San Luis Obispo Citywide Travel Model

Model Documentation

prepared for

City of San Luis Obispo

prepared by

Cambridge Systematics, Inc.

with

Central Coast Transportation Consulting

September 28, 2020

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report

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1.0 Roadway Network

1.1 Context and Background

The roadway network contains basic input information for use in the travel demand model and represents real-world conditions for the 2016 base year. The roadway networks are used in the model to distribute trips and route automobile trips. The networks in the GIS environment used by the model are databases in which all kinds of information can be stored and managed. In addition, the networks provide a foundation for system performance analysis including vehicle miles of travel, congestion delay, level of service, and other performance criteria. This chapter provides a description of the network attributes and lookup tables for the roadway networks. The assumptions and parameters identified herein were identified during the development of the model's 2016 base year network, but they generally apply to all model year networks.

The roadway network is a GIS-based representation of the street and highway system in the City of San Luis Obispo and, at a reduced level of detail, San Luis Obispo County. It operates both as an input database containing roadway characteristics (such as facility type, number of lanes, area type, etc.) and as a data repository that can be used to store and view travel model results. The roadway network is one of the foundational components of the travel model as it serves to represent the supply side of the travel demand/transportation system relationship. As such, the establishment and review of detailed network attribute data was very important to the model's development.

1.2 Roadway Network Development

Two primary sources were available for developing the 2016 base year network: The 2008 roadway network from the City's previous travel model and the 2010 network from the most recent model of the San Luis Obispo Council of Governments (SLOCOG). These networks vary in several ways as shown in Table 1.1. The right-most column of Table 1.1 contains recommendations for addressing the differences.

SLOCOG's most recent 2010 model roadway network is used as the basis for the outside of the Sphere of Influence (SOI). The SLOCOG network outside the SOI was simplified by removing all facilities below minor arterials. The links in the SLOCOG network that fall within the boundaries of the SOI were then removed and replaced with the City of San Luis Obispo 2008 network. The two networks were then stitched at the boundary to ensure network connectivity. Once the two networks were combined, the relevant attributes necessary for travel demand modeling were added to the network file.

1.3 Roadway Network Structure

The roadway network is structured to contain data for multiple timeframes. The roadway network delivered with the SLO Citywide Travel Model contains the 2016 base year network, a 2040 forecast year roadway network, and a buildout network. The model includes the capability to represent the base year, existing plus committed networks, plan forecast networks, interim horizon year networks, and any other network scenarios that are desired within a single network database. In addition, the network is structured so that localized alternatives can be represented within the same file. These alternatives can be activated and deactivated based on the year of analysis and infrastructure scenario desired using the scenario management system that forms the basis of the travel model user interface.

1.3.1 Input and Output Networks

The roadway network file contains travel model input data, and it also acts as a repository for both intermediate (e.g., speed feedback data) and final (e.g., traffic volumes) model data. For this reason, a separate output model network is created for each model scenario. This output network is created by making a copy of the input network and then modifying this network to contain data and results specific to each model run. This copy of the roadway network is created and modified automatically by a network initialization step when the travel model is run. Required attributes present on the input network link and node layers are listed in Table 1.1 and Table 1.2. Additional attributes that are created on the output network are listed in Table 1.3.

Table 1.1. Input Network Link Fields

Field Name	Description	Comments
ID	TransCAD Unique ID	Maintained automatically by TransCAD
Length	Link Length in miles	Maintained automatically by TransCAD
Dir	Link Direction of Flow	Direction of Flow
NAME	Street Name	
HWY_LABEL	Route number for state and US highways	
Dir_yy	Scenario-Specific Direction Field	yy represents a two-digit year code (e.g., 16, 40, BOUT) or the string “AL”
FT_yy	Facility Type for year yy (See Table 1.4 for definition)	
AT_yy	Area Type for year yy (See Table 1.5 for definition)	
AB_LANE_yy	Number of Lanes for year yy	
AB_LANE_yy		
SPLM_yy	Speed Limit for year yy.	
AB_FBAM_yy	Fields used to store speed feedback results – not typically modified by the user.	“AL” versions of these fields are not present in the network.
BA_FBAM_yy		
AB_FBOP_yy		
BA_FBOP_yy		
ALT	Primary Alternative Number	
ALT2	Secondary Alternative Number	
ADJ_CNT	Adjusted Traffic Count representing 2016 conditions.	

Table 1.2. Input Network Node Fields

Field Name	Description	Comments
ID	TransCAD Unique ID	Maintained automatically by TransCAD
ZONE	Traffic Analysis Zone Number	Populated only for centroid nodes (including external station nodes). Null for all non-centroid nodes.
PNR_yy	Park and Ride Identifier (1 for park and ride nodes, 0 or null for other nodes)	yy represents a two-digit year code (e.g., 16, 40) or the string "AL"
ModelNode	Variable indicating nodes kept in a link consolidation exercise performed during model development.	This value can be set to 1 or null on all nodes and does not effect model results.
TimePointNode	Route time point	These fields contain notes used in building the route system and are not used by the model.
NewNode	Indicates nodes added for transit	
SOI	Identifies nodes within the model sphere of influence	
INT_ID	Intersection ID for turn movement reporting	Turn movement volumes will be stored for nodes identified by this field.
RPT_ID	Intersection report ID	ID number for SR-1 MIS reporting purposes (not required; not used directly by the model)

Table 1.3. Output Network Link Fields

Field Name	Description	Comments
FT	Facility Type for selected year and alternative(s)	These fields are populated based on data in fields identified with a "_yy" suffix in the input network.
AT	Area Type for selected year and alternative(s)	
AB_LANE	Number of Lanes for selected year and alternative(s)	
AB_LANE		
SPLM	Speed Limit for selected year and alternative(s)	
AB_FBAM	Speed feedback data for selected year	
BA_FBAM		
AB_FBOP		
BA_FBOP		
Mode	Mode field used to identify walk and drive access links	
FF_SPD	Calculated freeflow travel speed	Based on speed limit
AB_OPSPD	Calculated directional off-peak and peak congested travel speed	Populated based on speed feedback results
BA_OPSPD		
AB_PKSPD		
BA_PKSPD		
FF_TIME	Calculated freeflow travel time	
AB_OPTIME	Calculated directional off-peak and peak congested travel time	
BA_OPTIME		
AB_PKTIME		
BA_PKTIME		
AB_OPTRSPD	Directional off-peak transit speed and time	
BA_OPTRSPD		
AB_OPTRTIM		
BA_OPTRTIM		
AB_PKTRSPD	Directional peak transit speed and time	
BA_PKTRSPD		
AB_PKTRTIM		
BA_PKTRTIM		
LANE_CAP	Calculated per-lane capacity	Retrieved from lookup table
AB_CAP	Calculated directional capacity	
BA_CAP		
ALPHA	Volume delay parameters	Retrieved from lookup table
BETA		

The model's directory structure allows multiple model output directories to exist as subdirectories to a single input directory. Each time the travel model is run, files located in the input directory are not modified by model macros. Instead, if a file is to be modified it will be copied to an output directory; only the copy is modified.

1.3.2 Facility Type

The facility type of each roadway link reflects its role in the system of streets and highways. Facility type is used in the travel model as a foundational element for describing the roadway system using mathematical relationships that correspond to the function, operation, and characteristics of the roadway. Roadway speed, capacity, and volume-delay characteristics are dependent on facility type.

Most local roads are not included in the travel model facility type scheme, except for the following two cases:

- Local streets used to accommodate local bus routes, and
- Roadways identified as Urban Local roads.

Traffic is assigned to urban local roadways, but is not assigned to roadways included solely for purposes of the transit route system. The facility types included in the model are listed in Table 1.4.

Table 1.4. Facility Type Classifications

Code	Facility Type
1	Freeway
2	Not Used (reserved for Expressway)
3	Principal Arterial
4	Minor Arterial
5	Collector
6	Ramp
7	Urban Local
9	Walk Access Connector (Present only in the output transit line layer)
11	Highway (Outside SOI)
12	Arterial (Outside SOI)
13	Rural Arterial (Outside SOI)
50	Centroid Connector
51	Transit Local (roadway traffic is not assigned to these links)
60	Bike Only Link
null	Inactive Link (does not exist in the specified network)

The numbering system used for facility types generally increases as the primary function of roadways moves from mobility toward access. While freeways function to provide mobility rather than direct access to homes and businesses, local streets exist almost exclusively to provide access while providing limited mobility at low speeds. Maps demonstrating facility type on roadways included in the model are included as Figure 1.1 and Figure 1.2.

Figure 1.1. Facility Type- Entire Modeled Area

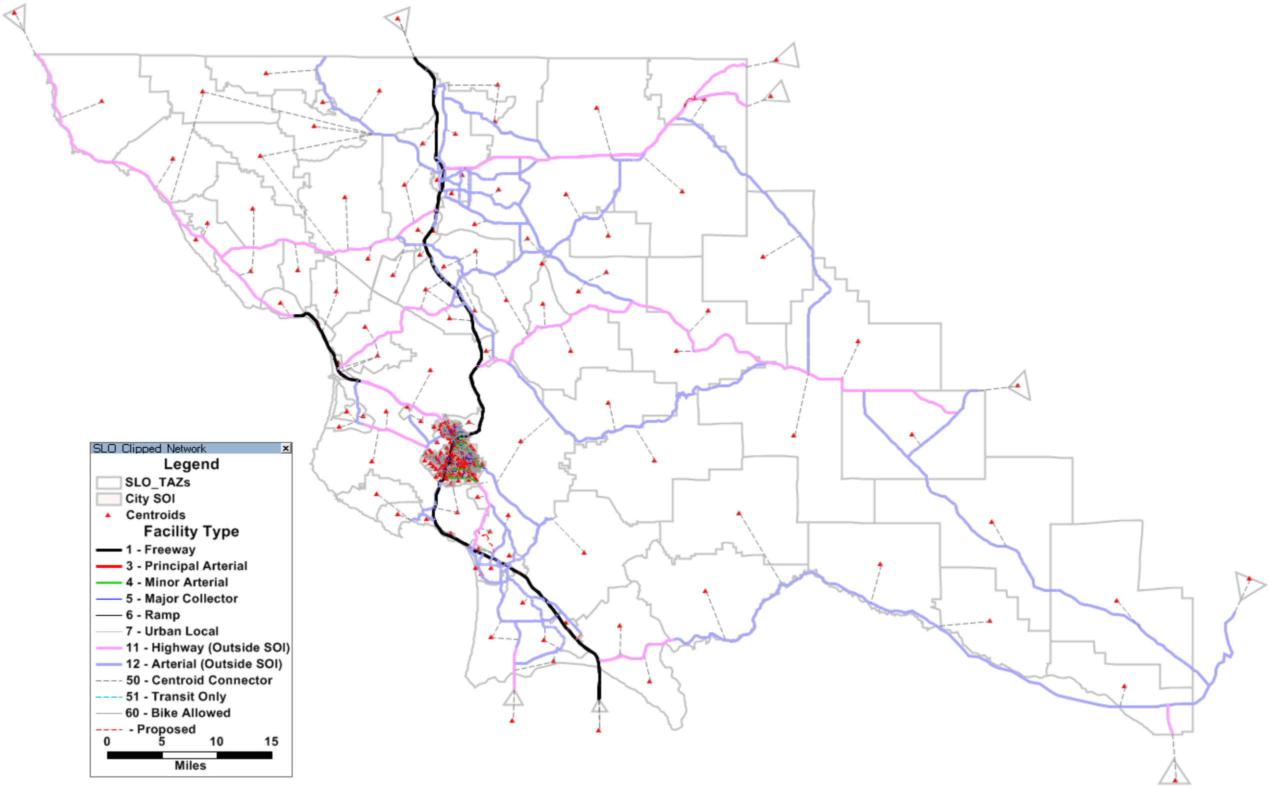
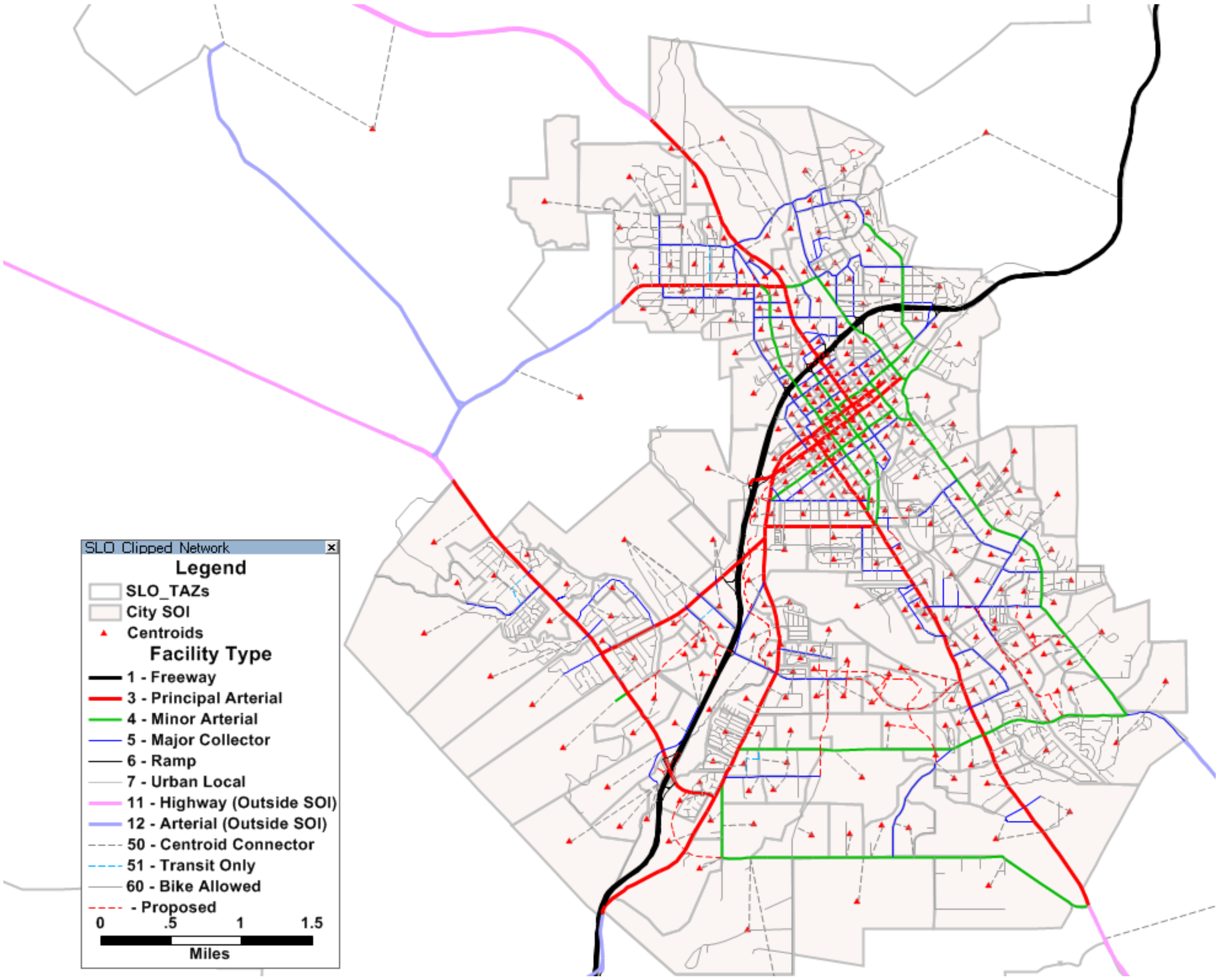


Figure 1.2. Highway Network Facility Type- City SOI



Descriptions of the facility types are provided below.

- **Freeway** – A divided, restricted access facility with no direct land access and no at-grade crossings or intersections. Freeways are intended to provide the highest degree of mobility serving higher traffic volumes and longer-length trips. Freeways in Washtenaw County have 4 or 6 travel lanes (2 or 3 in each direction). All Interstate facilities are freeways. Freeways in Washtenaw County include I-94, US-23, and M-14. These are represented by the NFC codes for interstate freeways and other freeways.

- **Ramp** – A link that provides connections between freeways and other non-freeway roadway facilities. On freeway to non-freeway ramps, traffic usually accelerates or decelerates to or from a stop. Therefore, the speed on freeway to arterial ramps is often coded slower than the ramp speed limit. Most ramp facilities were identified using the “CSBRANCH” attribute in the Michigan Geographic Framework, but some have been identified manually. Facility types shown in Attachment 2.1 represent manual identification of ramp facilities.

- **Principal Arterial** – These permit traffic flow through and within urban areas and between major destinations. These are of great importance in the transportation system since they provide local land access by connecting major traffic generators, such as central business districts and universities, to other major activity centers. Containing 4 travel lanes, principal arterials carry a high proportion of the total urban travel on a minimum of roadway mileage. They typically receive priority in traffic signal systems (i.e., have a high level of coordination and receive longer green times than other facility types), have turn bays at intersections, include medians or center turn lanes, and sometimes contain grade separations and other higher-type design features. State and U.S. highways are typically designated as principal arterials unless they are classified as freeways.

- **Minor Arterial** – Minor arterials collect and distribute traffic from principal arterials, freeways, and expressways to streets of lower classification and, in some cases, allow traffic to directly access destinations. They serve secondary traffic generators, such as community business centers, neighborhood shopping centers, multifamily residential areas, and traffic between neighborhoods. Access to land use activities is generally permitted, but should be consolidated, shared, or limited to larger-scale users. Minor arterials generally have slower speed limits than major arterials, may or may not have medians and center turn lanes, and receive lower signal priority than other facility types (i.e., are only coordinated to the extent that major arterials are not disrupted and receive shorter green times than major arterials).

- **Collector Street** – Collectors provide for land access and traffic circulation within and between residential neighborhoods and commercial and industrial areas. They distribute traffic movements from these areas to the arterial streets. Except in rural areas, collectors do not typically accommodate long through trips and are not continuous for long distances. The cross-section of a collector street may vary widely depending on the scale and density of adjacent land uses and the character of the local area. Left turn lanes sometimes occur on collector streets adjacent to nonresidential development. Collector streets should generally be limited to two lanes, but sometimes have 4-lane sections. In rural areas, major collectors act similarly to minor arterials, while rural minor collectors fit more closely with the characterizations described here. Minor collectors do not exist in urban areas.

- **Centroid Connector** – These facilities represent local and/or residential street systems that are too detailed for modeling purposes. Centroid connectors are usually not coded along actual streets, but rather they are the means through which the trip and other data at the traffic analysis zone (TAZ) level are attached to the street system.

- **Walk Access Connector** – This facility type is included to provide pedestrian access directly to a transit stop or to the collector/arterial roadway network where vehicle access is not possible. The transit network will utilize the roadway network to provide walk access to transit, but this does not in itself accurately represent walk access. This facility type ensures that walk access to transit is represented by the shortest realistic distance between a zone centroid and nearby transit stops. Walk access connectors are not present in the input network, but are instead created automatically when the model is run.

- **Bikes Allowed** – Local streets are not typically represented in regional travel models except where required to support the transit route system. Some local streets in the urban core of San Luis Obispo are included as “Urban Local” in the focused City model to better represent detailed access and traffic flow conditions. Remaining local streets are retained in the model network as bikes only facilities and have been assigned a facility type of 60. When the traffic assignment is run, links with a facility of 60 are ignored by the pathfinding and traffic assignment algorithms. However, they are considered in the bike assignment and skims.

- **Transit Local** – This facility type is included to support the transit route system and transit network. The facility type on local streets that serve transit routes is 51 resulting in the model allowing transit routes to utilize these links. Transit local links are not used in the trip distribution or traffic assignment procedures.

1.4 Area Type

Area type is an attribute assigned to each traffic analysis zone (TAZ) and roadway and is based on the activity level and character of each zone. Terminal times, speed-limit to freeflow speed conversion factors, roadway capacity, and volume-delay characteristics are dependent on area type. Area type is first defined at the TAZ level based on activity characteristics and then transferred to the roadway network.

Area type is an attribute that can vary with time. Therefore, it was important that area type definitions are specified in a manner that can be updated for future conditions based on available forecast data. While area type definitions based on external information such as corridor characteristics (e.g., commercial vs. residential) or the U.S. Census urbanized area boundary are useful in defining existing area type, this information is not very useful in defining future year area types. Area type definitions were therefore specified so that area type forecasts can be developed using forecast socioeconomic data.

The area type guidelines presented herein were developed based on a visual analysis of aerial photography and street characteristics and input from City staff. The SLOCOG model does not define different area types within the City of San Luis Obispo SOI. The area type categories defined for the SLO Citywide Travel Model are listed in Table 1.5.

Table 1.5. Area Type Categories

ID	Area Type
1	Central Business District (CBD)
2	CBD Fringe (dense area surrounding CBD)
3	Urban
4	Suburban
5	Rural
6	Outside SOI

Note: For each TAZ, the most dense non-CBD area type is applied for which at least one of the criteria is met.

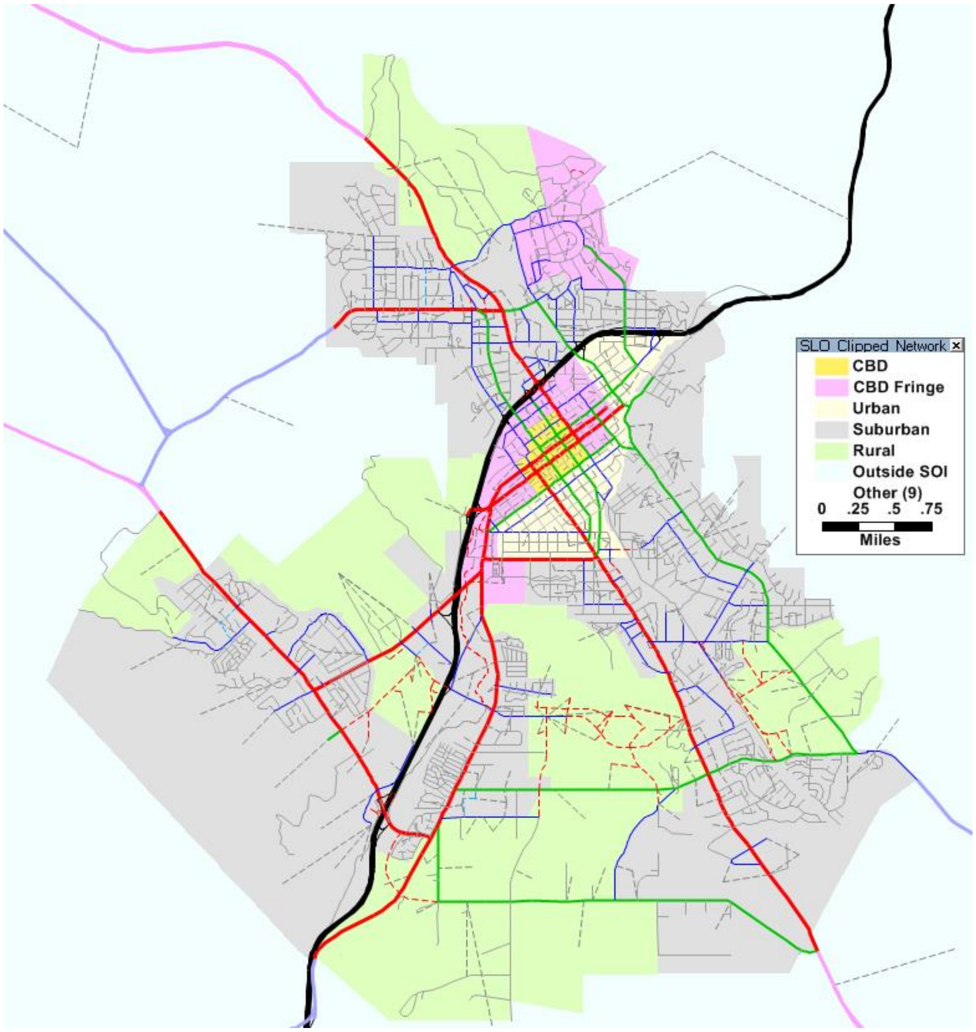
Due to the more compact and dense nature of the City of San Luis Obispo Central Business District, it has been included as a separate area type. The definition of the CBD area type is based on a rough approximation of the San Luis Obispo Downtown Business Association boundary. An approximation of the boundary was necessary to accommodate TAZ boundaries. The area assigned the CBD area type is shown in Figure 1.3. Typically, the definition of the CBD area type will not change in forecast year datasets.

