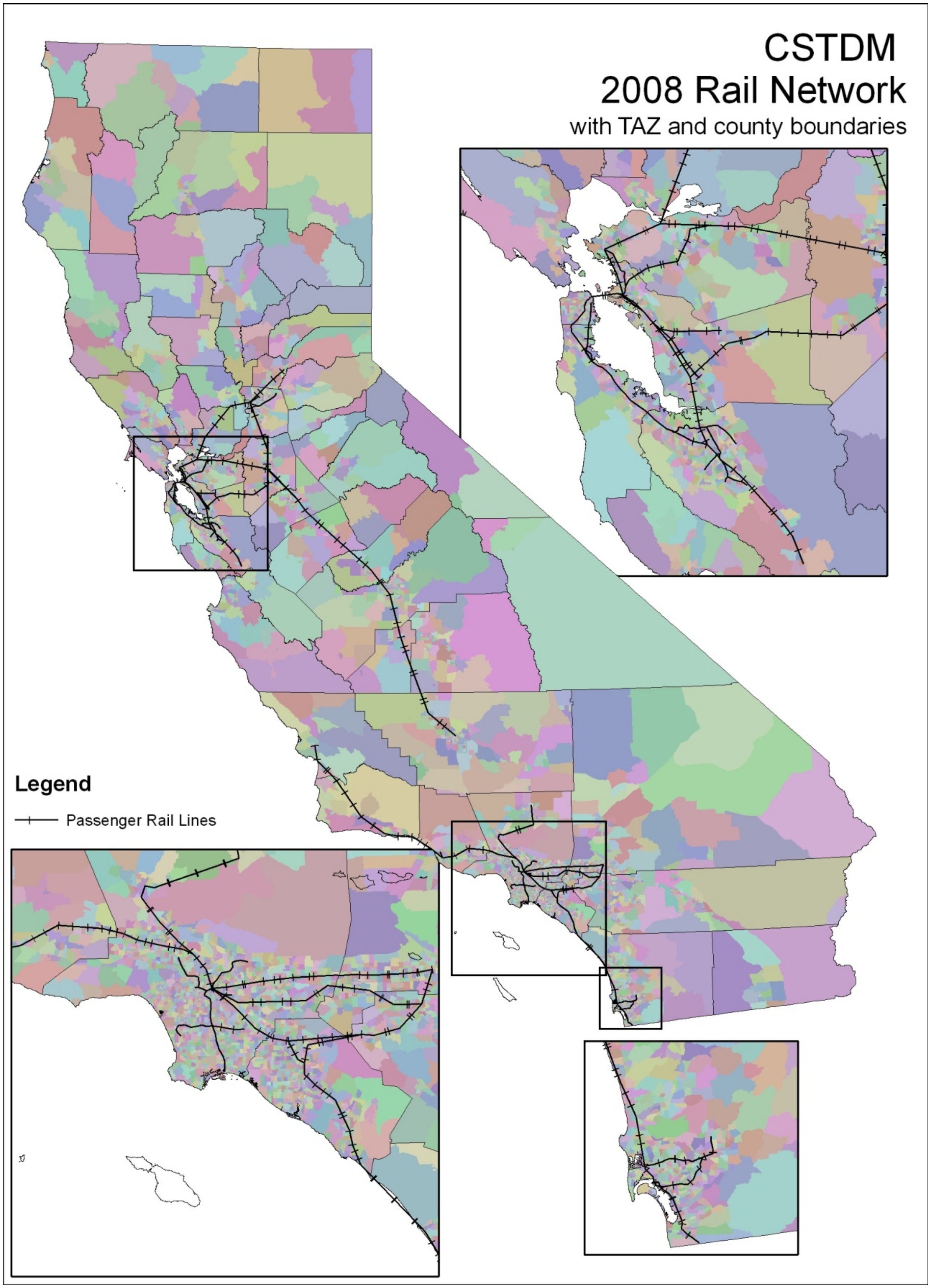

Figure 4: Rail Network for 2008. The 2000 network uses the same link system, but is constrained by line files specific to 2000.

