CHAPTER 5 – TRIP DISTRIBUTION

INTRODUCTION

The trip distribution models estimate the number of trips from each traffic analysis zone (TAZ) to each other TAZ. The trip distribution model is the second of the four primary model components identified as part of the four-step modeling process. The trips are estimated as a function of the travel impedance from one zone to another. For all trip purposes of the Regional Model, gravity models were applied for both peak and off-peak conditions. These models were developed using the 2001 SCAG Household Travel Survey data.

This Chapter summarizes the process for creating the trip tables by trip type for the Year 2003 Model Validation, and presents statistics reporting trip making within and between the six counties in the SCAG region.

TRIP PURPOSE

The trip distribution models were applied for the same trip purposes used in trip generation for both peak and off-peak conditions:

- Home Based Work Direct (HBWD);
- Home Based Work Strategic (HBWS);
- Home Based School (HBSc);
- Home Based University/College (HBU);
- Home Based Shopping (HBSh);
- Home Based Social Recreational (HBSR);
- Home Based Other (HBO);
- Home Based Serve Passenger (HBSP);
- Work-Based Other (WBO); and
- Other-Based Other (OBO).

For the home based work direct and home based work strategic trips, separate gravity models were applied for trips in each of the three income categories.

GRAVITY MODELS

The gravity model is used to distribute trips from origin zone to each destination zone in the region. It is based on Newton's law of gravity, which describes the gravitational force between two bodies. The number of trips between zones in transportation models is a function of the attractiveness of a zone and the travel impedance between zones:

$$T_{ij} = \frac{P_i * (A_j * F(I_{ij}) * K_{ij})}{\sum_j (A_j * F(I_{ij}) * K_{ij})}$$

where, Tij is the number of trips produced in zone i and attracted to zone j;
Pi is the number of trips produced in zone i;
Aj is the number of trips attracted to zone j;
Iij is a measure of impedance of travel from i to j;
F is a friction factor, which is a function of the impedance that represents the disutility of travel between i and j; and
Kij is the zone-to-zone adjustment factor, which takes into account the effect of undefined socioeconomic linkages not otherwise incorporated in the gravity model.

The gravity model in this application will apportion the trips produced at each production zone among attraction zones according to the attractiveness of each zone and the disutility of travel for each trip interchange. This application is doubly constrained, which means that the program will iterate until the trips produced from and attracted to each zone are consistent with the input assumptions on trips.

The friction factors for all trip purposes were derived by fitting the trip length frequency distributions to the observed distributions for each trip purpose and time period (peak and off-peak). For the two home based work trip purposes (direct and strategic), the friction factors are estimated for each of three income groups as well (low, medium, and high). The basic functional formula for the friction factors (except for the HBWD purpose) is given by the gamma function as follows:

$$\mathbf{f(x) = ax^{-b}e^{-cx}}$$

where, parameters a, b, and c are to be calibrated; and x is the impedance.

The gamma function of HBWD trips is as follows:

$$\mathbf{f(x) = at^{-b}e^{-cx}}$$

where: t is the travel time and x is the logsum from mode choice.

The coefficients in the friction factor equations are provided in Table 5-1 by trip purpose.