Figure 1.3. CBD Area Type Definition

1.4.1 Existing Fringe, Urban, Suburban, and Rural Area Type Specification

Specification of existing area types was performed by reviewing street centerline data and aerial photography. The area surrounding the CBD that includes a higher density of buildings, and a denser street grid has been classified as urban or fringe, with urban including the area with a higher level of density and greater commercial uses. The suburban area type was assigned to areas with lower building and street density. Undeveloped areas, or areas with very sparse development, were identified as rural. Resulting area type definitions are shown in Figure 1.4.

Figure 1.4. Area Types within City SOI



1.5 Link Speeds

Network speeds are used in trip distribution to distribute trips throughout the region, in mode choice to determine mode-specific travel times, and in trip assignment to route traffic on the roadway network.

Link speeds represent average travel time, including intersection delay, needed to traverse the distance of a link with little or no traffic (i.e., no congestion effects). These speeds are generally similar to the speed limit and are calculated as a function of the speed limit, functional class, and area type. Freeflow speeds are typically lower than the speed limit to account for intersection delay on arterials, collectors, and ramps. On other facility types, the speed limit and freeflow speed may be the same.

1.5.1 Estimating Link Speeds

Speed limit data is available for the model-level roadway links in the network. This speed limit data can be used in combination with corridor travel time survey data to approximate a freeflow speed on each network link. Because the travel model freeflow speed must include intersection delay experienced in uncongested conditions, freeflow speed is typically lower than the posted speed limit. The relationship between speed limit and freeflow speed has been observed to vary by characteristics such as facility type and area type.

No local data is available to facilitate the development of a model relating posted speed limit, facility type, and area type to freeflow speed. To facilitate estimation of such a model using local data, a comprehensive and current travel time survey would be necessary. Freeflow speed factors from the previous version of the model were initially carried forward to the updated model. Adjustments were made during the model calibration and validation process to better match count volumes on arterials and freeways. The model freeflow factors are shown in Table 1.6.

Table 1.6. Speed Limit to Freeflow Speed Conversion Factors

ID	Class	CBD	Fringe	Urban	Suburban	Rural	Outside SOI
1	Freeway	1	1	1	0.95	0.95	0.95
3	Principal Arterial	0.98	0.97	0.92	0.9	0.95	0.95
4	Minor Arterial	0.97	0.95	0.9	0.9	0.85	0.85
5	Collector	0.95	0.92	0.88	0.9	0.75	0.75
7	Urban Local	0.75	0.75	0.75	0.75	0.75	0.75
6	Ramp	0.92	0.9	0.85	0.9	0.75	0.75
11	Highway (Outside SOI)	0.85	0.85	0.85	0.9	0.95	0.95
12	Arterial (Outside SOI)	0.85	0.85	0.85	0.9	0.95	0.95
13	Rural Arterial (Outside SOI)	0.85	0.85	0.85	0.9	0.95	0.95
50	Centroid Connectors	1	1	1	1	1	1
51	Transit Links	1	1	1	1	1	1

For centroid connectors and transit only links, values in Table 1.7 are used if speed limit data is not populated on the network. Speed limits must be provided for all other roadway links to successfully run the travel model.

Table 1.7. Centroid Connector and Transit Freeflow Speeds

ID	Functional Class	Area Type					
		CBD	Fringe	Urban	Suburban	Rural	Outside SOI
50	Centroid Connector	15	20	20	20	35	40
51	Transit Local	15	15	15	15	15	15

1.5.2 Travel Time

Freeflow and congested speeds in the roadway network are used to compute travel time for each link. Travel time is computed in minutes.

1.5.3 Link Capacities

Traffic assignment, especially capacity constrained traffic assignment, requires accurate roadway capacity values. Capacity is used in the model to measure congestion and to determine route diversion due to congestion. This is accomplished through the use of volume-delay equations that will be defined and applied in the traffic assignment model.

In the model, per-lane capacity values are retrieved from a lookup table based on the facility type and area type of each link in the roadway network. This approach eliminates opportunities for error in defining capacities at the link level and enforces consistent application of capacity values. Hourly per-lane capacities are retrieved from a lookup table that is stored in an Access database. These hourly lane capacities are used in combination with the number of lane information present on the network to define hourly directional capacity.

The Highway Capacity Manual (HCM or HCM 2000)[1] provides guidance on the definition of roadway capacity. The HCM provides link-level capacity guidelines for freeways and rural highways, but does not provide detailed link-level capacity guidelines for urban and suburban collector and arterial streets. Therefore, HCM intersection capacity was used in place of link capacity to develop capacities for these other facilities.

1.5.4 Freeways

Capacity guidelines for freeways and expressways are provided in Chapters 21 and 23 of HCM 2000. Unadjusted, or ideal, per-lane capacities based on freeflow speed are provided. These capacities must then be adjusted for various conditions. The conditions for which adjustments can be applied are described below.

- **Heavy Vehicle Adjustment Factor** – The heavy vehicle adjustment factor accounts for passenger car equivalents for trucks, buses, and recreational vehicles. HCM 2000 recommends default values of 10% heavy vehicles in rural areas and 5% heavy vehicles in non-rural areas unless additional data is available. However, for regional modeling purposes, a heavy vehicle adjustment factor of 1.0 has been used.

- **Driver Population Factor** – The driver population factor represents the familiarity of drivers with roadway facilities. Because the model represents traffic on a typical weekday when school is in session, normal driver familiarity was assumed. Driver population factors are typically used for weekend conditions or in areas with a high amount of tourist/recreational activity.

- **Peak Hour Factor** – A peak hour factor (PHF) represents the variation of traffic volumes within an hour. Default values of 0.88 for rural area types and 0.92 for non-rural area types were applied[2].

The HCM suggests adjusting flow rate (traffic volume) according to the equation below.

[1] Highway Capacity Manual. Transportation Research Board, 2000.

[2] HCM 2000, p. 13-11

$$V_P = \frac{V}{PHF \cdot N \cdot f_{HV} \cdot f_P}$$

Where:

V_P	= 15-min passenger equivalent flow rate (pc/hr/ln)
V	= hourly volume (veh/hr)
PHF	= peak-hour factor
N	= number of lanes
f_{HV}	= heavy-vehicle adjustment factor
f_P	= driver population factor

For travel model application, it is more practical to adjust capacity than vehicle flow rate. This eliminates the need to adjust vehicle trip tables prior to and subsequent to traffic assignment. By replacing V_P with ideal capacity (C_I) and V with hourly capacity (C), the equation above can be used to adjust ideal capacity to effective hourly capacity. Furthermore, it is useful to consider capacity on a per lane (veh/hr/ln) basis, allowing number of lane calculations to be applied at the link level. The resulting equation can be used to compute per lane capacity for freeways and expressways. The equation below was used to compute hourly capacities for rural and freeway facilities.

$$C = C_I \cdot PHF \cdot f_{HV} \cdot f_P$$

Where:

C_I	= Ideal (unadjusted) capacity (pc/hr/ln)
C	= link capacity (veh/hr)
PHF	= peak-hour factor
f_{HV}	= heavy-vehicle adjustment factor
f_P	= driver population factor

Ideal capacities are defined in HCM according to freeflow speed[3]. Ideal capacities based on typical freeflow speeds are shown in Table 1.8, along with adjusted capacities computed using the methodology described above. Adjusted capacities have been rounded to 100 vehicles per hour. It is noted that these calculations result in a lower capacity on rural freeways than on suburban and urban freeways. This is due to the difference in peaking factors associated with rural facilities. In practice, it is unlikely that rural freeway facilities will reach capacity. Instead, rural facilities are likely to become suburban or urban facilities before nearing capacity. As this occurs peaking characteristics should be adjusted. This is accomplished by using updated area type information in forecast-year model runs.

[3] HCM 2000, p. 23-5

Table 1.8. Ideal and Adjusted Capacities for Freeways and Expressway Based on HCM 2000

Facility Type	Area Type	Freeflow Speed (mph)	Ideal Capacity (Upper Limit LOS E, pc/h/ln)	PHF	FHV	FP	Adjusted Capacity (Upper Limit LOS E, pc/h/ln)
Freeway	Rural	70	2,400	0.88	1	1	2,100
Freeway	Suburban	70	2,400	0.92	1	1	2,200
Freeway	Urban	65	2,350	0.92	1	1	2,200

1.5.5 Collectors and Arterials

For non-rural arterial and collector streets, HCM recommends identifying capacity on an intersection basis, with the intersection with the lowest capacity determining the overall arterial link capacity. The link capacity at each intersection can be computed using the equation below.

$$c = S_0 \cdot N \cdot f_w \cdot f_{hv} \cdot f_g \cdot f_p \cdot f_{bb} \cdot f_a \cdot f_{LU} \cdot F_{LT} \cdot F_{RT} \cdot F_{Lpb} \cdot F_{Rbp} \cdot PHF \cdot \frac{g}{C}$$

Where:

c	= Capacity
S_0	= base saturation flow per lane (pc/h/ln) – assumed at 1900
N	= number of lanes in lane group (intersection approach lanes, not bid-block lanes)
f_w	= adjustment factor for lane width– assumed at 1.0
F_{HV}	= adjustment factor for heavy vehicles in traffic stream assumed at 1.0
f_g	= adjustment factor for approach grade – assumed at 1.0
f_p	= adjustment factor for existing of a parking lane and parking activity – assumed at 1.0
f_{bb}	= adjustment factor for blocking effect of local busses – assumed at 1.0
f_a	= adjustment factor for CBD area type
f_{LU}	= adjustment factor for lane utilization – assumed at 0.95
f_{LT}	= adjustment factor for left turns in lane group – assumed at 1.0
f_{RT}	= adjustment factor for right turns in lane group – assumed at 1.0
f_{Lpb}	= pedestrian adjustment factor for left-turn movements – assumed at 1.0
f_{Rpb}	= pedestrian-bicycle adjustment factor for right turn movements – assumed at 1.0
PHF	= peak-hour factor – assumed at 0.92
$\frac{g}{c}$	= effective green time per cycle

The equation above accounts for specific details that are not practical to maintain in a regional travel model. Therefore, a number of adjustment factors can be assumed constant or set to 1.0 for all cases. Some variables that have been set to 1.0, such as lane width, parking, turns, bus blocking, and pedestrian/bicycle effects, are instead captured in the area type adjustment. Other variables can be approximated based on the facility type and area type of each link. Additionally, a regional travel model must rely on the number of through lanes on each link, rather than the number of approach lanes at each intersection. This can be addressed by an intersection widening factor that varies by facility type and accounts for the presence of left and right turn lanes at intersection approaches.

The simplified equation below is useful in a regional travel modeling context. Assumed values for adjustment factors that vary by facility type and area type are shown in Table 1.9, along with the resulting capacity values.

$$c = S_0 \cdot N_t \cdot f_a \cdot f_{LU} \cdot PHF \cdot \frac{g}{C}$$

Where:

c	= Capacity
S_0	= base saturation flow per lane (pc/h/ln) – *assumed at 1900*
N_t	= number of through (mid-block) lanes, excluding center turn lanes
f_a	= adjustment factor for area type
f_{LU}	= adjustment factor for lane utilization – *assumed at 0.95*
PHF	= peak-hour factor – *assumed at 0.92*
$\frac{g}{c}$	= effective green time per cycle
f_w	= adjustment factor for intersection widening

Table 1.9. Link Capacity Adjustment Factors and Resulting Capacity

FT	AT	f_a	$\frac{g}{C}$	f_w	Capacity
Expressway	CBD	0.90	0.55	1.30	1,100
	Urban / Fringe	0.97	0.55	1.30	1,200
	Suburban	0.99	0.55	1.30	1,200
Principal Arterial	CBD	0.76	0.45	1.30	740
	Urban / Fringe	0.95	0.45	1.30	920
	Suburban	0.99	0.45	1.30	960
Minor Arterial	CBD	0.76	0.45	1.15	650
	Urban	0.95	0.42	1.15	760
	Suburban	0.99	0.42	1.15	790
Collector	CBD	0.75	0.45	1.05	590
	Urban / Fringe	0.95	0.41	1.05	680
	Suburban	0.99	0.41	1.05	710
Local	CBD	0.74	0.45	1.00	550
	Urban / Fringe	0.95	0.40	1.00	630
	Suburban	0.99	0.40	1.00	660

Presence of a center left turn lane, median, or left turn prohibitions can also impact link capacity. The intersection widening factors assumed above account for the presence of frequent left turn lanes or medians on principal arterials, with occasional left turn lanes and medians on minor arterials. The Corridor MPO roadway network contains a specific variable that identifies roadway corridors where medians or center left turn lanes are present. Any corridor where all possible left turns are served by a left turn lane are identified by this variable. To account for center left turn lanes, the number of lanes used to compute total directional flow is adjusted as follows:

Principal Arterial:

- Left turn lane present: Add 0.25 lanes (0.125 lanes in each direction)
- No left turn lane present: Subtract 0.5 lanes (0.25 lanes in each direction)

Minor Arterial:

- Left turn lane present Add 0.5 lanes (0.25 lanes in each direction)
- No left turn lane present: Subtract 0.25 lanes (0.125 lanes in each direction)

No adjustments are made on expressway, local, or collector facilities.

1.5.6 Resulting Capacity Model

The calculations above provide capacity values that can be applied based on the facility type, area type, number of lanes, and center turn lane presence of each link in the network. The model begins by applying the hourly lane capacities shown in Table 1.10.

Table 1.10. Roadway Capacities (Vehicles per Hour per Lane, LOS E)

	Functional Classification	CBD	Fringe	Urban	Suburban	Rural	Outside SOI
1	Freeway	2,100	2,200	2,200	2,200	2,100	2,100
3	Principal Arterial	740	920	920	960	1,162	1,162
4	Minor Arterial	650	760	760	790	956	956
5	Collector	590	680	680	710	850	850
7	Urban Local	590	680	680	710	850	850
6	Ramp	650	750	750	800	800	800
11	Highway (Outside SOI)	740	920	920	960	1,162	1,162
12	Arterial (Outside SOI)	740	920	920	960	1,162	1,162
13	Rural Arterial (Outside SOI)	740	920	920	960	1,162	1,162
50	Centroid Connectors	10,000	10,000	10,000	10,000	10,000	10,000

1.5.7 Turn Prohibitions and Penalties

There are two primary types of turn penalties that can be included in the network. Specific (localized) turn penalties or prohibitions represent known turn penalties or prohibitions at individual locations. Global turn penalties represent the generally increased amount of time required to make a left or right turn rather than travel straight through an intersection.

Inclusion of specific turn penalties in the roadway network was not recommended for the SLO Citywide Travel Model. When used, individual turn penalties often represent existing congestion at particular intersections that may or may not exist in the future, especially if operational improvements are made. While it is possible to adjust specific turn penalties for future conditions based on planned intersection or signal timing improvements, this task is beyond the capability or desire of most jurisdictions. Not only can maintenance of specific turn penalties be a time consuming task, but detailed plans for intersections and traffic signal timings in a 25-year forecast scenario do not often exist. As a result, turning penalties are not used.

Turn prohibitions, meanwhile, are a valuable addition to a travel model. Turn prohibitions are used in locations where turns are prohibited entirely. Specific turn prohibitions often include left turns or prohibited movements in interchanges. When future changes are made to the roadway network, the practitioner should be aware of the need to potentially add or remove turning prohibitions.

1.6 Routable Network

Many functions in TransCAD require the creation of a routable network file, identified by a ".net" extension. Of particular interest for the SLO Citywide Travel Model, pathbuilding/skimming and traffic assignment procedures require a routable network that contains only model-level links (i.e., no transit-only or local links). Length and travel time information for each link is stored in the routable network file, as are turn prohibitions. Specific turn prohibitions are initially stored in a separate file that is referenced when creating the routable network. An appropriate routable network file is created during the automated network initialization step. Routable network files are also required when building a transit network and performing interactive pathbuilding, but these can be created using the TransCAD interface designed for these purposes.

The routable network used for pathbuilding and traffic assignment includes only model-level links, excluding all bike and transit only links. To accomplish this, a selection set is created containing only links where facility type is less than or equal to 50 (FT < 50). A routable network file is then created to include only these links.

The routable network file also contains information about centroid connectors. This prevents the pathbuilder and traffic assignment algorithms from routing trips through centroids. This is accomplished automatically in the model by creating a selection set where facility type is equal to 50 (FT = 50) and identifying these links as centroid links in the routable network file.

2.0 Traffic Analysis Zone Structure

Traffic analysis zones (TAZ) are small areas containing the land use data that is used as the foundation for trip-making in the travel model. For the SLO Citywide Travel Model, the TAZ layer is formatted as a polygon layer in TransCAD's GIS structure. The TAZs are attached to the network using zone centroids and centroid connectors that allow travelers access to the transportation system by simulating local and neighborhood streets. Once the roadway network and TAZ structure were finalized, the zone centroids and centroid connectors were created.

TAZs are ideally but not always sized and shaped to provide a relatively homogeneous amount and type of activity within each zone. TAZ delineations traditionally follow the natural and manmade boundaries that tend to segregate different land uses. These boundaries include water features, roads, railroads, and other lines that form logical boundaries. Jurisdictional and census boundaries often do not make for good TAZ definitions because they can be arbitrary in relation to the needs of the model; but they are usually desirable for data development and reporting functions.

The definition of traffic analysis zones has implications throughout the travel model. For roadway model components, traffic analysis zone resolution affects the amount of precision that can be achieved when loading vehicles onto the collector and arterial roadway network. This precision is obtained by increasing detail in the roadway network, TAZ structure, and socioeconomic data. The desire for increased detail must, however, be balanced with the ability to develop and maintain the data at the increased level of detail.

For transit model components, the size of traffic analysis zones affects the accuracy of transit pathbuilding, particularly the walk to transit component. Algorithms used in the transit network processing and mode choice model have been designed to work properly with the TAZ structure, including the aggregated zones outside of the SOI.

The TAZ layer from the 2008 model was carried forward for most of the region. Some TAZs that are anticipated to experience significant population or employment growth were split. Figure 2.1, Figure 2.2, and Figure 2.3 show the roadway network and TAZs used by the SLO Citywide Travel Model.

Figure 2.1. Traffic Analysis Zones (Countywide)

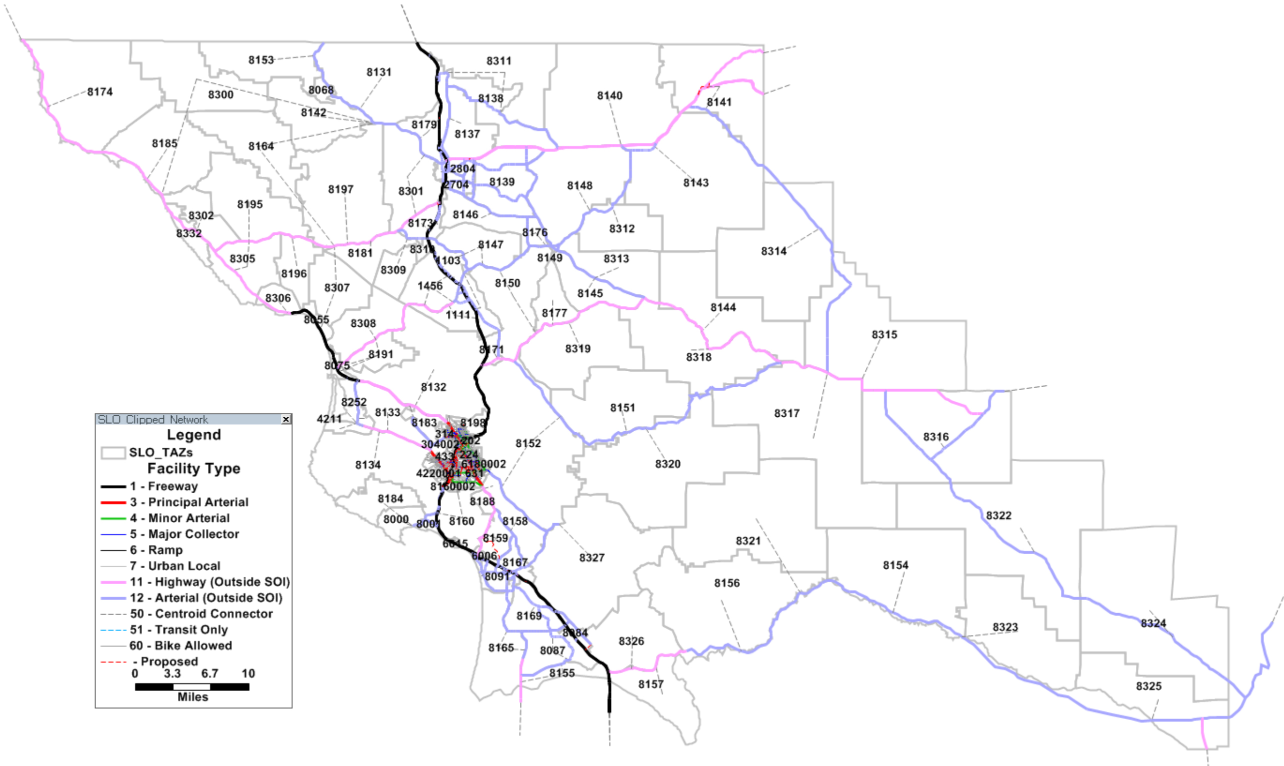


Figure 2.2. Traffic Analysis Zones (Citywide)