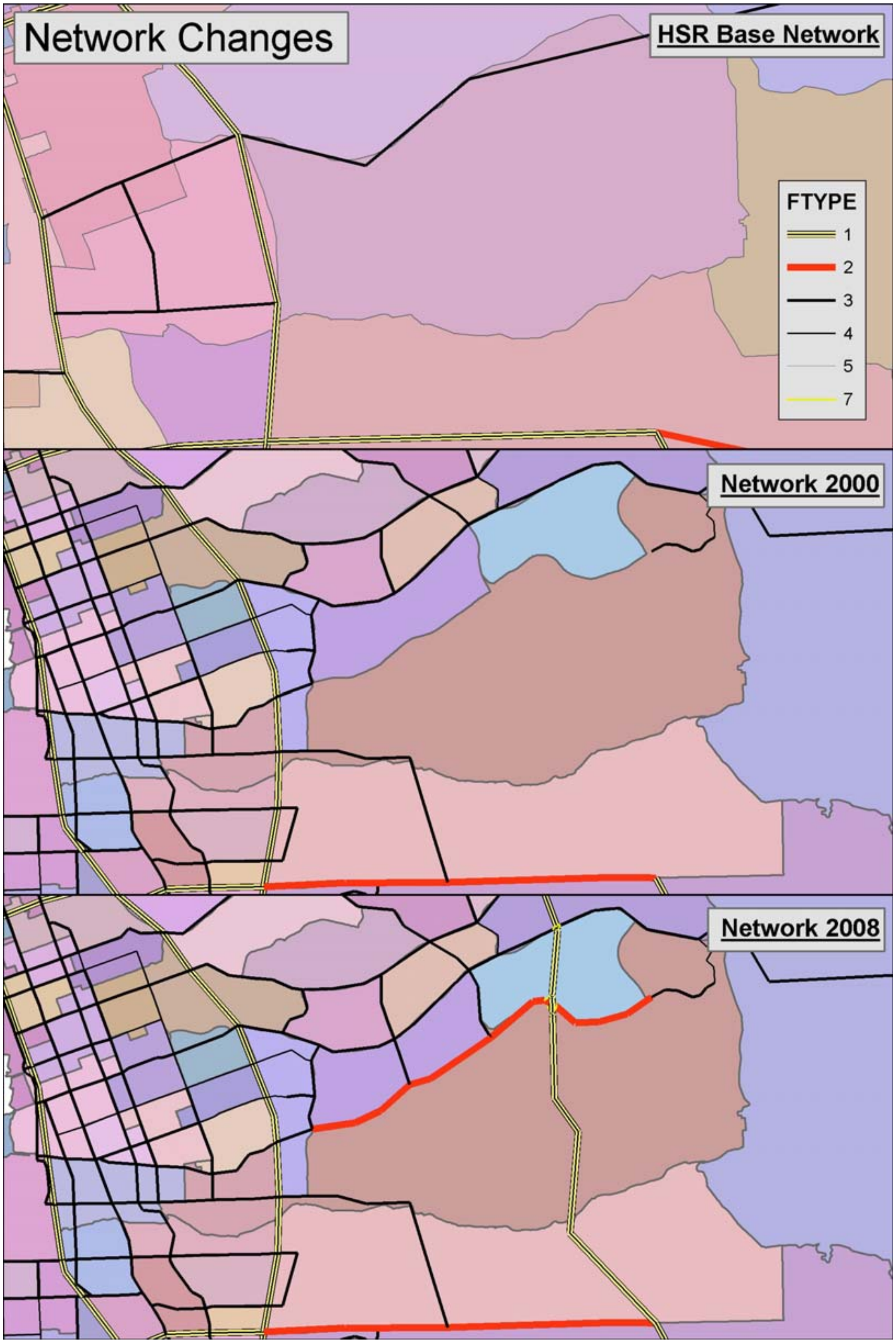

Figure 5: An Example of the Changes from the HSR Network Visible in both the 2000 and 2008 Networks.

8. Documentation

8.1 Log Files

The daily log files provided a reliable daily record of the edits done during the development of the networks.

8.2 Network Backups

The networks were backed up on a weekly basis during the development of the model.

8.3 Data Sources

Data for the initial editing is a mix of sources. The initial source was the HSR road network. Additional sources were obtained from several dataset, including the 2004 TeleAtlas North America (TANA), and roads as identifiable in Google Earth/Google maps.

Other road data (by year) were available for reference while editing the network:

a. 2004 TANA roads.
b. 2001 ESRI Street maps which has roads from 1999-2000 sourced from GDT (subsequently purchased by TeleAtlas).
c. 2000 Tiger (US Census): the spatial accuracy is somewhat suspect in some locations.
d. 2008 Tiger (US Census).
e. R6b_LOS_Assumptions & Alternatives_Final.pdf: Bay Area/ California High-speed Rail Ridership and Revenue Forecasting Study (section 3: Future Baseline Network), Prepared for the Metropolitan Transportation Commission and California High Speed Rail Authority by Cambridge Systematics, SYSTRA Consulting, Inc. Citilabs. August 2006.

Data note: None of these road datasets identify the number of lanes and the Tiger datasets have only limited attributes on the functional class of the road way.