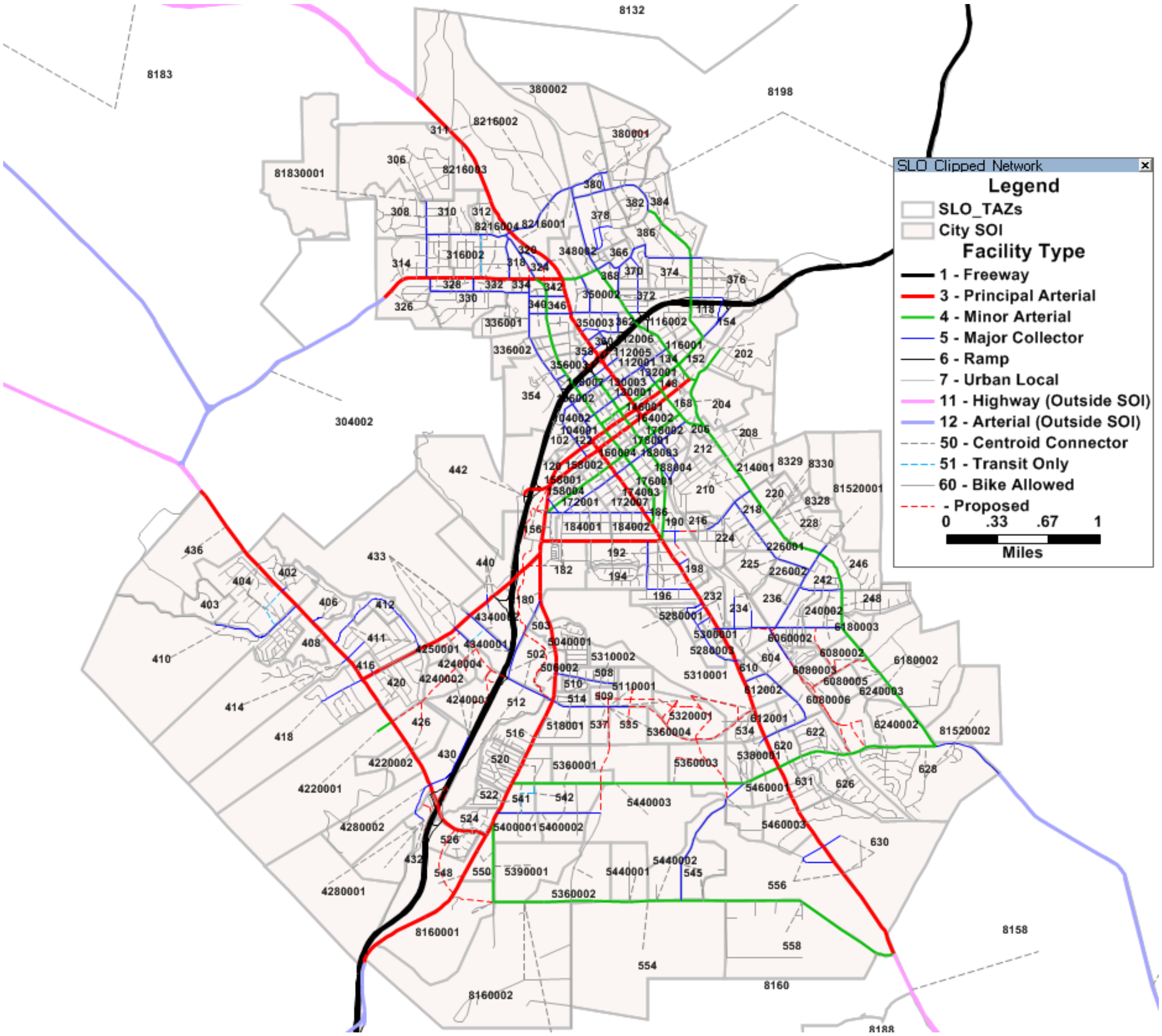
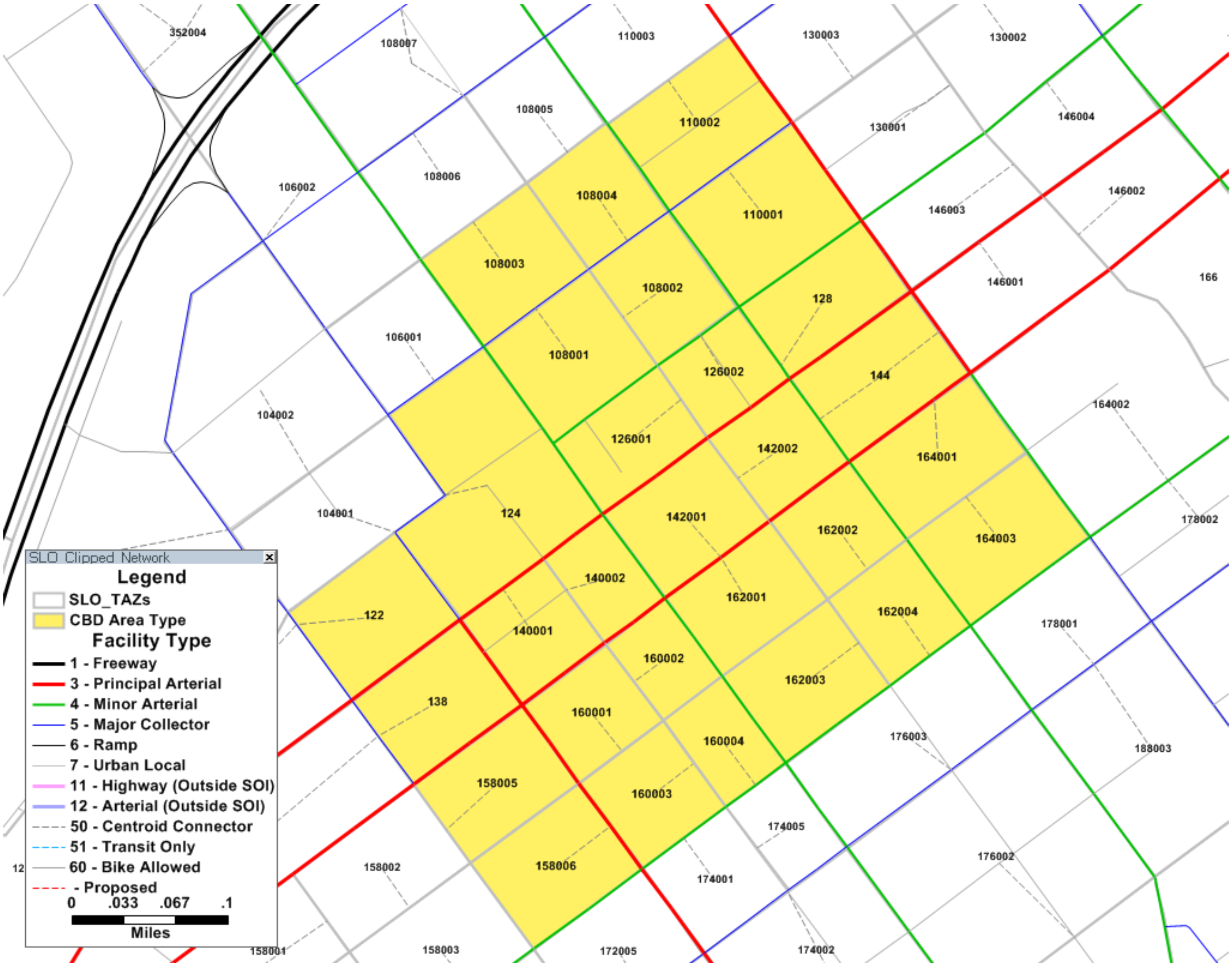


Figure 2.3. Traffic Analysis Zones (CBD)



3.0 Land Use Dataset Development

Land use and socioeconomic data provides the fundamental supply side input to the travel model. Information about households and about non-residential land uses is used determine the total number of trips made to and from each traffic analysis zone (TAZ).

3.1 Data Sources

This section identifies the development of the land use dataset for the SLO Citywide Travel Model. Several sources were considered for development of the input data:

- City of San Luis Obispo land use and parcel data (available in the SOI/City areas);
- ACS 2011-2015 5-year dataset; and,
- 2010 Census.

Each of these is discussed separately below. A discussion of the approach used to develop the model dataset follows.

3.1.1 City of San Luis Obispo Land Use Data

The City provided a parcel database that contains a snapshot of the land uses in the City. This database was fundamental in developing the base year 2016 land use data for the SLO Citywide Travel Model. After initial development of the 2016 base year land use data, the City performed a comprehensive update to the land use database. Base year land use data was updated in 2019 based on this updated database. The City's parcel dataset was processed to produce land use data for input to the travel model as discussed in section 3.2.

3.1.2 ACS 2011-2015 Dataset

The ACS dataset provides household income and size data that can be applied to household data at the TAZ level. While the year ACS household totals are inconsistent with the 2016 base year for the model, the distribution of households by income and size is still useful. Household classification by size and income is available at the block group level. Income data is provided in the following groups:

1. Less than $10,000;
2. $10,000 to 74,999 (in $5,000 increments);
3. $75,000 - $99,999;
4. $100,000 - $124,999;
5. $125,000 - $149,999;
6. $150,000 - $199,999; and

7. Over $200,000.

Median income for each TAZ and average household size for each TAZ can also be determined using ACS data.

3.1.3 2010 Census

Cross-classification of households by income and size is only available in the decennial Census and only at the Public Use Microdata Areas (PUMAs) geography. There are two PUMAs in San Luis Obispo County, one containing San Luis Obispo, Pismo Beach, Grover Beach, Arroyo Grande, Oceano, and Nipomo. A countywide cross-classified distribution of households for 2010 has been obtained from the American FactFinder. It was then used to determine the number of households in each income and household size group while maintaining the ACS totals for each income level and household size.

3.2 Model Dataset

The land use and socioeconomic data for the SLO Citywide Travel Model has been derived from the various data sources as listed in Table 3.1.

Table 3.1. Source of Input Socioeconomic and Land Use Data

Data Requirement	Data Source (Existing)	Data Source (Future)
City / SOI Non-Residential Land Use	City Parcel Dataset	City Comprehensive Plan
City / SOI Residential Household Totals	City Parcel Dataset	City Comprehensive Plan
City / SOI Median Household Income and Size by TAZ	ACS 2011-2015	Area type templates, optional additional detail
County Data	SLOCOG Model	SLOCOG Model

The City's parcel dataset has been processed to produce a TAZ-level dataset that contains the square footage of non-residential land use by land use categories used by the model. It was also used to obtain the number of households in each TAZ. Land use categories used by the model are shown in Table 3.2 along with additional household-based socioeconomic variables. Outside of the SOI, trip generation results imported from the SLOCOG model are used directly. Therefore, socioeconomic data from the SLOCOG data is not required outside of the SOI.

In addition to total households, TAZ-level information about household size and income is used to improve the model's accuracy in the trip generation, trip distribution, and mode choice components. To provide this additional accuracy, average household size and median household income for each TAZ are required model inputs. These variables have been approximated at the TAZ level based on 2011-2015 ACS data.

Table 3.2. Model Land Use and Socioeconomic TAZ Input Data

General Category	Travel Model Category	Units	Field Name
Household	Household	Households	TOT_HH
	Median Household Income	1999 dollars	MED_INC

General Category	Travel Model Category	Units	Field Name
	Average Household Size	Persons/HH	AVG_HHSZ
Office and Service	General Office	ksf	OFFICE
Service	Religious Organizations and Meeting Halls	ksf	RELIG
	Hospitals	ksf	HOSP
	Airport (rate per thousand annual enplanements)	Enpl	AIRPORT
Lodging	Motels and Hotels	Rooms	MOTEL
	Beach Resorts	Acres	BEACH_RST
Retail	High Generation Retail	ksf	HIGH_RET
	Medium Generation Retail	ksf	MED_RET
	Low Generation Retail	ksf	LOW_RET
Schools	Elementary Schools	Students	ELM_SCH
	High Schools	Students	HIGH_SCH
	CalPoly Students	Students	CP_STUD
	CalPoly Employees	Jobs	CP_EMP
	Cuesta College Students	Students	CC_STUD
	Cuesta College Employees	Jobs	CC_EMP
Industry	Light Industrial	ksf	L_IND
	Heavy Industrial	ksf	H_IND
Other	Parks & Recreation	Acres	PARKREC
	Agricultural	Acres	AG
	Undeveloped	Acres	UNDEV

Forecasting of Household Size and Income

Due to the household income and size data for future year conditions not being available at the TAZ level, a method has been developed to simplify the input of household income and size data in future year datasets. Different approaches are recommended depending on the existing amount of development in a zones as well as the amount of growth forecast. Four options are suggested for development of household size and income data for each TAZ:

1. Use the base year TAZ median income and/or average household size,
2. Use the regional median income and/or average household size,
3. Specify median income and/or average household size based on a template (e.g., by area type), or
4. Specify the average median income and/or average household size directly.

The simplest case, using the base year data by TAZ, is appropriate in many cases. However, there may be cases in which additional refinement is desired. The flowcharts provided in Figure 3.1 and Figure 3.2

describe a process through which a more refined approach can be implemented. Relevant numbers that are useful in refinement of the data are included in Table 3.3.

Table 3.3. Selected Household Size and Income Summary Data

Variable	Value
Base Year Citywide Median Income	$49,669
+ 1 Standard Deviation	$77,019
- 1 Standard Deviation	$22,319
Base Year Citywide Average Household Size	2.46
+ 1 Standard Deviation	3.23
- 1 Standard Deviation	1.69
Base Year CBD Median Income	$48,983
Base Year Fringe Median Income	$38,036
Base Year Urban Median Income	$48,983
Base Year Suburban Median Income	$56,657
Base Year Rural Median Income	$35,089
Base Year CBD Average HH Size	1.64
Base Year Fringe Average HH Size	1.92
Base Year Urban Average HH Size	2.21
Base Year Suburban Average HH Size	2.57
Base Year Rural Average HH Size	2.35

Figure 3.1. Median Income Forecasting Flowchart

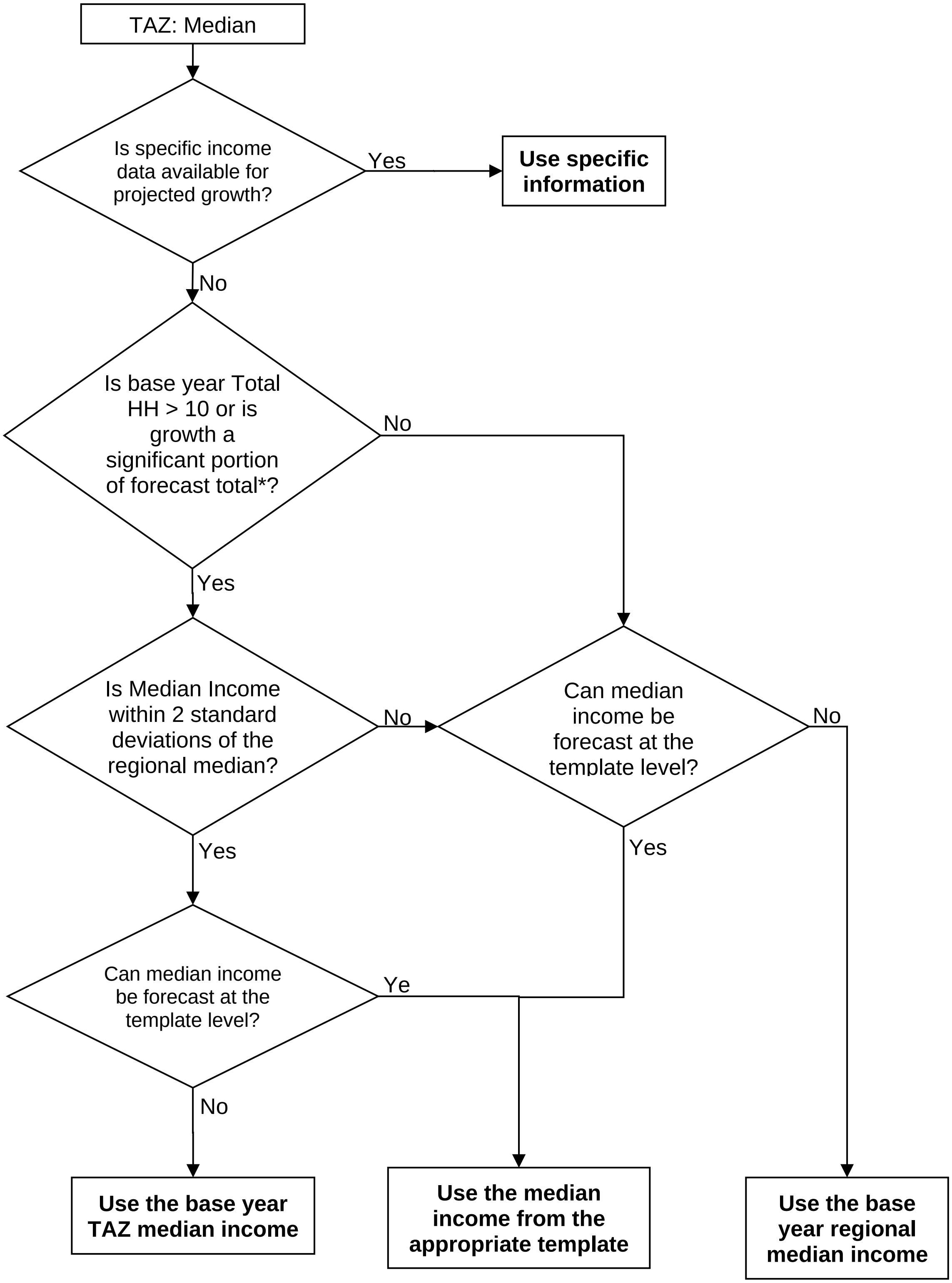
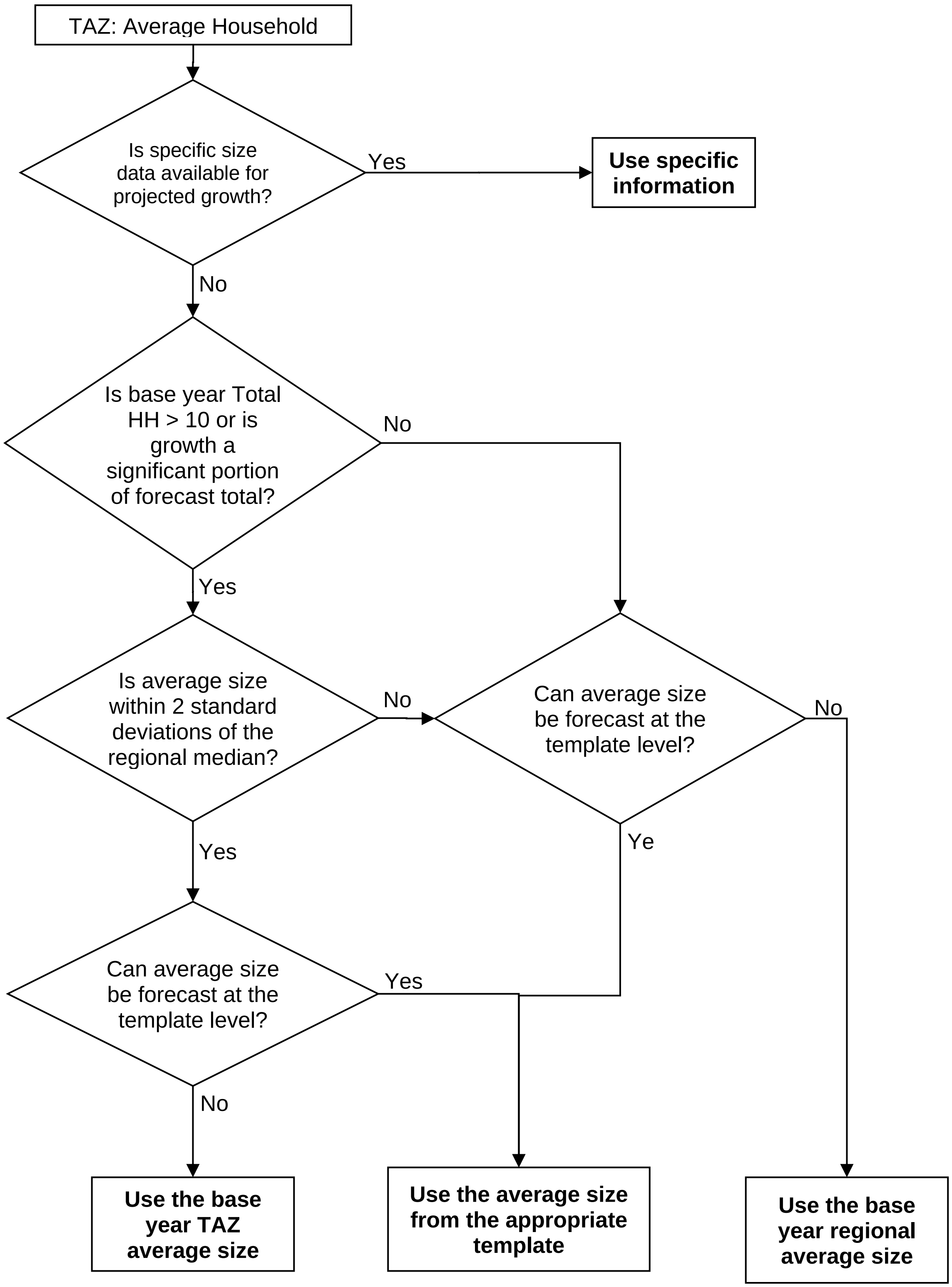


Figure 3.2. Average Household Size Forecasting Flowchart



3.3 Household Disaggregation Models

The socioeconomic input data includes information about median household income and average household size. Household disaggregation models are then used to estimate the univariate distribution of households by size and by income group for each TAZ. These models are based on US Census data at the block and block-group level.

To apply these models, each known variable is used to look up a distribution of households by classification. For example, a zone with an average household size of 1 person would be comprised entirely of 1-person households (by definition). Conversely, a zone with an average household size of 4 people would be modeled as a combination of 1, 2, 3, 4, and 5+ person households. Distributions are represented by hand-fitted curves based on US Census and ACS data aggregated to TAZs.

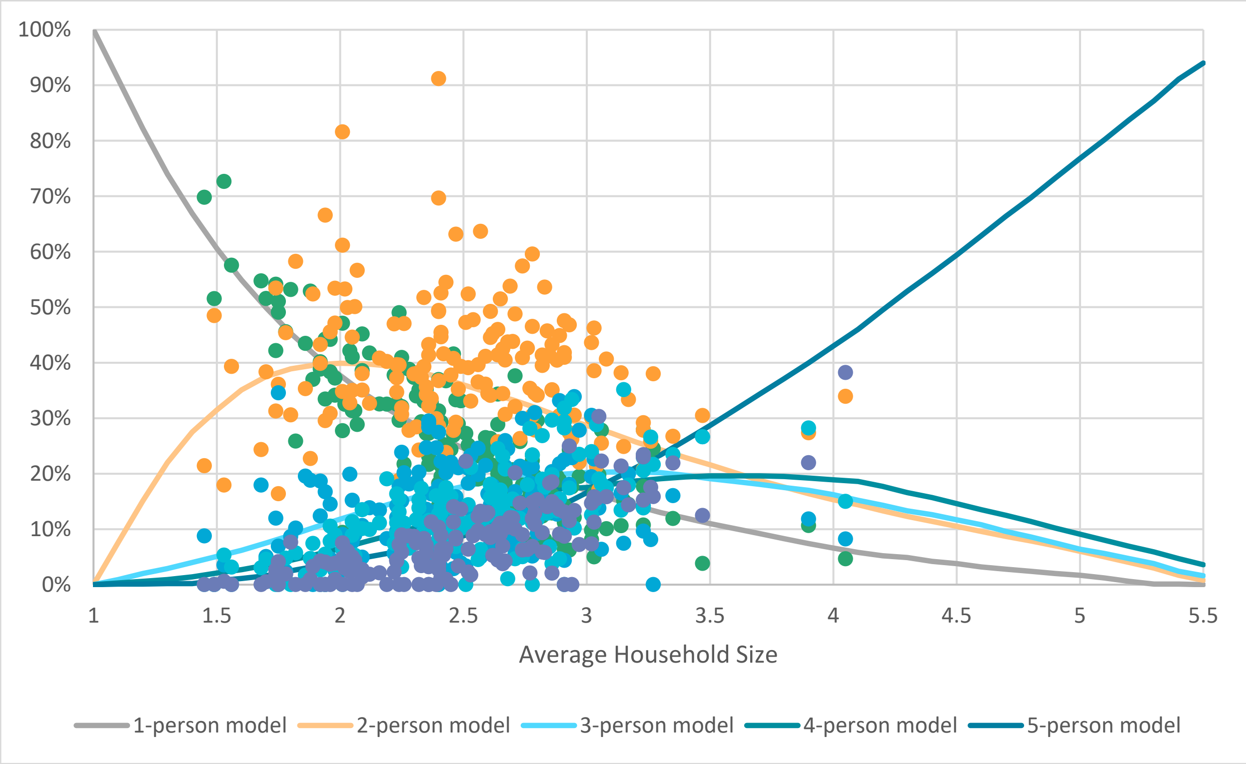
It is important that the distribution curves always sum to 100% and that, for the household size model, the results are consistent with the input value when averaged. Hand-fitted curves have been adjusted to fit the observed data points, sum to 100%, and produce the appropriate average.

The household income model is expressed as a percentage of regional income rather than an income value in dollars. This is done to allow for median income data to be input to the model in any chosen units, as long as the units are consistent for all zones.

3.3.1 Household Size Disaggregation Model

Model trip rates are classified by 5 household size groups. The portion of households in each group can be approximated for any given TAZ based on the average household size. Disaggregation curves are shown along with Census data in Figure 3.3. The resulting model is defined as a lookup table provided with the travel model input dataset.

Figure 3.3. Household Size Disaggregation Curves



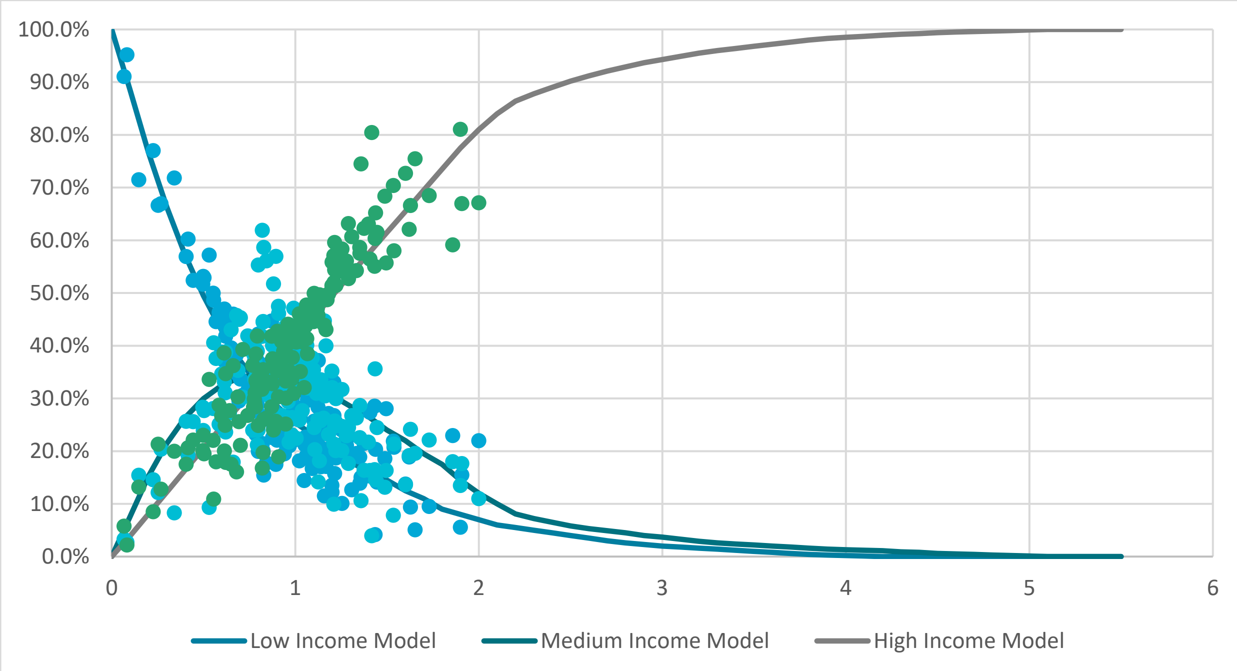
3.3.2 Household Income Disaggregation Model

The household income group model was developed in a manner similar to the household size disaggregation model. Low, medium, and high income groups are defined in Table 3.4. Disaggregation curves are shown along with Census data in Figure 3.4. The resulting model is defined as a lookup table provided with the travel model input dataset.

Table 3.4. Income Group Definitions

Income Group	Income Range
Low	$34,999 and lower
Medium	$35,000 – $99,999
High	$100,000 and higher

Figure 3.4. Household Income Disaggregation Model



3.3.3 TAZ-Level Bivariate Data

The household income and size disaggregation models produce *univariate* data for each TAZ. To apply trip production rates that vary by household size and income, *bivariate* household data is required at the TAZ level. The TAZ-level data resulting from the household size disaggregation models is used along with the regional bivariate distribution of households by size and income to estimate the bivariate distribution of households for each TAZ. The regional bivariate distribution of households by size and income, shown in Table 3.5, was obtained from the 2010 Public Use Microsample (PUMS) dataset.

Table 3.5. Bivariate Household Distribution for San Luis Obispo County

Income Group	1 Person	2 Person	3 Person	4 Person	5+ Person	Total
Low	11,625	6,106	2,204	2,068	1,632	**23,635**
Medium	7,420	15,327	5,622	4,383	2,843	**35,595**
High	1,788	10,154	4,110	3,578	2,571	**22,201**
Total	**20,833**	**31,587**	**11,936**	**10,029**	**7,046**	**81,431**

Source: 2010 PUMS Dataset for San Luis Obispo County

4.0 Trip Generation

Trip generation is the first phase of the traditional 4-step travel demand modeling process. It identifies the trip ends (productions and attractions) that correspond to the places at which activities occur as represented by land use data (e.g., dwelling units, square feet of commercial development). Productions and attractions are estimated for each TAZ by trip purpose, and then balanced at the county level. Production and attraction allocation sub-models are applied in some cases to better represent the geographic locations at which these trip ends occur. The resulting productions and attractions by trip purpose and TAZ are subsequently used by the Trip Distribution model to estimate zone-to-zone travel patterns.

Trip productions and attractions are the fundamental variables for defining the trip ends associated with travel. With the exception of non-home-based trips and trips external to the modeling area, productions occur at the home end of a trip and attractions occur at the non-home end of the trip.

The primary data source for estimating trip productions and attractions is the California Household Travel Survey (CHTS) conducted in 2012. Since the survey is household-based, it provides excellent information with regard to household trip-making. Therefore, the CHTS is especially well suited for estimating trip production rates. The CHTS also provides some information about trip attractions, but is not particularly well suited for this purpose due to the absence of data about land use activities at the attraction end of recorded trips. Attraction rates were carried forward from the 2008 base year model and adjusted during model calibration and validation.

4.1 California Household Travel Survey (CHTS)

Caltrans conducted the most recent CHTS between October 2012 and December 2012 among households located in each of the 58 counties throughout the State. Household socioeconomic data gathered in this survey includes information on household size, income, vehicle ownership, employment status of each household member, and housing unit type. Travel information was also collected including trip times, mode, activity at each trip-end, and vehicle occupancy. The survey was conducted among randomly selected households using telephone recruitment, followed by a diary mail out. Travel diary information was collected using a telephone interview.

The CHTS data provided by Caltrans had already been through a quality control process. All household and trip-end locations in the survey database had been geocoded. The survey process and results are summarized in *2012 California Statewide Travel Survey* published by the California Department of Transportation.

There are 573 records available for households within San Luis Obispo County. When classified by variables such as household income and size, trip generation characteristics for the County as a whole are assumed to be representative of trip generation rates within the City of San Luis Obispo. This assumption allows use of the countywide dataset to develop trip rates for the SLO Citywide Travel Model.

The CHTS included a combined weighting and expansion factor for each household. Weights are sensitive to vehicle availability, household tenure (rent/own status), county of residence, household size, and household income. The expanded number of household from the CHTS were similar to the total number of households in the PUMS dataset and hence weighted trip and household data from the CHTS were used directly to estimate the trip rates.

4.2 Trip Purposes

Generally, a trip is defined as a distinct travel movement from one clearly identifiable starting place/activity to another with a distance of at more than one block. The number of trip purposes was retained from the previous model including:

- ***Home-Based Work (HBW)***: Commute trips between home and work, including work trips made by CalPoly employees.
- ***Home-Based University (HBU)***: Trips between home and the CalPoly campus for school related purposes by people not employed by the University.
- ***Home-Based Shop (HBS)***: Trips between home and shopping locations for the purpose of shopping.
- ***Home-Based Other (HBO)***: All other trips that have one end at home.
- ***Work-Based Other (WBO)***: Work-related trips without an end at home.
- ***Other-Based Other (OBO)***: Trips with neither an end at home nor a work-related purpose.

Survey data was processed to identify 612,527 weighted weekday trips in San Luis Obispo County reported by survey participants. Because weekend survey participants also reported trip activity on a weekday, only the trips reported on weekends were dropped from the analysis. Households participating in the weekend portion of the survey were retained in the household total, as were the weekday trips made by these households.

Survey respondents were asked to report their primary activity at each place visited during the course of a day. These primary activities were used to categorize each trip into one of the purposes used in the travel model, resulting in the total number of trips by each purpose shown in Table 4.1. Because only trips that occur entirely within San Luis Obispo County are included in the model's trip rates, trips which begin or end outside the county were dropped from the analysis. Trip purposes were identified based on the origin and destination activity for each trip using the relationship shown in Table 4.2. Certain origin/destination trip activity combinations, such as home to home, have been designated as NA and dropped from the trip rate analysis. Such occurrences were exceedingly rare and do not have a significant impact on overall trip rates.

Table 4.1. CHTS Weighted and Expanded Trips by Purpose for San Luis Obispo County

Trip Purpose	Expanded Weekday Trips	Percent of Total
HBW	105,137	17.2%
HBS	89,056	14.5%
HBU	6,583	1.1%
HBO	233,633	38.1%
WBO	61,115	10.0%
OBO	117,002	19.1%
Total	**612,527**	**100%**

Table 4.2. Trip Purpose by Trip Origin and Destination Activities

	Home	Intermodal	Work / volunteer	School (K12)	College / University	Shopping	Other Activities
Home	NA	HBO	HBW	HBO	HBU	HBS	HBO
Intermodal activities	HBO	OBO	WBO	OBO	OBO	OBO	OBO
Work/volunteer	HBW	WBO	WBO	WBO	WBO	WBO	WBO
School (K12)	HBO	OBO	WBO	OBO	OBO	OBO	OBO
College/University	HBU	OBO	WBO	OBO	OBO	OBO	OBO
Shopping	HBS	OBO	WBO	OBO	OBO	OBO	OBO
Other activities	HBO	OBO	WBO	OBO	OBO	OBO	OBO

4.3 Production Rates

A detailed analysis of CHTS was conducted in order to develop trip production rates for the SLO Citywide Travel Model. Past experience has shown that trip production rates are generally sensitive to household size and to a measure of wealth (such as income or auto ownership). Analysis of CHTS data for the County of San Luis Obispo has shown sensitivity to these variables. The production model for the updated model is sensitive to both income and household size.

4.3.1 Income Groups

The CHTS places each household into one of seven income groups. Although useful, there are not sufficient records in the dataset to retain all seven groupings as income categories. Hence, the income categories were grouped as shown in Table 4.3.

Table 4.3. Income Categories

Income Group (Model)	Income Category (Survey)
Low	Under 24K
	25 - 34K
Medium	35 - 49K
	50 - 74K
	75 - 99K
High	100 - 149K
	Over 150K

4.3.2 Cross Classified Production Rates

Cross classified (by household size and income) trip rates can be initially computed as the mean number of trips per household for each combination of household income and size. However, a sufficient number of samples are not available for each combination. A review of mean trip rates, trip rate standard deviations, and trip rate confidence intervals was conducted. Initial trip rates were adjusted through grouping of cells across multiple income groups or household sizes where appropriate. The resulting trip rates by purpose are shown in Table 4.4 through Table 4.9.

Trip rates for HBU trips are not shown, because sample sizes were not sufficient to develop meaningful trip rates. HBU trips are instead handled by a special generator and production allocation model.

Table 4.4. Household Trip Production Rates – HBW

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	0.46	0.85	1.86	3.09	3.39	**1.08**
Medium	0.71	1.31	2.50	3.09	3.39	**1.80**
High	1.36	1.75	2.50	3.09	4.52	**2.42**
Total	**0.62**	**1.29**	**2.37**	**3.09**	**3.67**	**1.69**

Table 4.5. Household Trip Production Rates – HBS

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	1.11	1.11	1.57	1.57	1.57	**1.20**
Medium	1.11	2.05	2.05	2.25	2.25	**1.89**
High	1.37	2.05	2.72	2.72	2.72	**2.28**
Total	**1.12**	**1.8**	**2.04**	**2.28**	**2.22**	**1.72**

Table 4.6. Household Trip Production Rates – HBO

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	0.94	1.82	2.46	5.83	5.83	**1.99**
Medium	0.94	1.82	2.46	5.83	5.83	**2.65**
High	0.94	1.82	2.54	7.41	7.41	**3.49**
Total	**0.94**	**1.82**	**2.49**	**6.28**	**6.24**	**2.60**

Table 4.7. Household Trip Production Rates – WBO

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	0.37	0.37	0.37	0.37	0.53	**0.37**
Medium	0.44	1.18	1.60	1.60	1.60	**1.16**
High	0.21	1.11	1.60	1.60	1.60	**1.25**
Total	**0.39**	**0.95**	**1.20**	**1.42**	**1.46**	**0.91**

Table 4.8. Household trip Production Rates – OBO

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	0.57	1.30	1.30	2.33	3.90	**1.07**
Medium	0.57	1.54	1.94	2.33	3.90	**1.69**
High	0.57	1.54	2.63	8.57	8.57	**3.27**
Total	**0.57**	**1.48**	**1.88**	**3.99**	**4.55**	**1.74**

Table 4.9. Household Trip Production Rates – Total

Income Group (Model)	Household Size					TOTAL
	1	2	3	4	5 or more	
Low	3.45	5.45	7.56	13.19	15.22	**5.71**
Medium	3.77	7.9	10.55	15.1	16.97	**9.19**
High	4.45	8.27	11.99	23.39	24.82	**12.71**
Total	**3.64**	**7.34**	**9.98**	**17.06**	**18.14**	**8.66**

4.4 Attraction Rates

Attraction rates are used to identify the ends of trips that occur at locations other than the trip-maker's home. For home-based trip purposes, the attraction end of a trip occurs at a non-residential location, or occasionally at another person's home. For WBO trips, the trip production occurs at the trip maker's workplace and the trip attraction occurs at the non-work end of the trip. For OBO trips, the trip production and attraction are synonymous with trip origin and destination. For both non home-based trip purposes, allocation models and special procedures are used to properly locate the production and attraction end of each trip.

The CHTS did not identify a land use or employment type at all trip attraction locations. This prevents use of the data to generate trip attraction rates specific to San Luis Obispo. Many recent surveys conducted in the State of California suffer from a similar exclusion. Trip rates were developed for the 2008 base year model using data from a household travel survey conducted in San Diego, along with trip rates published in the Institute of Transportation Engineers (ITE) Trip Generation manual. These trip rates have been carried forward into the 2016 base year model. Trip attraction rates used in the model are shown in Table 4.10.

Table 4.10. Refined City of SLO Travel Model Attraction Rates

General Category	ID	Detailed Category	Units	Person Attraction Rates By Purpose					WBO
				HBW	HBS	HBO	WBO	OBO	Production Allocation Rate
Residential	11	Single-Family Residential	DU	0.08	0.00	0.97	0.11	0.37	0.05
	12	Multi-Family Residential	DU	0.12	0.00	0.37	0.11	0.37	0.08
Office	20	General Office	KSF	3.65	0.00	2.32	0.15	0.89	0.88
Service	31	Religious Organizations and Meeting Halls	KSF	0.43	0.00	7.73	0.51	2.98	0.10
	32	General Service	KSF	3.65	0.00	3.81	0.25	1.47	0.88
	33	Hospitals	KSF	5.37	0.00	2.78	0.18	1.07	1.29
	34	Airport (rate per thousand annual enplanements)	Enpl	5.79	0.00	11.59	5.79	5.79	1.39
Lodging	41	Motels and Hotels	Rooms	0.97	0.00	0.11	0.74	0.95	0.23
	42	Beach Resorts	Acres	0.00	0.00	3.36	0.12	0.97	0.00
Retail	51	Drive In Retail	KSF	13.40	18.82	28.01	8.94	23.23	1.97
	52	High Generation Retail	KSF	3.75	14.12	20.17	6.71	17.43	0.55
	53	Medium Generation Retail	KSF	3.75	9.41	12.33	4.47	11.61	0.55
	54	Low Generation Retail	KSF	1.64	4.71	6.72	2.24	5.81	0.24
Schools	61	Elementary Schools	Students	0.13	0.00	1.36	0.19	0.41	0.03
	62	High Schools	Students	0.27	0.00	1.60	0.37	0.78	0.07
	63	CalPoly Students	Students	See special generator discussion					
	64	CalPoly Employees	Jobs						
	65	Cuesta College Students	Students	0.00	0.00	1.18	0.00	0.41	0.00
	66	Cuesta College Employees	Jobs	0.80	0.00	0.00	1.00	1.33	0.19
Industry	71	Heavy Industrial	KSF	2.84	0.00	0.62	0.83	0.38	0.60
	72	Light Industrial	KSF	3.17	2.80	0.67	0.45	0.90	0.67
Other	81	Parks & Recreation	Acres	0.03	0.00	0.02	0.01	0.01	0.01
	82	Agricultural	Acres	0.02	0.00	0.13	0.01	0.01	0.00
	83	Undeveloped	Acres	0.00	0.00	0.00	0.00	0.00	0.00

4.4.1 Non-Home-Based Production Allocation Models

While WBO trips and OBO are initially generated using household based production rates, these trip productions occur at non-residential locations. The total number of WBO and OBO productions generated at households is used as a control total for trip balancing, but production allocation rates are used to move non home-based productions to the appropriate work locations. For WBO trips, trip productions are defined as the work trip end and attractions are defined as the non-work trip end. To accommodate this, a set of WBO production allocation rates have been developed.

4.4.2 Trip Rate Factors and Adjustments

During model validation, it was observed that traffic volumes in and around the SOI were significantly lower than traffic counts while the trips into and out of the SOI were higher than counts. Trip rates were adjusted to account for the following issues:

- Although localized, the CHTS dataset includes a relatively small sample size within San Luis Obispo County.
- Trip generation outside the SOI is based on the SLOCOG model instead of trip rates.
- Aggregation of traffic analysis zones outside of the SOI results in aggregation bias. Trip rate adjustments were made to counteract this phenomenon.

Trip rate factors are applied by district, as shown in Table 4.11 and Table 4.12. These factors are applied in combination with K-factors described in Chapter 5.

Table 4.11. Trip Production Rate Adjustment Factors

District	HBW	HBS	HBO	HBU	WBO	OBO	IE
Rural / External	1	1	1	1	1	1	1
SOI - Non-CBD	1.8	1.9	1.8	1.0	2.0	1.8	1.5
Morro Bay (North of SLO)	1	1	1	1	1	1	1
Atascadero (North of SLO)	1	1	1	1	1	1	1
Paso Robles (North of SLO)	1	1	1	1	1	1	1
Shandon (North of SLO)	1	1	1	1	1	1	1
California Valley	1	1	1	1	1	1	1
Pismo Beach (South of SLO)	1	1	1	1	1	1	1
Oceano (South of SLO)	1	1	1	1	1	1	1
SOI - CBD	1.8	1.8	1.8	1	1.8	1.8	1.5
Camp SLO / Cuesta	1.5	1.5	1.5	1	1.5	1.5	1.5

Table 4.12. Trip Attraction Rate Adjustment Factors

District	HBW	HBS	HBO	HBU	WBO	OBO	IE
Rural / External	1	1	1	1	1	1	1
SOI - Non-CBD	2.0	1.9	1.8	1.8	1.8	1.8	1.5
Morro Bay (North of SLO)	1.2	1.2	1.2	1.2	1.2	1.2	1
Atascadero (North of SLO)	1.5	1.5	1.5	1.5	1.5	1.5	1
Paso Robles (North of SLO)	1.5	1.5	1.5	1.5	1.5	1.5	1
Shandon (North of SLO)	1	1	1	1	1	1	1
California Valley	1	1	1	1	1	1	1
Pismo Beach (South of SLO)	1.2	1.2	1.2	1.2	1.2	1.2	1
Oceano (South of SLO)	1.2	1.2	1.2	1.2	1.2	1.2	1
SOI - CBD	1.8	1.8	1.8	1.8	1.8	1.8	1.5
Camp SLO / Cuesta	2.5	2.5	2.5	2.5	2.5	2.5	1.5

4.5 CalPoly Trip Generation and Production Allocation

San Luis Obispo County is home to the California Polytechnic State University, San Luis Obispo (CalPoly) and Cuesta College, a community college. Because CalPoly is a four-year college, students attending this university tend to be concentrated at households near the universities or live on campus. This suggests that a special university trip purpose and allocation model can improve representation of CalPoly in the travel model.

On the other hand, Cuesta College is a community college and is likely to experience conditions that can be adequately represented by the trip rates and gravity model used for other non-university purposes. Furthermore, Cuesta College is located outside of the SOI. Therefore, Cuesta College has been represented using trips directly from the SLOCOG model.

4.5.1 University Definition

The CalPoly campus is separated into seven traffic analysis zones as shown in Figure 4.1. Based on a review of aerial photography and the CalPoly On-Campus Housing Map, zones were identified as zones that produce trips (zones that include on-campus housing) and zones that attract trips (zones that contain uses such as classes and offices). Production and attraction activity was then apportioned to zones based on zone size and density. A summary of activity allocation by zone is included in Table 4.13.

Figure 4.1. CalPoly Campus Zones

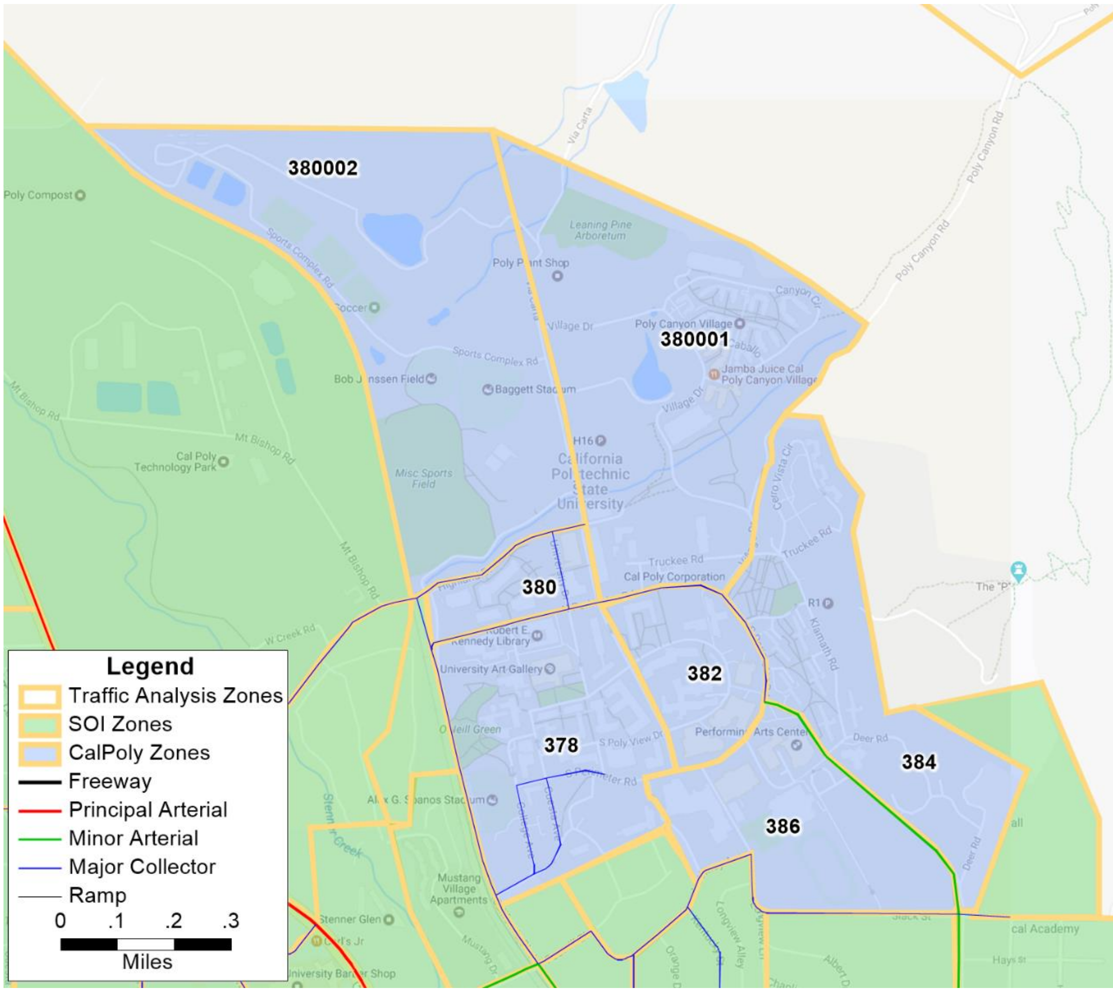


Table 4.13. CalPoly Activity Allocation by Zone

TAZ	Description	% of Productions	% of Attractions
378	Central Campus	0%	20%
380	Campus Activity	0%	20%
380001	Campus Activity, plus Poly Canyon Village On-Campus Housing	50%	20%
380002	Sports Complex	0%	5%
382	Central Campus	0%	30%
384	Primarily On-Campus Housing	50%	0%
386	Sports Complex / Campus Activity	0%	5%
Total		**100%**	**100%**

4.5.2 Trip Types at CalPoly

Because universities do not fall into the normal trip patterns used by the model, some special considerations are given to trip types at CalPoly. In particular, the Home-Based University (HBU) trip purpose is defined as a trip by a university student or visitor between home and any location on the university campus. Trip ends at the University are associated with University faculty and staff, students living on campus, and students and visitors living off campus and described as follows:

- **HBW, HBS, and HBO Productions:** These production trip ends can occur only for students living on campus.
- **HBW Attractions and WBO Productions:** These trip ends can occur only for University faculty and staff.
- **WBO Attractions and all OBO Trips:** These trip ends can only occur for students and visitors living off campus.
- **HBS and HBO Attractions:** These trip ends cannot occur at the University. All home-based trips to the University by students and visitors are considered HBU trips and all home-based trips to the University by faculty and staff is considered HBW trips.
- **HBU Productions:** Trips within the University are not modeled, so HBU productions cannot occur on campus.
- **HBU Attractions:** HBU attractions can occur only for students and visitors living off campus.

4.5.3 Special Generator Survey Adaptation

Detailed survey data was not available for CalPoly, so university special generator surveys from outside of the region have been used to specify a special generator models for CalPoly. Special generator studies conducted for Colorado State University (CSU) and the University of Northern Colorado (UNC) were used to estimate a special generator model for the North Front Range (Colorado) Regional Travel Model (NFR RTM). These studies and special generator models were borrowed and adjusted for application at CalPoly.

4.5.4 Employment and Enrollment Data

Total employment and enrollment data for CalPoly was retrieved from the University website[4]. Because employment data includes part-time employees, a factor of 0.90 was applied to convert total employment to full-time equivalent employees (for consistency with the UNC and CSU surveys). Total enrollment was divided into on-campus and off-campus enrollment based on the number of on-campus housing units. Employment and enrollment data for CalPoly is summarized in Table 4.14.

[4] http://www.calpolynews.calpoly.edu/quickfacts.html

Table 4.14. CalPoly Employment and Enrollment

Trip Maker	Employment or Enrollment
FTE Faculty and Staff	3,015
On-Campus Students	7,200
Off-Campus Students	13,744
Total Enrollment	20,944

Special Generator Values

Special generator values from the NFR RTM were adapted for use in the model by computing a surrogate trip rate for each trip type based on FTE employment, on-campus students, or off-campus students. Where data was available, the CSU special generator values were used because CSU is more similar to CalPoly. The CSU special generator study grouped WBO and OBO trips into non home-based trips, so UNC values were used to compute WBO and OBO special generator values. During model validation, cordon counts surrounding the university were reviewed and special generator values were adjusted accordingly. Trip rates, initial special generator values, and adjusted special generator values are shown in Table 4.15.

Table 4.15. University Special Generator Values

Trip Purpose	Trip Rate	Unit	Generator Value
HBW Productions	0.22	On Campus Students	1,584
HBW Attractions	1.6	FTE Employment	4,824
HBS Productions	0.2	On Campus Students	1,440
HBS Attractions	n/a	n/a	0
HBU Productions	n/a	n/a	0
HBU Attractions	3.80	Off Campus Students	52,227
HBO Productions	0.5	On Campus Students	3,600
HBO Attractions	n/a	n/a	0
WBO Production	0.37	FTE Employment	1,116
WBO Attractions	0.19	Off Campus Student	2,611
OBO Productions	0.25	Off Campus Student	3,436
OBO Attractions	0.25	Off Campus Student	3,436

Production Allocation

The production end of each HBU trip will occur at a household, most likely near the university. Analysis of the CHTS survey data was not possible due to the low capture rate of university trips. Instead, student housing information was used to allocate HBU trip productions to TAZs.

In 2015, 20,944 students were enrolled at Cal Poly with 34% living in dorms on campus. The remaining 13,744 students lived in off-campus housing including dedicated student housing and regular housing. In order for the model to allocate these students, a three-step process was followed:

1. Identify dedicated off-campus student housing locations.
2. Determine capacity of dedicated off-campus student housing and assign students to available off-campus student housing.
3. Allocate the remaining student to other housing throughout the region.

The first step is to identify off-campus student housing where only students are likely to live- this includes official student apartments as well as apartments located in the campus vicinity. Official student off-campus housing includes the Mustang Village and Stenner Glen Apartments. In addition, apartment complexes within one mile from campus and those identified by City staff are also considered dedicated student off-campus housing since these are very likely occupied only by students.

Next, it is necessary to determine the capacity for the dedicated student off-campus housing. The number of available units for off-campus housing was previously provided by City of SLO and is used for this analysis. The list of dedicated off-campus student housing along with the unit count is shown in Table 4.16.

Table 4.16. Dedicated Off Campus Student Housing

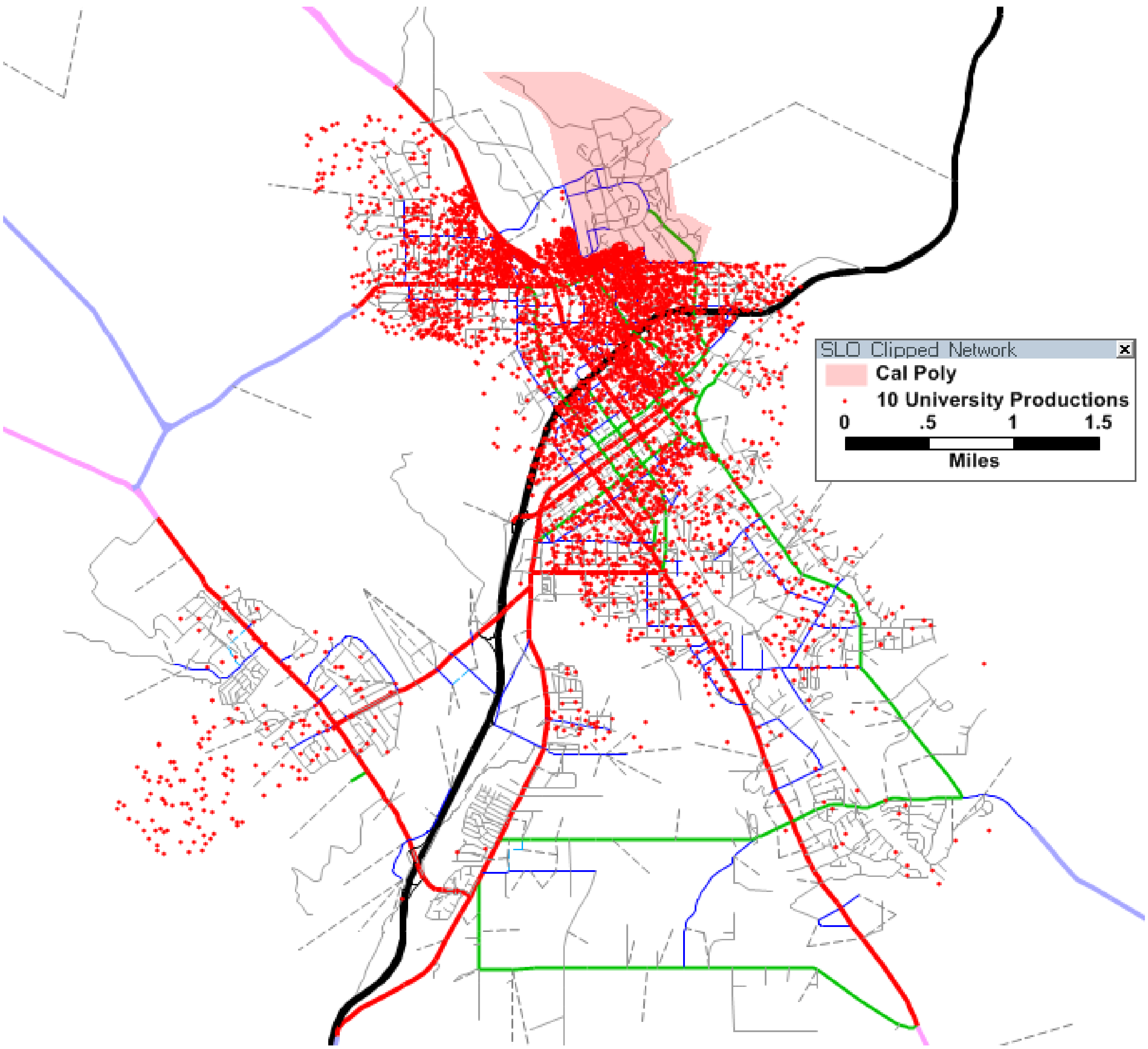
Apartment Name	Address	Units	Beds / Unit	Beds
Mustang Village	1 Mustang Dr.	534	1 to 4	1,335
Stenner Glen	1050 Foothill Blvd.	420	1	420
Valencia Apartments	555 Ramona Dr.	160	3	480
Murray Station	1262 Murray St	82	1 to 4	164
Cedar Creek Association	75 Stenner St.	68	2	136
Stafford Gardens	1415 Stafford St.	59	1 to 2	89
University Vista Apartments	1230 Murray	34	1 to 4	85
Pine Creek	1185 Foothill Blvd.	36	2	72
College Gardens	284 North Chorro St.	44	1 to 2	66
Segrado Corazon Townhomes	60 Casa Street	32	2	64
Foothill Gardens	1311 Foothill Blvd.	53	1	53
Alta Vista Park	265-305 N. Chorro	25	2	50
Cal Park Apartments	250 California Blvd.	24	2	48
Foothill Hacienda	190 California Blvd.	23	2	46
Lee Arms Apartments	258 California	21	2	42
Sierra Vista	510 Foothill Blvd.	26	1 to 2	39
Glen Mar Apartments	1127 Foothill Blvd.	18	2	36
Alta Vista Woods	355-385 N. Chorro	18	2	36
San Luis Village	204 California Blvd.	23	1 to 2	35
Casa Bonita	28-38 Casa Street	12	1 to 2	14
Fairview Apartments	1629 Johnson	22	1 to 2	33
Garfield Arms	738 Grand Ave.	61	1 to 2	91.5
Irish Hills Apartments	11343 Los Osos Valley	146	1 to 3	292
Kris Kai Townhomes	607 Grand Ave.	20	2	40
Sheri Apartments	721 Johnson	122	1	122
Madonna Rd. Apartments	1550 Madonna Rd.	120	1 to 4	300
Total of Apts (included in off campus housing)		2,203		4,489

Once identified, the dedicated student housing units are added to the land use database as a separate residential “student housing” category. Instead of using the number of housing units, the number of beds is included in the database to avoid applying a household size parameter to student housing. When the model is run, the home end of the home-based university trips will be allocated to these zones first before being allocated to the rest of the region. Note that student housing is assumed to be fully occupied.

Finally, the students who do not reside in dorms or dedicated off-campus housing are allocated to the general housing supply in the region based on the distance from the university. Since students are more likely to reside in multi-family units, these are assigned a higher weight than the single family units during the allocation process. Prior to the allocation process, housing that cannot be occupied by students including retirement homes and mobile homes is removed from the available supply. This is accomplished by splitting the multi-family units in the land use database into multi-family 1, which includes all multi-family households, and multi-family 2, which cannot be used by students. Multi-family 2 is a subset of the total multi-family households included in multi-family 1.

In the model, the students not residing in the dedicated on-campus or off-campus student housing are allocated to zones based on their proximity to campus and availability of single-family and multi-family units. Once the allocation is complete, the total number of student households as a share of total households has been compared to the percent of rentals for the area where the household is located. This check ensures that a reasonable number of students are assigned to zones neighboring the Cal Poly campus. The resulting university production allocation is shown in Figure 4.2.

Figure 4.2. University Production Allocation



4.6 External Trips

The SLO Citywide Travel Model covers all of San Luis Obispo County, but does not extend beyond the County's boundary. Therefore, the model must include all trips that traverse the County or have at least one end in the County. Trips with at least one end outside of the County are called external trips. The model includes external trips as follows:

- External-External (EE) Trips – These are through trips that start and end outside of the county modeling domain. In processing data, EE trips can also include short convenience stops within the county since these stops are not true destinations and do not reflect the true purpose of the trip. EE trips are applied in the travel model as a balanced input table of trips between external stations.
- Internal-External (IE) and External-Internal (EI) Trips – These trips have one end within the modeling domain and the other outside of it. For the purposes of the SLO Citywide Travel Model, these trips are referred to as IE trips.

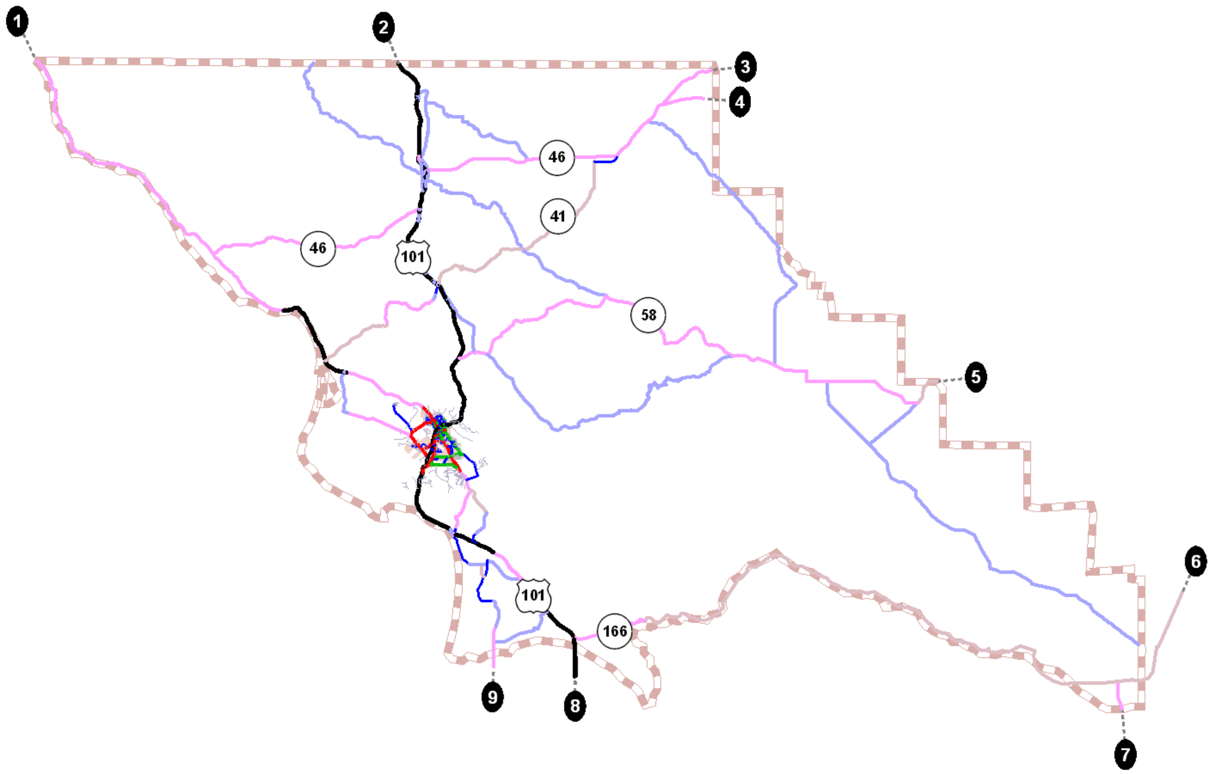
External travel is applied at the boundary of the model using the external stations shown in Figure 4.3. These are nodes that receive special processing for external travel. Traffic counts collected at each external station provide some of the necessary data for estimating external travel. Traffic counts do not indicate origin or destination, trip purpose, split of through trips, or much extra information other than total vehicles, time of day, and possibly vehicle classification.

Household travel diary surveys provide detailed information about Internal-Internal (II) trips and some information about IE/EI trips, but only those that are generated (produced) by households within the surveyed area. The CHTS provides some limited information about external travel and was used to develop a methodology for handling of IE and EE trips for the SLOCOG model.

External travel studies and surveys are relatively expensive and not as common as other surveys such as household travel diary surveys. External travel cordon studies can utilize noninvasive techniques such as matching license plates at external stations using camera and radar technology combined with special software that interprets the license plate data. These studies are particularly useful for obtaining EE split and orientation data. They do not, however, provide any detailed information about the trip purpose.

External travel surveys, on the other hand, can provide a significant amount of trip-specific data by including some sort of interaction with the driver through roadside pullover interviews, postcard surveys based on license plate address data, or other means. These tend to be relatively expensive and generally do not attain high participation rates from the traveling public.

Figure 4.3. External Station Locations



4.6.1 Internal/External Trip Methodology

The SLO Citywide Travel Model includes internal/external and external/internal trips as a single trip purpose, referred to in the model as IE trips. IE Trip attractions are defined as the internal trip end, with IE productions defined as the external trip end. This allows IE trips to be balanced to trip productions, which occur at external stations and are based on traffic count data.

IE Attractions and are generated for each internal TAZ using attraction rates. The IE attraction rates were adapted from rates used by the SLOCOG model, which are in turn based on data from the CHTS. The SLOCOG model uses different IE trip rates for different parts of the county. These rates have been simplified to two sets of rates for use in the SLO Citywide Travel Model: one set for zones within the SOI and another for zones outside of the SOI. IE attraction rates are shown in Table 4.17.

Table 4.17. IE Trip Attraction Rates

General Category	ID	Detailed Category	Units	IE Attraction Rate (SOI)*	IE Attraction Rate (non-SOI)**
Residential	11	Single Family Household	DU	0.075	0.313
	12	Multi Family Household	DU	0.050	0.286
Office	20	General Office	KSF	0	0
Service	31	Religious Organizations and Meeting Halls	KSF	0	0
	32	General Service	KSF	0	0
	33	Hospitals	KSF	0	0.001
	34	Airport		0	0
Lodging	41	Motels and Hotels	Rooms	0.155	0.334
	42	Beach Resorts	Acres	4.695	4.320
Retail	51	Drive In Retail	KSF	0	0
	52	High Generation Retail	KSF	0.014	0.041
	53	Medium Generation Retail	KSF	0	0.003
	54	Low Generation Retail	KSF	0	0.001
Schools	61	Elementary Schools	Students	0.022	0.057
	62	High Schools	Students	0.029	0.075
	63	CalPoly Students	Students	0	0
	64	CalPoly Employees	Jobs	0	0
	65	Cuesta College Students	Students	0	0
	66	Cuesta College Employees	Jobs	0	0
Industry	71	Heavy Industrial	KSF	0	0
	72	Light Industrial	KSF	0	0
Other	81	Parks & Recreation	Acres	0.001	0.003
	82	Agricultural	Acres	0	0
	83	Undeveloped	Acres	0	0

** Total IX+XI production and attraction rates from the SLOCOG model for Area Type 1: the City of San Luis Obispo and nearest suburbs.*

*** Average total IX+XI production and attraction rates for Area Type 2 through 5.*

IE productions are defined in the SLO Citywide Travel Model at the external stations. The number of IE productions occurring at each external station is based on the two data sources described below.

- <u>The total vehicle trips at the external station:</u> Total vehicle trips for 2016 at external stations were borrowed from the SLOCOG Model. Volumes implied by the external station data are available for the year 2015.

- <u>The assumed percentage of EE trips at each external station:</u> The SLOCOG model assumes a consistent split between IE and EE trips at each external station for 2015. These assumptions were used directly.

External station data for the SLO Citywide Travel Model is summarized in Table 4.18.

Table 4.18. Base Year External Station Data

External Station		Volume	% IE	% EE	IE Volume	EE Volume
ID	Name					
1	California 1 North	2,692	73%	27%	1,953	738
2	US 101 North	23,346	86%	14%	20,148	3,198
3	California 41	7,630	95%	5%	7,247	383
4	California 46	7,070	83%	17%	5,889	1,181
5	Carrisa Hwy	134	100%	0%	134	0
6	Maricopa Hwy East	5,205	9%	91%	490	4,715
7	Maricopa Hwy South	1,647	0%	100%	5	1,642
8	US 101 South	66,822	91%	9%	60,745	6,077
9	California 1 South	8,912	99%	1%	8,819	93

4.6.2 External/External Trip Methodology

External-External trips (EE trips) are input to the SLO Citywide Travel Model directly as a vehicle trip table. The through trip table is based on the through trip table used by the SLOCOG model for 2015. The resulting 2016 EE trip table is presented as Table 4.19.

Table 4.19. Base Year (2016) 24-hour EE Vehicle Trip Table

External Station ID	1	2	3	4	5	6	7	8	9	Total
1	0	0	13	337	0	0	0	18	1	**370**
2	0	0	0	253	0	0	0	1,308	64	**1,625**
3	13	0	0	0	0	0	0	164	28	**206**
4	337	253	0	0	0	0	0	0	0	**590**
5	0	0	0	0	0	0	0	0	0	**0**
6	0	0	0	0	0	0	817	1,539	0	**2,356**
7	0	0	0	0	0	820	0	3	0	**823**
8	18	1,320	164	0	0	1,539	3	0	0	**3,044**
9	0	0	0	0	0	0	0	0	0	**0**
Total	**369**	**1,573**	**178**	**591**	**0**	**2,359**	**819**	**3,033**	**93**	**9,014**

4.6.3 Forecast External Trips

External trip data for the forecast year was available from the SLOCOG model. Resulting IE/ and EE assumptions are shown in Table 4.20 and Table 4.21.

Table 4.20. Forecast Year External Station Data

External Station		Volume	% IE	% EE	IE Volume	EE Volume
ID	Name					
1	California 1 North	4,155	82%	18%	3,417	738
2	US 101 North	32,932	90%	10%	29,733	3,198
3	California 41	10,482	96%	4%	10,099	383
4	California 46	10,873	89%	11%	9,692	1,181
5	Carrisa Hwy	148	100%	0%	148	0
6	Maricopa Hwy East	5,244	10%	90%	529	4,715
7	Maricopa Hwy South	1,656	1%	99%	14	1,642
8	US 101 South	88,458	93%	7%	82,380	6,077
9	California 1 South	10,616	99%	1%	10,523	93

Table 4.21. Future Year (2040) 24-hour EE Vehicle Trip Table

External Station ID	1	2	3	4	5	6	7	8	9	Total
1	0	0	18	527	0	0	0	21	1	**567**
2	0	0	0	395	0	0	0	1,557	74	**2,027**
3	18	0	0	0	0	0	0	217	37	**272**
4	527	395	0	0	0	0	0	0	0	**922**
5	0	0	0	0	0	0	0	0	0	**0**
6	0	0	0	0	0	0	855	1,832	0	**2,687**
7	0	0	0	0	0	859	0	3	0	**862**
8	22	1,571	217	0	0	1,832	3	0	0	**3,645**
9	0	0	0	0	0	0	0	0	0	**0**
Total	**566**	**1,966**	**235**	**922**	**0**	**2,690**	**859**	**3,631**	**112**	**10,981**

4.7 Trip Balancing

Trip productions and attractions are estimated separately by purpose using the trip rates and allocation models previously described. While an attempt is made to make the initial estimate of productions equal to the initial estimate of attractions, it is not feasible to make them exactly equal in all scenarios, which is necessary to ensure conservation of trips in the model. The balancing process provides this conservation by making the productions and attractions equal.

Balancing depends on the level of confidence associated with the initial estimate of productions and attractions. Since household survey data was available to estimate trip production rates, the home-based trip purposes are balanced to trip productions. One exception to this is the HBU trip purpose. The special generator studies and cordon counts upon which the CalPoly estimates are based provided an increase of reliability for HBU trip attractions to the university campus, so HBU productions are balanced to attractions.

Non-Home-Based trips (WBO and OBO) are also balanced to productions. These trips are balanced to the initial estimate of productions from the basic trip rates in the cross-classified trip production model. Then, the productions are re-allocated using the allocation models previously discussed.

5.0 Trip Distribution

This chapter describes the process used to update the Trip Distribution model for the SLO Citywide Travel Model. Highway skim parameters and gravity model parameters are defined herein.

5.1 Context and Background

Trip distribution is the second phase of the traditional 4-step travel demand model. Trip distribution is the process through which balanced person trip productions and attractions from the trip generation model are apportioned among all zone pairs in the modeling domain by trip purpose. The resulting trip table matrix contains both intrazonal (e.g., trips that don't leave the zone) on the diagonal and interzonal trips in all other zone interchange cells for each trip purpose.

The SLO Citywide Travel Model uses a standard gravity model equation and applies friction factors to represent the effects of impedance between zones. As the impedance (e.g., travel time, spatial separation) between zones increases, the number of trips between them will decrease as represented by a decreasing friction factor. This is similar to the standard gravity model which assumes that the gravitational attraction between two bodies decreases as they become further apart. The gravity model also assumes that the gravitational attraction between the two bodies is directly proportional to their masses. The trip distribution model makes a similar assumption in that the number of trips between two zones is directly proportional to the number of productions and attractions contained in those zones. The gravity model used by trip distribution to estimate the number of trips between each zone pair is defined in below.

$$T_{ij} = \mathrm{P_i} \cdot \frac{\left(A_j \cdot F_{ij} \cdot K_{ij}\right)}{\sum_{j=1}^{n} A_j \cdot F_{ij} \cdot K_{ij}}$$

Where:

Tij	=	trips from zone i to zone j
Pi	=	productions in zone i
Aj	=	attractions in zone j
Kij	=	K-factor adjustment from i to zone j
i	=	production zone
j	=	attraction zone
n	=	total number of zones
Fij	=	friction factor (a function of impedance between zones i and j)

K-factors are often used in travel demand models to account for nuances in travel behavior and the transportation system that cannot be accurately modeled with simplified aggregate modeling techniques. They are often applied at the district or jurisdictional level to adjust regional distribution patterns. They may be applied by trip purpose or for all trips. In the SLO Citywide Travel Model, K-factors are used to correct for aggregation bias outside of the SOI and to account for the attractiveness of the SLO Central Business District (CBD).

Friction factors represent the impedance to travel between each zone pair. Friction factors have been calibrated for each trip purpose based on observed trip length (time) frequency distributions and average travel times implied therein. Friction factors were calibrated using data from the 2012 California Statewide

Household Travel Survey (CHTS) for San Luis Obispo County and the City of San Luis Obispo Sphere of Influence (SOI).

5.2 Peak and Off-Peak Period Definitions

Trips occurring during the AM and PM peak periods are distributed based on peak congested speeds and trips occurring during off-peak times are distributed based on off-peak congested speeds. Trip distribution is performed in Production-Attraction (PA) format rather than Origin-Destination (OD) format. This is because the majority of trips in the AM peak period travel from production to attraction (e.g., to work) and the majority of trips in the PM peak period travel from attraction to production (e.g., from work). The model uses directional AM peak period speeds to compute impedance for both AM and PM peak period trips in PA format.

Due to limited survey data, trips from the survey were not separated into peak and off-peak time periods for the calibration exercise.

5.3 Roadway Network Shortest Path

The impedance portion of the gravity model equation is based on shortest paths between each zone pair. Each shortest path is determined through a process called pathbuilding. This process identifies the shortest route between two network centroids that minimizes an impedance variable. Shortest paths cannot pass through other centroid connectors. Various data, such as path distance, can be “skimmed” along the shortest impedance route. The set of all zone to zone shortest paths is called a “shortest path matrix” and is sometimes referred to as a “skim matrix” with the understanding that the skimmed variable may differ from the variable(s) used to determine the shortest path. This section describes the process used to generate shortest path matrices for use in trip distribution.

The shortest path process is performed for the highway and transit networks. This section focuses on the roadway network shortest path process. Discussion of transit shortest paths is included in the mode choice chapter.

5.3.1 Terminal Penalties

Terminal penalties are applied in the model to the shortest paths. They simulate several travel-related variables, such as the time to locate a parking space, walking to a final destination, paying for a parking space, etc. Terminal penalties, shown in Table 5.1, are added to both the production and attraction end of each zone pair based on the area type of each zone.

Table 5.1. Terminal Penalties by Area Type

Area Type		Terminal Time
1	CBD	1.5
2	Fringe	1
3	Urban	1
4	Suburban	0.75
5	Rural	0.50
6	Non-SOI	0.50

5.4 Intrazonal Impedance

Impedance, or travel time, for trips within a zone (intrazonal impedance) is not generated in the zone to zone pathbuilding process because the roadway network is not detailed enough for a sub-TAZ level analysis. Instead, the nearest neighbor rule is used to estimate intrazonal impedance. The nearest neighbor rule is applied by taking an average of one or more nearby TAZs and multiplying that average by a factor. Intrazonal travel time has been calculated by multiplying the travel time to the single nearest neighbor by 75% for zones within the SOI and by 70% for zones outside of the SOI.

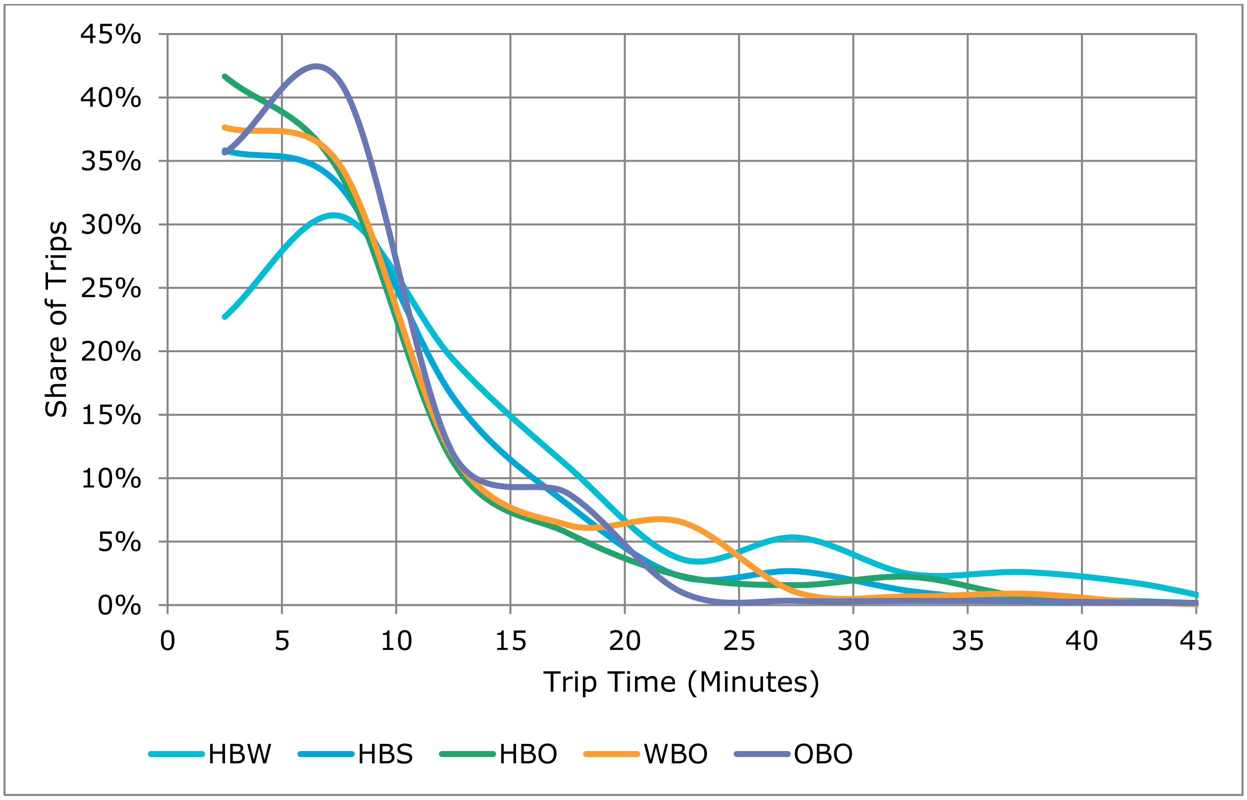
5.5 Friction Factor Calibration

Friction factors were calibrated based on trip time distributions derived from CHTS data, using speed-based shortest path matrices. While travel time information was available directly from the survey data, the gravity model relies on network-based shortest paths. For consistency, calibration targets were created using the same travel time data as the model.

5.5.1 Calibration Targets

Trip time distribution curves for each trip type have been generated using CHTS data. Shortest path matrices used to develop these curves are based on freeflow speed and include both intrazonal travel time and terminal penalties. The resulting countywide trip time distribution curves are shown in Figure 5.1.

Figure 5.1. Countywide Trip Time Distribution Curves by Trip Purpose



5.5.2 Income Processing

In the SLO Citywide Travel Model, HBW trips are segmented into three income groups. Initially, HBW trip distribution was calibrated for all income groups combined. Then, an attempt was made to develop separate friction factors for each HBW income group. For the low and medium income groups, slight modifications were made. However, there was not sufficient survey data to modify the high income HBW friction factors.

5.5.3 Calibration Process

The trip distribution model was calibrated by applying the gravity model using results of the trip generation model. Friction factors based on the gamma function, defined in the equation below, were calibrated for each trip type. The gravity model was applied using an initial set of gamma function parameters followed by iterative adjustment of parameters. Iteration continued until no further improvement in replication of the calibration target could be achieved through friction factor adjustments. Terminal penalties and intrazonal travel times were included in the shortest path matrices for both the calibration targets and modeled trip time distribution.

$$f(d_{ij}) = a \cdot d_{ij}^{-b} \cdot e^{-c \cdot d_{ij}}$$

Where:

$f(d_{ij})$ = Friction factor for zone pair i,j

D_{ij} = Impedance (i.e., travel time) between zones i and j

a, b, c = Calibration parameters

In addition to friction factor adjustments, other model variables and parameters including terminal penalties, intrazonal travel times, volume/delay equations, and K-factors can affect calibration of trip length distribution curves.

For each iteration of the calibration process, parameters were adjusted in one of two ways:

1. For initial iterations, the equation below was used to predict friction factor values at 1 minute increments. Gamma parameters were then adjusted to fit a curve to the predicted friction factors. Equation (3) compares the trip length distribution that results from application of a set of friction factors to the calibration target and predicts new friction factor values that are more likely to replicate the calibration target.

$$F_i^r = F_{i-1}^r \left(\frac{SurveyTrips^r}{ModelTrips_{i-1}^r} \right)$$

Where:

F_i^r = Predicted friction factor value for impedance range r and iteration i

F_{i-1}^r = Gamma function based friction factor value for impedance range r and iteration i-1

$SurveyTrips^r$ = The percentage of surveyed trips in impedance range r

$ModelTrips_{i-1}^r$ = The percentage of trips in impedance range r resulting from application of iteration i-1 of the gravity model

2. Once application of the calibration equation stopped producing improvements, the gamma parameters were manually adjusted for each iteration.

Trip length and trip distributions for the county as a whole, for trips within the SOI, and to/from the SOI were monitored during the calibration process. Because the focus of the model is the SOI, increased error in the countywide distribution was accepted in order to improve trip distribution within the SOI.

5.5.4 Calibration Results

A measure that can be used to quantify the relationship between the observed and modeled trip length distribution curves is the coincidence ratio. The coincidence ratio is a number between zero and one that specifies the area under both the calibration target and model result trip length distribution curve. Coincidence ratios for each trip type and period are shown in Table 5.2. Ratios closer to 1.0 indicate a better calibration. Average trip times by purpose and intrazonal trip percentages by purpose are also shown in Table 5.2.

Table 5.2. Coincidence Ratios for Calibrated Trip Time Distribution Curves

Trip Purpose	Average Trip Length		Coincidence Ratio
	Observed	Modeled	
HBW	12.34	12.4	54%
HBS	9.02	8.61	49%
HBO	8.39	8.9	54%
WBO	8.99	9.27	36%
OBO	7.92	8.45	59%

Resulting trip time distribution curves for each trip type are shown in Figure 5.2 through Figure 5.6. Friction factors by trip type are shown in Figure 5.7 and documented in Table 5.3.

Figure 5.2. HBW Trip Time Distribution Curve (Countywide)

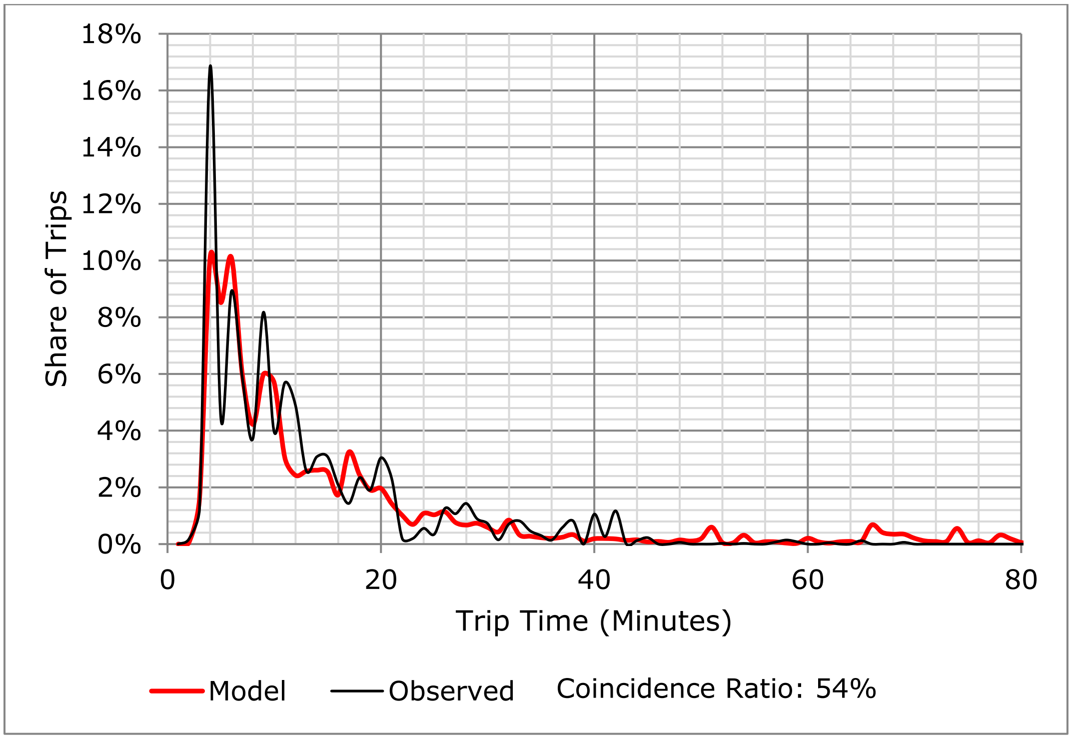


Figure 5.3. HBS Trip Time Distribution Curve (Countywide)

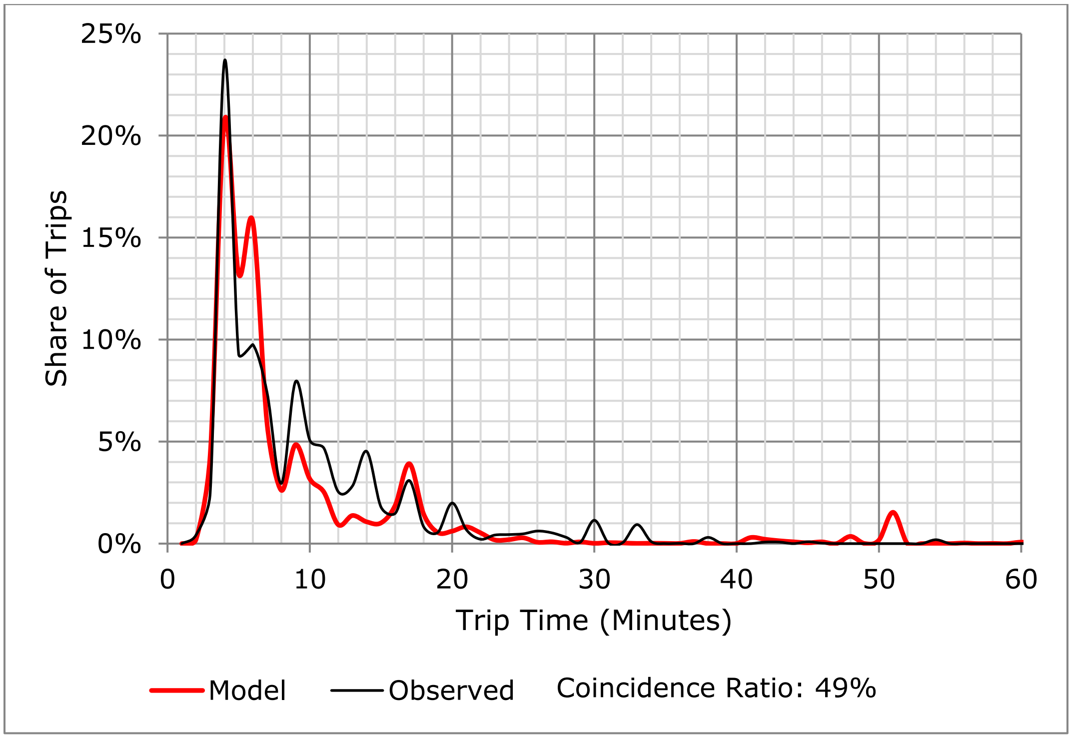


Figure 5.4. HBO Trip Time Distribution Curve (Countywide)

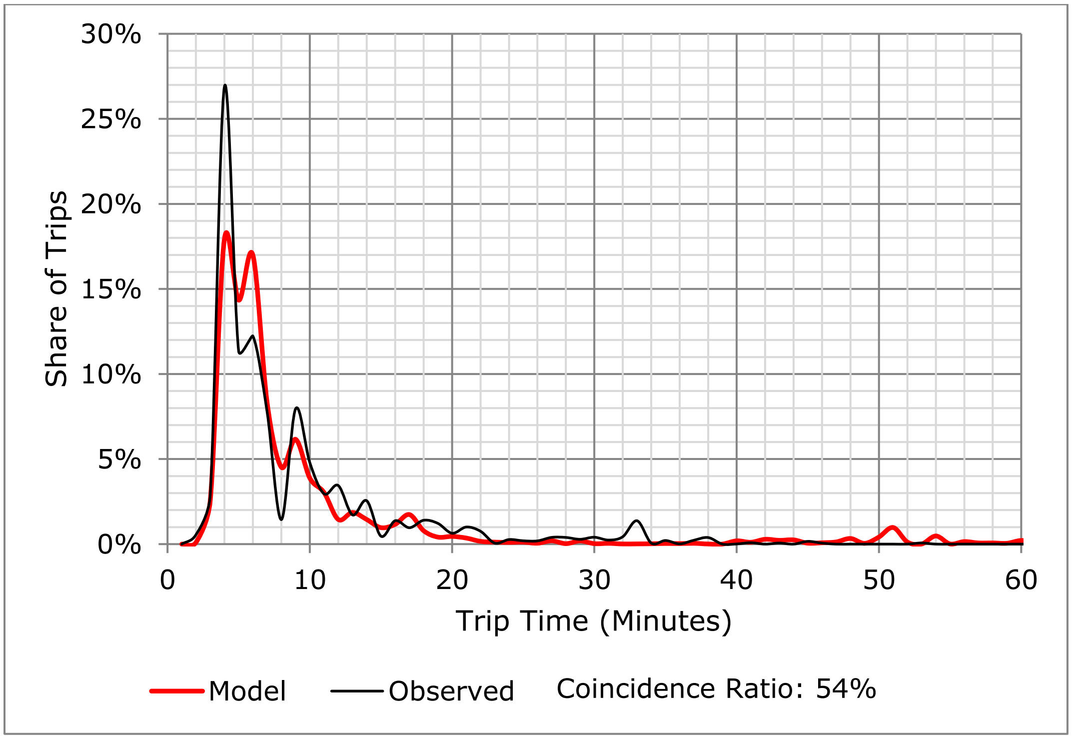


Figure 5.5. WBO Trip Time Distribution Curve (Countywide)

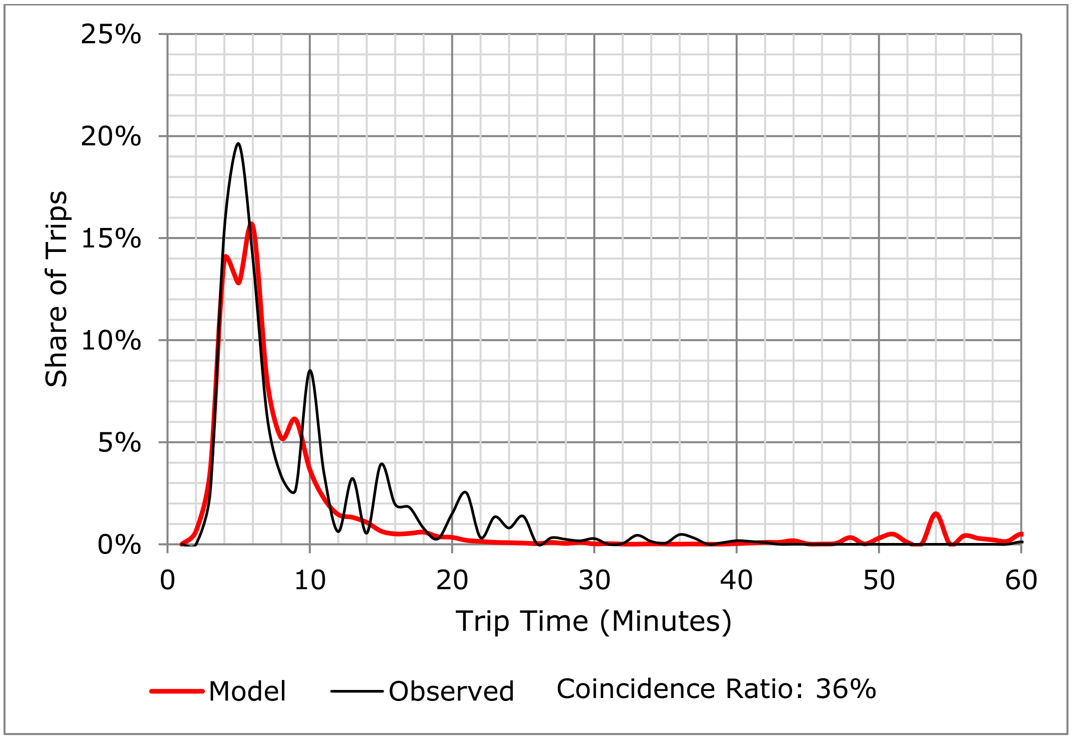


Figure 5.6. OBO Trip Time Distribution Curve (Countywide)

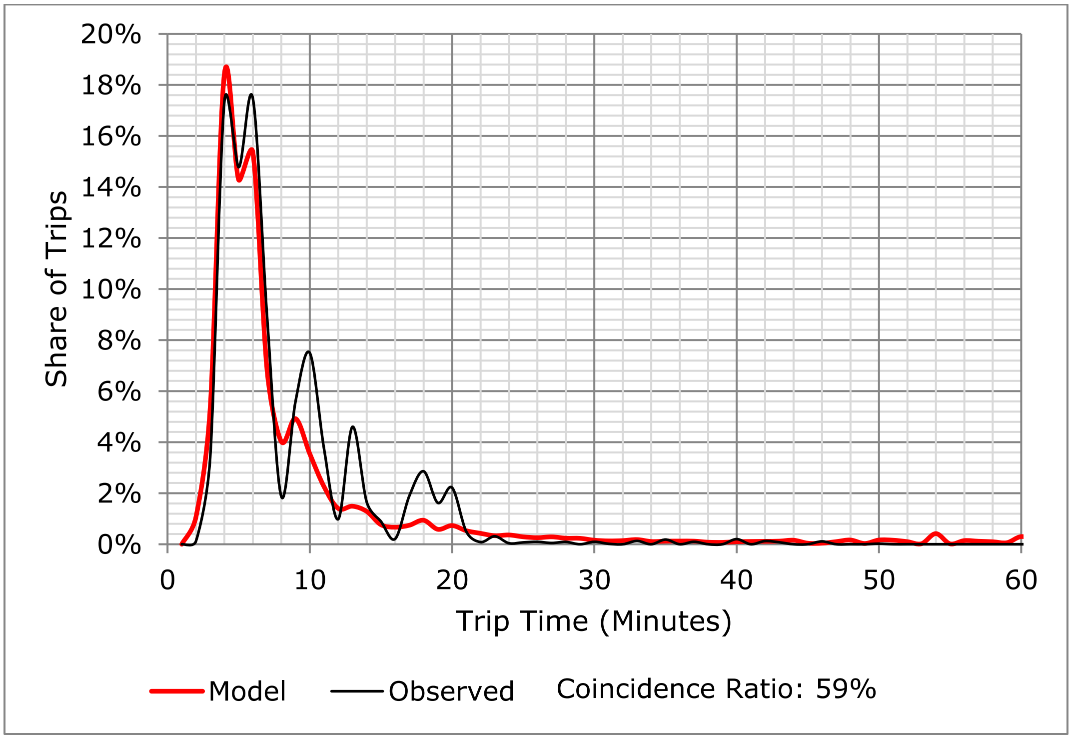


Table 5.3. Friction Factors for All Purposes

	HBW HI	HBW MI	HBW LI	HBS	HBU	HBO	WBO	OBO
A	100	100	100	100	100	100	100	100
B	1.1	0.9	0.7	1.2	1	0.5	0.8	2.37
C	0.2	0.15	0.05	0.9	0.1	0.38	0.22	0.03

Note: HBU friction factors are placeholders, as these trips are distributed using a production allocation model.

5.6 K Factors

While it is generally desirable to calibrate and validate travel models without the use of K-factors, it was determined that K factors were necessary to produce reasonable base year model results. The K-factors in the SLO Citywide Travel Model are used to account for the following issues:

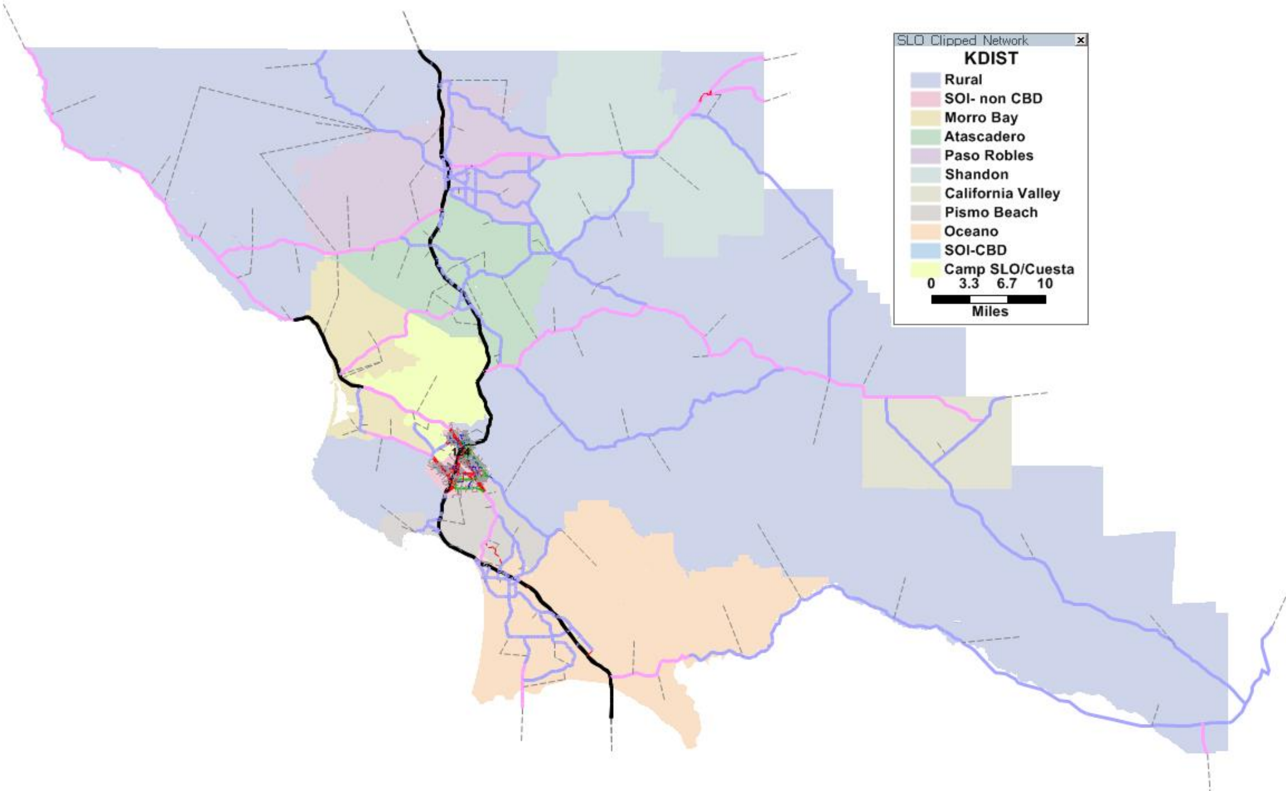
- CBD Activity: The SLO CBD acts as a regional destination, attracting longer trips than the remainder of the City of SLO.
- Aggregation Bias: Aggregation of TAZs outside of the SOI generally reduces the likelihood that trips will remain within these aggregated communities. K-factors were used to better represent the amount of travel remaining within these communities.

During the model validation process, the K-factor values shown in Table 5.4 were implemented. K-districts are defined as shown in Figure 5.7.

Table 5.4. K Factors

District		1	2	3	4	5	6	7	8	9	10	11	97	98	99
1	Rural / External	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	SOI - Non-CBD	1	2	1	1	1	1	1	1	1	2	2	1	1	1
3	Morro Bay	1	1	3	3	3	3	1	0.5	0.5	1	1	1	1	1
4	Atascadero	1	1	3	3	3	3	1	0.5	0.5	1	1	1	1	1
5	Paso Robles	1	1	3	3	3	3	1	0.5	0.5	1	1	1	1	1
6	Shandon	1	1	3	3	3	3	1	0.5	0.5	1	1	1	1	1
7	California Valley	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	Pismo Beach	1	1	0.5	0.5	0.5	0.5	1	3	3	1	1	1	1	1
9	Oceano	1	1	0.5	0.5	0.5	0.5	1	3	3	1	1	1	1	1
10	SOI - CBD	1	2	1	1	1	1	1	1	1	2	2	1	1	1
11	Camp SLO/ Cuesta	1	2	1	1	1	1	1	1	1	2	2	1	1	1
97	Hwy 101 North External	1	1	1	1	1	1	1	1	1	1	1	1	1	1
98	Hwy 101 South External	1	1	1	1	1	1	1	1	1	1	1	1	1	1
99	Other External	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 5.7. K Districts



6.0 Mode Choice

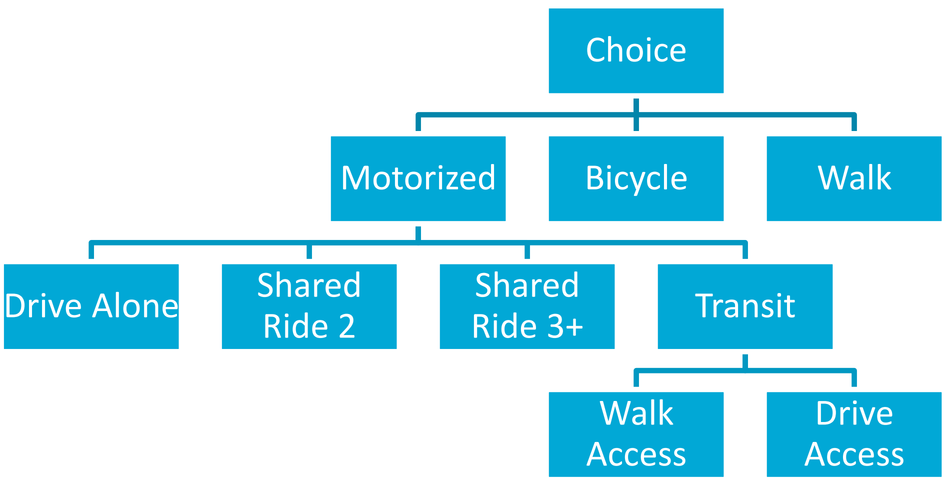
6.1 Background

The mode choice model is the third step in the 4-step travel demand model. Mode choice separates the person trip tables resulting from trip distribution into the various non-motorized, transit, and auto modes. The process results in the personal vehicle trips, transit trips, and bicycle trips that are used in the assignment step. The SLO Citywide Travel Model includes a number of different travel modes. Trips using personal vehicles are subdivided by vehicle occupancy. Non-motorized trips are split into walking and biking. Mode choice is determined using a nested logit model that uses information from roadway, transit, and bicycle networks.

6.2 Mode Choice Model Structure

The SLO Citywide Travel Model uses a nested-logit model for all trip purposes as shown in Figure 6.1.

Figure 6.1. San Luis Obispo Mode Choice Model Nesting Structure



Nested-logit mode choice models define the state-of-the-practice for regions employing detailed transit processing and mode choice. The multinomial logit model is defined as:

$$P_i = \frac{e^{u_i}}{\sum_j e^{u_i}}$$

Where:

P_i = probability of selecting mode i

u_i = a linear function describing the utility of mode i

In a nested-logit model, the utilities of modes in lower level nests are included in higher level nests through logsum variables, where the logsum is defined as:

$$Logsum = \ln\left(\sum_i e^{U_i}\right)$$

Logsums are multiplied by a logsum coefficient in the range 0.0 to 1.0 when they are added into the appropriate utilities for the next higher level nest.

6.3 Mode Choice Model Coefficients

The SLO Citywide Travel Model uses an asserted model as opposed to a model estimated using maximum likelihood estimation techniques. The specification of mode choice model coefficients is based, in part, on guidelines recommended by the Federal Transit Administration (FTA) for Section 5309 New Starts Applications. Table 6.1 shows the FTA guidelines for in-vehicle travel time coefficients, out-of-vehicle travel time coefficients, and cost coefficients. Table 6.1 shows the coefficients at the "motorized level" of the nesting structure. In the mode choice model structure for the City of San Luis Obispo shown in Figure 6.1, the motorized level is where choices are made among the auto driver-drive alone, auto driver-shared ride 2, auto driver-shared ride 3+, and transit modes. In addition to the FTA guidelines, coefficients for the mode choice models are also based on other models employed in California.

Table 6.1. FTA Mode Choice Model Coefficient Guidelines

	FTA Guidelines[1]	
	Low Value	High Value
Coefficient		
In-vehicle travel time	-0.03	-0.02
Initial wait	-0.09	-0.04
Second wait	-0.09	-0.04
Walk time	-0.09	-0.04
Cost[2]	–	–
Equivalent Minutes of IVTT		
Initial wait	2.00	3.00
Second wait	2.00	3.00
Walk time	2.00	3.00
Home-Based Work Value of Time (Estimated Median Household Income)		
Low Income ($20,000)	$2.30	$3.10
Middle Income ($55,000)	$6.60	$8.70
High Income ($140,000)	$16.80	$22.40

[1] *Information from PowerPoint Presentation by FTA at TRB 83rd Annual Meeting, Session 501, January 13, 2004.*

[2] *Value of Time is determined as Coefficient of In-Vehicle Travel Time/Coefficient of Cost. Actual guidelines are: (average income)/4 < Civt/Ccost < (average income)/3.*

Table 6.2 shows the model coefficients for the SLO Citywide Travel Model mode choice models.

Table 6.2. Mode Choice Model Coefficients

Coefficient	Apply to Modes	Home-Based Work	Home-Based Shop	Home-Based University	Home-Based Other	Work-Based Other	Other-Based Other
In-Vehicle Time (Minutes)	Motorized	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025
Terminal Time (Minutes)	Auto	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025
Walk Time (Minutes)	Transit	-0.050	-0.075	-0.050	-0.075	-0.050	-0.075
First Wait ≤ 7.5 Minutes	Transit	-0.050	-0.075	-0.050	-0.075	-0.050	-0.075
First Wait > 7.5 Minutes	Transit	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025
Transfer Wait (Minutes)	Transit	-0.050	-0.075	-0.050	-0.075	-0.050	-0.075
Number of Transfers	Transit	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875
Cost (Cents)							
All Households	Motorized		-0.00508	-0.00254	-0.00508	-0.00254	-0.00508
Low Income Household	Motorized	-0.00556					
Middle Income Household	Motorized	-0.00195					
High Income Household	Motorized	-0.00077					
Walk Time	Walk	-0.05	-0.075	-0.05	-0.075	-0.05	-0.075
Ride Time	Bicycle	-0.05	-0.075	-0.05	-0.075	-0.05	-0.075
Cal Poly Destination (0/1)							
Transit	Transit	0.06	0.009	0.060	0.009	0.009	0.009
Walk	Walk	0.009	0.009	0.300	0.009	0.009	0.009
Bicycle	Bicycle	0.009	0.009	0.500	0.009	0.009	0.009
CBD Destination (0/1)							
Transit	Transit	0.009	0.009	0.009	0.009	0.009	0.009
Walk	Walk	0.009	0.009	0.009	0.009	0.009	0.009
Bicycle	Bicycle	0.009	0.009	0.009	0.009	0.009	0.009
Nesting Coefficients[1]							
Top Level		0.9	0.9	0.9	0.9	0.9	0.9
Bottom Level		0.7	0.7	0.7	0.7	0.7	0.7
OVTT/IVTT Ratio		2.0	3.0	2.0	3.0	2.0	3.0
Value of Time ($/Hr)							
All Households			$2.95	$5.90	$2.95	$5.90	$2.95
Low Income Household		$2.70					
Middle Income Household		$7.70					
High Income Household		$19.60					

[1] All model coefficients are specified at the "motorized" choice level. If utilities for walk and bicycle modes are calculated at the top level, the appropriate coefficients should be multiplied by the top level nesting coefficient. If walk to transit and drive to transit utilities are calculated at the lowest level of the nesting structure, the appropriate coefficients should be divided by the bottom level nesting coefficient.

6.4 Mode Choice Model Calibration Targets

6.4.1 Target Trips and Shares by Mode and Purpose

Table 6.3 shows the modal shares for San Luis Obispo County based on the 2012 California Statewide Household Travel Survey. These mode shares were used to create modal targets and perform the initial calibration of the mode choice model. However, once the bicycle trips based on the mode choice model output were assigned (as discussed in Chapter 8) and compared to the observed bike counts, a need to reduce the bicycle targets became apparent. The initial bike assignment overestimated the observed bike volumes by more than a factor of 2. The bicycle mode share targets were reduced to those shown in Table 6.4.

Table 6.3. Initial Calibration Target Trips by Mode and Purpose for City of San Luis Obispo Travel Model

Mode	Home-Based Work			Home-Based Shop	Home-Based University	Home-Based Other	Work-Based Other	Other-Based Other
	Low Income	Middle Income	High Income					
Drive Alone	74.1%	85.8%	90.6%	48.7%	64.0%	37.4%	83.2%	35.7%
Shared Ride 2	19.0%	7.6%	2.7%	32.3%	19.6%	33.9%	7.1%	31.6%
Shared Ride 3	3.1%	2.8%	2.9%	14.4%	3.1%	16.2%	4.7%	24.9%
Bus	337	211	127	127	2,573	633	42	506
Walk	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bicycle	3.2%	3.2%	3.2%	4.3%	5.3%	11.7%	4.9%	7.6%
Total	0.6%	0.6%	0.6%	0.3%	8.0%	0.8%	0.2%	0.3%

Table 6.4. Revised Calibration Target Trips

Mode	Home-Based Work			Home-Based Shop	Home-Based University	Home-Based Other	Work-Based Other	Other-Based Other
	Low Income	Middle Income	High Income					
Drive Alone	73.1%	86.2%	91.9%	48.7%	64.0%	37.3%	83.1%	35.7%
Shared Ride 2	19.0%	7.6%	2.7%	32.3%	19.6%	34.0%	7.1%	31.6%
Shared Ride 3	3.1%	2.8%	2.9%	14.4%	3.1%	16.2%	4.7%	24.9%
Bus	337	211	127	127	2,573	635	42	506
Walk	4.0%	2.9%	2.0%	4.3%	5.3%	11.7%	4.9%	7.6%
Bicycle	0.7%	0.5%	0.5%	0.3%	8.0%	0.8%	0.2%	0.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.4.2 Transit Trips

While targets for most trip purposes were developed based on the 2012 CHTS, due to the small sample of transit trips in the statewide travel survey, transit targets could not be developed using this data source.

Instead the 2007 transit survey updated to 2016 boardings was used.[5] Responses were received from 776 passengers out of 5,451 surveys distributed with about three-quarters (71%) of the survey responses received from students at Cal Poly. Trips by purpose were summarized from the on-board survey data. Trip purposes were based on the reported purpose for the trip and whether the trip originated or ended at "home." Since home-based work trips will be stratified by income group in the mode choice model, estimates of home-based work trips by income are also required. Income information was reported for 47 of the 58 home-based work trips surveyed. Twenty-eight (60%) of the home-based work travelers reported incomes less than $35,000 per year and 19 (40%) reported incomes of $35,000 or more. The maximum income range included in the survey was $75,000 or more while starting income for the high income group used for the travel model is $100,000. Home-based university trips include only those trips made to or from Cal Poly or Cuesta College. Home-based school trips to middle and high schools were aggregated into home-based other trips. Table 6.5 summarizes the shares by trip purpose shown in the on-board survey documentation.

Table 6.5. Estimated Shares of Transit Trips by Trip Purpose from 2007 SLO Transit On-board Survey

Trip Purpose	Share	Estimated Linked Trips
Home-Based Work	8%	368
Low Income (less than $35,000)	5%	230
Middle Income ($35,000 - $99,999) High Income ($100,000 or more)	3%	138
Home-Based Shop	3%	138
Home-Based University	61%	2,806
Home-Based Other	15%	690
Work-Based Other	1%	46
Other-Based Other	12%	552
Total	100%	4,600

In addition to the survey data, the most recent bus boardings were used to update the 2007 survey data to 2016. Table 6.6 summarizes the boardings by route by time of day from the 2016 boarding and alighting count data.

5 *Technical Memorandum #4, On-Board Survey Results*, Short Range Transit Plan Update, Prepared for City of San Luis Obispo, California, prepared by Urbitran Associates, Inc., February 2008.

Table 6.6. SLO Transit Boarding Counts

Route	Total Daily Boardings
1	189
2	384
3	371
4	1,123
5	1,173
6a	945
6b	663
Total	4,848

The resulting transit targets by trip purpose are shown in Table 6.7. To match modeled transit trips close to observed data, actual observed transit trips were used instead of transit shares during model calibration.

Table 6.7. Transit Targets (2016)

Trip Purpose	Share	Estimated Linked Trips
Home-Based Work	8%	337
Low Income (less than $35,000)	5%	211
Middle Income ($35,000 - $99,999) High Income ($100,000 or more)	3%	127
Home-Based Shop	3%	127
Home-Based University	61%	2,573
Home-Based Other	15%	633
Work-Based Other	1%	42
Other-Based Other	12%	506
Total	**100%**	**4,218**

7.0 Time of Day

In the time of day model component, the vehicle trip tables by trip purpose from the mode split process are converted from production-attraction (PA) format into origin-destination (OD) format and factored into time periods for assignment on the roadway network. The time of day process is not considered a separate step in the 4-step transportation modeling process, but is instead grouped with the traffic assignment model.

In the remaining traffic assignment model steps, vehicle trip tables by time of day are assigned to the network using an equilibrium procedure for the two peak hours (AM and PM) and for the off-peak period. Transit trips are also assigned to the transit route system using network settings consistent with mode choice.

Based on discussions with City staff and analysis of traffic count data, the AM and PM peak hours were defined as shown in Table 7.1.

Table 7.1. Peak Period Definitions

Period Name	Period Definition
AM Peak Hour	7:00 AM – 8:00 AM
PM Peak Hour	5:00 PM – 6:00 PM
Off-Peak Period	All Remaining Time (22 hours)

Directional time of day factors are used to convert trips from production/attraction (P/A) format to origin/destination (O/D) format and into peak and off-peak time periods used in the model. This process is based on extensive data indicating that trips are made directionally by time of day. For example, HBW trips generally occur from the production to the attraction (i.e., from home to work) in the AM peak and from the attraction to the production (i.e., from work to home) in the PM peak. It is also recognized that some trips are made in the reverse of this pattern and many trips are made outside of the peak periods.

Trip time data from the CHTS was used to develop directional time of day parameters. Each recorded trip was categorized by direction and by time of travel. Since some trips may begin in one period and end in another, trips were placed into time periods based on the trip mid-point.

In the travel model, the factors are applied directly to the purpose-specific vehicle trip tables created by the mode split model. As described in *Chapter 4: Trip Distribution*, daily trip tables are separated into peak period (combined AM and PM peak periods) and off-peak period trips prior to trip distribution and mode choice. The traffic assignment time of day module further separates peak period trips into AM and PM peak hour trips. At the same time, all trip tables are converted from P/A format to O/D format.

Time of day factors shown in Table 7.2 demonstrate the portion of trips by purpose and direction assigned to each time period. These factors are applied in a two stage process: first in a pre-distribution time of day module and second in a pre-assignment time of day module. The pre-distribution time of day parameters are shown in Table 7.3. The pre-assignment time of day parameters are shown in Table 7.4.

Pre-distribution time of day factors are computed based on the 24-hour time of day factors. For the off-peak period, the distribution time of day factor is simply the sum of the PA and AP factors. For the peak period, the distribution time of day factor is the sum of PA and AP factors for the AM and PM periods. Distribution time of day factors are applied by simple multiplication of time of day factors and trip tables.

Pre-assignment time of day factors are also calculated based on 24-hour time periods. Because they are applied to trip tables that have already been separated into peak and off-peak periods, pre-assignment time of day factors are computed by diving 24-hour factors by the pre-distribution factors for each period and trip purpose. They are applied to the peak and off-peak PA tables using the equation below. Because EE trips are not processed through trip distribution or mode choice, EE time of day is applied prior to trip distribution. EE time of day is computed by simply multiplying time of day factors by the 24-hour EE trip tables.

$$T_{OD,subper} = \left(\frac{1}{2} \cdot T_{PA,per} \cdot F_{PA}\right) + \left(\frac{1}{2} \cdot T'_{PA,per} \cdot F_{AP}\right)$$

Where:

$T_{OD,subper}$ = OD trip-table for the AM or PM hour (or for the off-peak period)

$T_{PA,per}$ = PA trip-table for the peak or off-peak period

$T'_{PA,per}$ = Transposed PA trip-table for the peak or off-peak period

F_{PA} = Pre-assignment time of day factor for the PA direction

F_{AP} = Pre-assignment time of day factor for the AP direction

Table 7.2. Time of Day Factors

Period	HBW		HBS		HBU		HBO		WBO		OBO	IE	EE
	PA	AP	PA	AP	PA	AP	PA	AP	PA	AP			
Off-Peak	42.7%	38.7%	35.1%	53.9%	38.8%	41.0%	38.0%	39.0%	53.7%	29.5%	87.2%	82.0%	82.0%
AM Peak	10.0%	0.5%	0.9%	0.3%	15.0%	0.0%	11.1%	1.2%	1.0%	6.0%	4.3%	6.0%	6.0%
PM Peak	0.5%	7.5%	4.6%	5.2%	1.5%	3.7%	3.0%	2.0%	9.6%	0.3%	8.5%	12.0%	12.0%

Table 7.3. Pre-distribution Time of Day Factors

	HBW	HBS	HBU	HBO	WBO	OBO	IE
Off-Peak	81%	89%	80%	77%	83%	87%	82.0%
Peak	19%	11%	20%	17%	17%	13%	18.0%

Table 7.4. Pre-assignment Time of Day Factors

Period	HBW		HBS		HBU		HBO		WBO		OBO	IE	EE
	PA	AP	PA	AP	PA	AP	PA	AP	PA	AP			
Off-Peak	52.5%	47.5%	39.5%	60.5%	48.6%	51.4%	49.3%	50.7%	64.6%	35.4%	50.0%	50.0%	82.0%
AM Peak	53.9%	2.7%	8.1%	3.0%	74.2%	0.0%	64.1%	7.1%	5.8%	35.5%	16.8%	16.7%	6.0%
PM Peak	2.9%	40.5%	41.6%	47.4%	7.4%	18.3%	17.3%	11.5%	57.1%	1.6%	33.2%	33.3%	12.0%

8.0 Trip Assignment

8.1 Parking Garage Allocation Model

In the San Luis Obispo CBD, many businesses are served by a combination of on-street parking and central parking garages rather than direct on-site parking. These parking garages are located in three zones, with the number of parking spaces available shown in Table 8.2. Prior to traffic assignment, a portion of vehicle trips destined to zones with in ¼ mile of a parking garage are moved from the destination zone to a parking garage zone.

Table 8.1. Parking Garages

Zone	Garage Name	Parking Spaces
108002	Morro/Palm Parking Structure	1,227
108003	City of San Luis Obispo Parking	775
162001	Marsh St. Parking Structure	1,988

Trips are allocated to each parking garage independently, using the formula below to determine the relative likelihood of trips from a zone to be allocated to a parking garage. The number of trips that are allocated is limited to the number of spaces available in each garage.

$$ParkingWeight = \alpha d^{-b} \cdot e^{-\gamma d}$$

Where:

d = distance to parking garage
α = calibration parameter alpha (1)
β = calibration parameter beta (0.4)
γ = calibration parameter gamma (8)

Due to the close proximity of the three parking garages, trips from some zones are allocated to multiple parking garages. The model is implemented to ensure that no more than 100% of the trips to any one zone are moved to parking garages.

8.2 Traffic Assignment Algorithms

The traffic assignment module loads the travel demand as represented by the time of day vehicle trip tables onto the roadway network, which is the supply side of the model. There are several different algorithms that have been use in past and present models. The methods that were considered are as follows:

- **Equilibrium**: This is the most common method, which assumes all travelers use the fastest possible route between origin and destination, considering the effects of congestion. With this method, the total travel time for all trip makers is minimized. This method tends to work best for short assignment periods in which an equilibrium condition can be defined.

- **Stochastic Equilibrium**: This method considers congestion and assumes that most, but not all, travelers use the fastest possible route between origin and destination. The stochastic component of this method represents imperfect knowledge of the roadway system.

- **All-or-Nothing**: This method does not consider congestion and assigns all trips to the fastest possible route between origin and destination. It is not appropriate for congested networks because it does not consider congestion effects and thus tends to overload some facilities and under-load others.

- **Stochastic**: This method does not consider congestion and assigns most, but not all, trips to the fastest possible route between origin and destination. For similar reasons as the all-or-nothing assignment, the stochastic assignment process is not appropriate for congested networks.

- **Incremental Capacity-Restrained Assignment**: With this method, the vehicle trip table is assigned incrementally. Network travel times are updated after each increment is assigned, so congestion effects are considered. With a very large number of increments, this method can approximate an equilibrium assignment. This method is very efficient and includes consideration of congestion effects. However, it has largely fallen out of favor because modern computing power allows for more widespread application of the equilibrium assignment process, which is less efficient computationally but is theoretically a more valid algorithm.

Because SLO experiences congestion, only the equilibrium and stochastic equilibrium assignment methods were considered. Based on previous experience, the equilibrium assignment method is preferred over the stochastic equilibrium method except in cases where specific problems are encountered. Therefore, the SLO Citywide Travel Model uses the equilibrium traffic assignment method.

8.3 Closure Criteria

When equilibrium traffic assignment is used, oscillations between equilibrium iterations can sometimes result in unstable assignment results. If closure criteria are not sufficient, two very similar model runs (e.g., with only one small adjustment to the roadway network) can produce un-intuitive results. This generally occurs when the equilibrium traffic assignment algorithm converges at a different number of iterations – sometimes only one apart – for each run. Even when equilibrium traffic assignment converges after the same number of iterations, alternating oscillations in traffic volumes can sometimes be observed in traffic assignment results based on slightly different model networks.

While oscillations introduced by the equilibrium traffic assignment procedure can be of concern, they can be managed through introduction of a very tight closure criterion. Traffic assignment is performed with a closure gap of 0.0001 (10^{-4}) and a maximum number of iterations of 500. Convergence is reached prior to the iteration limit of 500. Test model runs have also shown that a closure gap of 0.001 may be acceptable for some applications.

8.4 Impedance Calculations

The impedance used for determining the shortest path in the Traffic Assignment model can take many forms, but typically it includes one or more of the following – travel time, travel distance, and tolls. If more than one impedance variable is used, a generalized cost function is necessary so that the relevant variables can be added together into a single impedance function expression. Since tolls are not an issue in the SLO area, they were not seriously considered for the impedance function. Furthermore, experience has shown that distance is less important than travel time; and including distance is problematic because it essentially amounts to double-counting the emphasis on this variable since distance is also inherent in the travel time calculations.

Therefore, congested travel time, rather than a generalized cost function, is used in traffic assignment calculations as is done in numerous models around the country.

An example of the generalized cost function is shown below. This is provided for reference only since the SLO Citywide Travel Model uses travel time as the single impedance value. Use of a generalized cost function requires that assumptions are made regarding auto operating costs and the value of time. These can be difficult to obtain; and both of these values can vary by region and would be subject to adjustment during model calibration and validation. With only one variable used in the impedance equation for the SLO Citywide Travel Model, there is no need to convert them to common cost units.

Cost = (*Distance* * *AutoCost)* + *(Time* * *TimeCost)*

Where:

Cost	= Total link cost, or generalized cost
Distance	= Link distance
AutoCost	= Auto operating cost (in dollars per unit distance)
Time	= Congested travel time for link
TimeCost	= Value of time (in dollars per unit of time)

8.5 Volume-Delay Functions

A volume-delay function represents the effect of increasing traffic volume on link travel time. While several volume delay functions are available for consideration, the most commonly used function is the modified BPR function. The modified BPR function is based on the original Bureau of Public Roads (BPR) equation below.

$$T_C = T_F\left(1 + \alpha\left(\frac{V}{C}\right)^{\beta}\right)$$

Where:

T_C	= Congested travel time
T_F	= Freeflow travel time
V	= Traffic volume
C	= Highway design (practical) capacity
α	= Coefficient alpha (0.15)
β	= Exponent beta (4.0)

The modified BPR equation uses the same form, but replaces design capacity with ultimate roadway capacity. Ultimate roadway capacities for links in the SLO Citywide Travel Model roadway network are defined in *Chapter 1: Roadway Network*. The modified function also replaces the coefficient alpha and the exponent beta with calibrated values that vary by facility type and area type.

The Highway Capacity Manual (HCM 2000) provides alpha and beta parameters for the modified BPR equation that were developed to be consistent with HCM based delay calculations[6]. These parameters vary by facility type, freeflow speed, and signal spacing (signals/mi). Detailed signal location data is not available on each link in the SLO roadway network and, more importantly, is unlikely to be available on forecast networks. Therefore, the model uses a facility type and area type lookup table for determination of the parameters alpha and beta. The parameters are shown in Table 8.2.

The parameters in Table 8.2 were calibrated to the extent possible, but the little congestion that is present is not particularly suitable for a rigorous calibration. On the other hand, since the parameters were developed to be consistent with HCM-based delay calculations, the parameters are appropriate given the speed and capacity assumptions by area type and functional class.

Table 8.2. Volume Delay Parameters Alpha and Beta

Functional Class	CBD		Fringe		Urban		Suburban		Rural		Outside SOI	
	α	β	α	β	α	α	β	β	α	β	α	β
Freeway	1.5	12	1.5	12	1.5	12	1.5	12	1.5	12	1.5	12
Principal Arterial	0.4	5	0.7	5	0.7	5	0.45	5	1.2	5	1.2	5
Minor Arterial	3.5	5	0.6	5	0.6	5	1	5	1.5	5	1.5	5
Major Collector	3	5	0.95	5	0.95	5	1	5	1.5	5	1.5	5
Ramp	3.7	5	3.7	5	3.7	5	3.7	5	3.7	5	3.7	5
Urban Local	3	5	0.95	5	0.95	5	1	5	1.5	5	1.5	5
Highway (Outside SOI)	.4	5	0.7	5	0.7	5	0.45	5	1.2	5	1.2	5
Arterial (Outside SOI)	.4	5	0.7	5	0.7	5	0.45	5	1.2	5	1.2	5
Rural Arterial (Outside SOI)	.4	5	0.7	5	0.7	5	0.45	5	1.2	5	1.2	5
Centroid Connector	0	1.1	0	1.1	0	1.1	0	1.1	0	1.1	0	1.1

8.6 Transit Assignment

Unlike vehicle trips, transit trips are not converted from PA to OD format. Instead, transit trips are assigned in PA format. In addition, transit trips are assigned for a peak period (AM and PM) and an off-peak period. Transit trips are not assigned separately for AM and PM peak periods. While this is considered standard practice, it does require that transit assignment results are evaluated with this in mind.

TransCAD reports transit stop boarding and alighting data at the stop level and transit route volumes at the segment level. This information can be useful in evaluating the relative importance of different stops along a

[6] Highway Capacity Manual, Transportation Research Board, 2000. p. 30-39, Exhibits C30-1 and C30-2.

route and of different route segments. However, it is important that transit assignment results at this level of detail are viewed critically. Where stop-specific data is available, base year model results should be compared to base year observed data; this information should be taken into account when evaluating model forecast data.

Because trips are assigned in the production to attraction direction, it is important to use caution when viewing directional transit assignment results. In particular, one must use care when reviewing transit assignment results on loop routes. A loop route that connects a residential area to an activity center (e.g., university or employment center) may show high ridership on one side of the loop and low ridership on the other side of the loop.

A comparison of observed boardings and assigned boardings by route is shown in Table 8.3. The overall modeled transit ridership matches the observed closely. The largest differences are on routes 4, 6a, and 6b, all of which serve the Cal Poly campus.

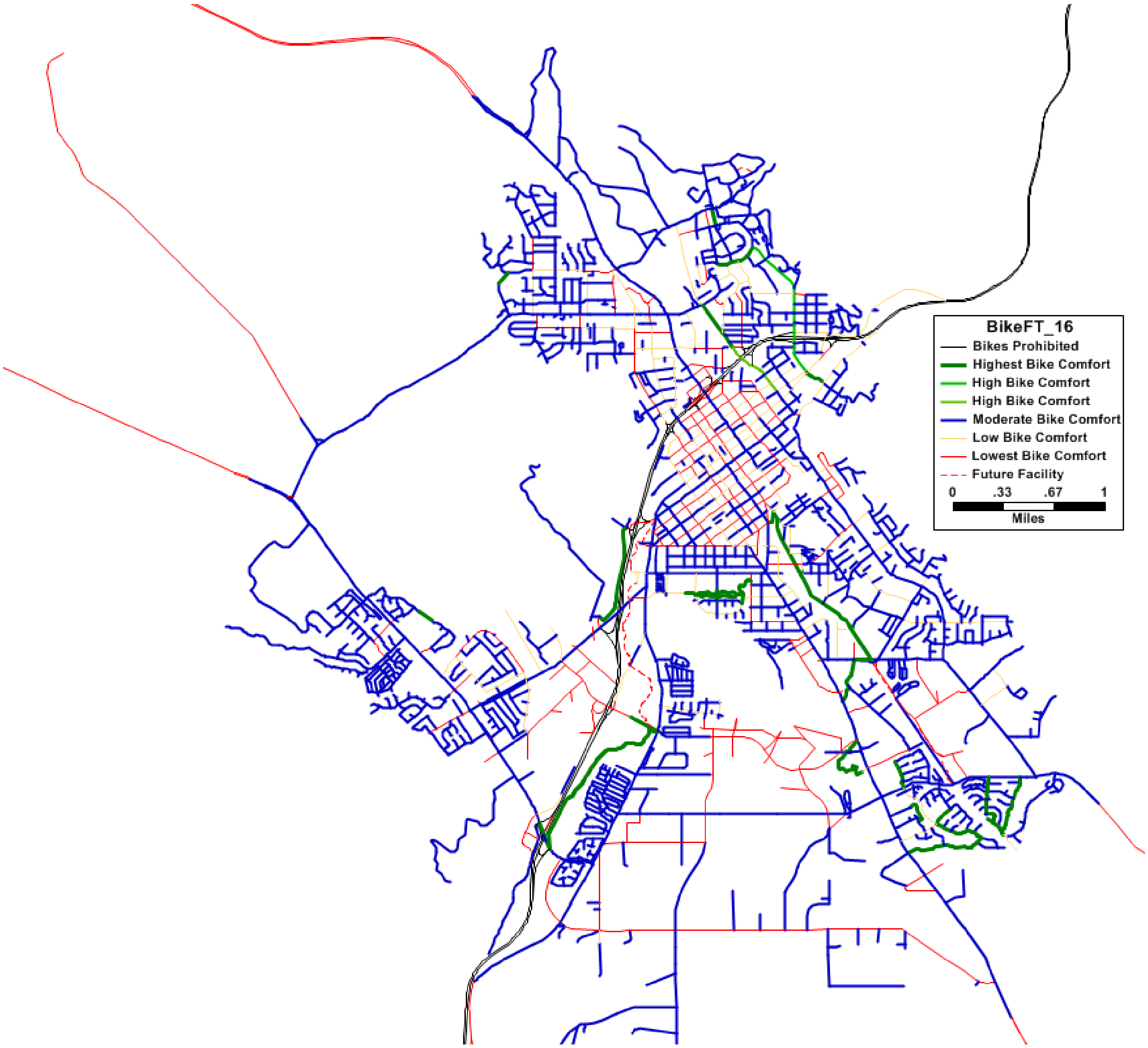
Table 8.3. Modeled and Observed Transit Boardings by Route

	Model Boardings	Survey Boardings	Difference
Route 1	26	189	(163)
Route 2	308	384	(76)
Route 3	494	371	123
Route 4	1,387	1,123	264
Route 5	1,358	1,173	185
Route 6a	418	945	(527)
Route 6b	651	663	(12)
Total	4,642	4,848	(206)

8.7 Bicycle Assignment

Bicycle assignment is a new component of the SLO Citywide Travel Model. It is performed similar to the traffic assignment and is based on the shortest travel time between an origin and a destination zone. However, the travel time used in the bicycle assignment is calculated not just based on the link distance but the type of facility. A Bicycle Comfort Index is assigned to each link to capture how a bicyclist perceives the level of safety and enjoyment on that facility. Dedicated bicycle trails are assigned the highest level of comfort while large arterials with no bicycle lanes are assigned the lowest level of comfort. Comfort levels by facility are shown in Figure 8.1.

Figure 8.1. Bike Comfort Levels



Also unlike traffic assignment, bicycle assignment uses an all-or-nothing assignment algorithm because travel times are unaffected by the number of bicycles on a network link (i.e., there is no bike congestion). The bicycle assignment uses a more detailed highway network that includes dedicated bike facilities as well as all local streets, which are omitted from traffic assignment.

The results of the bicycle assignment were validated using bike counts collected by the City of San Luis Obispo along with Strava data. Strava data includes records of bike trips made by the GPS-based Strava app users. Strava is used by both bicyclists making both recreational and commute trips, and requests that users mark each trip as either recreational or commute. The Strava dataset, limited to commute trips only, was attached to the model network to provide information on bicycle trip patterns.

Strava data contains only a sample of bicycle trips and may have inherent biases (e.g., by income or student status). To address these concerns, the Strava dataset was mapped alongside bicycle counts. The Strava dataset was then scaled to roughly match bicycle count totals. While this dataset is still not sufficient for a rigorous validation of commute/utilitarian bicycle trips represented by the model, it provided valuable information on the magnitude and locations of bicycle trips with in the city. A visual comparison of assigned bicycle trips to Strava data allowed the following adjustments to the bicycle model:

1. The total number of bicycle trips specified in the mode choice targets were adjusted to better match the overall bicycle activity indicated by the combined dataset.

2. Bicycle comfort index values were adjusted so that the model assigned more bicycle trips to heavily used facilities and fewer bicycle trips to less frequently used facilities.

The resulting bicycle assignment provides information on bicycle activity in the base year, and may be useful in better understanding how different development plans or infrastructure investments impact cyclists.