Table 5-1

TRIP DISTRIBUTION GAMMA FUNCTION PARAMETERS BY TIME PERIOD

PURPOSE	TIME PERIOD	GAMMA_A	GAMMA_B	GAMMA_C1	GAMMA_C2	CURVE_CHAN
HBWD1	Peak	500,000	1.5700	0.0400	0.0275	20.00
	Off-peak	500,000	1.5700	0.0400	0.0325	20.00
HBWD2	Peak	500,000	1.5700	0.0400	0.0275	20.00
	Off-peak	500,000	1.5700	0.0400	0.0313	20.00
HBWD3	Peak	500,000	1.5700	0.0400	0.3250	20.00
	Off-peak	500,000	1.5700	0.0400	0.0313	20.00
HBWS1	Peak	500,000	0.8050	0.0550	0.0900	28.00
	Off-peak	500,000	0.7500	0.0850	0.0500	20.00
HBWS2	Peak	500,000	0.5100	0.0880	0.0680	24.00
	Off-peak	500,000	0.4300	0.1230	0.0700	20.00
HBWS3	Peak	500,000	0.6750	0.0570	0.0760	24.00
	Off-peak	500,000	0.6650	0.0600	0.0710	22.00
HBSP	Peak	500,000	1.4400	0.1320	0.0360	15.00
	Off-peak	500,000	1.2400	0.1950	0.0250	15.00
HBSC	Peak	650,000	1.1100	0.1700	0.0500	15.00
	Off-peak	6,500,000	1.5300	0.1600	0.0500	13.00
HBCU	Peak	500,000	1.4700	0.1200	0.0510	15.00
	Off-peak	500,000	2.3500	0.1400	0.0390	15.00
HBSH	Peak	500,000	0.6850	0.4200	0.0550	9.00
	Off-peak	500,000	0.6100	0.6000	0.0450	9.00
HBSR	Peak	300,000	0.6050	0.2600	0.0460	12.00
	Off-peak	300,000	0.3900	0.3200	0.0450	12.00
HBO	Peak	500,000	0.8650	0.1900	0.0350	14.00
	Off-peak	500,000	0.9100	0.2300	0.0340	14.00
OBO	Peak	500,000	0.2010	0.2060	0.0500	20.00
	Off-peak	500,000	0.0900	0.2600	0.0340	22.00
WBO	Peak	500,000	0.4700	0.0940	0.0390	26.00
	Off-peak	500,000	0.3970	0.1920	0.0530	16.00
HBWD1Logsum	Peak	500,000	0.8000	-0.6300	-0.5200	-4.00
	Off-peak	500,000	0.9800	-0.5700	-0.5000	-4.00
HBWD2Logsum	Peak	500,000	0.4150	-1.0500	-0.9800	-2.30
	Off-peak	500,000	0.5700	-1.0500	-0.7000	-2.20
HBWD3Logsum	Peak	500,000	0.6000	-1.2500	-1.1100	-2.00
	Off-peak	500,000	0.7800	-1.1800	-0.9650	-1.80

INTERMEDIATE STOPS MODEL

The purpose of the intermediate stop model is to redistribute the home based work strategic trips from the direct origin-destination path to a path that goes from the origin to the intermediate stop to the destination. The home-based work strategic trips include, by definition, an intermediate stop between the origin and destination of the trip.
This intermediate stop model identifies the location of the intermediate stop as a function of the location of the home end of the trip. The goal of this model is to capture the extended trip length of these home-based work strategic trips, which will result in higher vehicle miles traveled than if the home-based work strategic trips were distributed directly from the origin to the destination. As a matter of simplification, the model assumes that there is only one stop on the strategic trip and then determines the location of this stop in manner that will match the overall trip length of the strategic trip. For the small portion of strategic trips that have more than one stop, this model will approximate the overall trip length reasonably well, even though only one stop is represented.

The intermediate stop model is a two-step process, as follows:

1. Estimate the distance from the home to the intermediate stop
2. Estimate the location of the intermediate stop

The intermediate stop model was estimated using the SCAG household travel survey. There were 5,329 total home-based work strategic trips for model estimation. These two steps are described further below.

Intermediate Stop Distance from Home

This first step is a regression model with the log-linear distance decay function between the number of home-based work strategic trips and the distance between home and the first intermediate stop, as follows:

$$\mathbf{ln(TripNumber) = 6.806 - 0.026*Distance}$$

where, TripNumber is the number of home-based work strategic trips; and
Distance is the distance between home and the intermediate stop.

This regression model has an R-squared of 0.14.

The IS model uses 5 distance categories: 0-2, 2-5, 5-10, 10-20 and 20-50 and that distance category weights are computed by the formula above, resulting in 0.274, 0.253, 0.222, 0.171 and 0.079. The observed mean travel distance for all travel segments (from home to destination) is 12.1 miles, and the observed mean travel distance between home and the first intermediate stop is 5.6 miles. The application of the distance decay model to the estimation data set produces the estimated travel distance from home to the destination of 31.19 miles, so the model is calibrated to match the observed distance between home and destination. This results in a calibrated distance decay function, as follows:

ln(TripNumber) = 6.009 – 0.026*Distance

The calibrated model results in an estimated distance from home to the destination of 12.1 miles and an estimated travel distance from home to the intermediate stop of 6.5 miles. The primary reason that this value from home to the intermediate stop is longer than observed is because of the simplification that there is only one stop on the strategic trip, when a portion of these strategic trips in the household survey have more than one stop (20 percent). Since the objective of this model is to provide better estimates of vehicle miles traveled in trip assignment, we match the overall trip length for these trips rather than the trip length from the home to the intermediate stop.

Intermediate Stop Location

The second step in the process is to identify the location of the intermediate stop based on the attractiveness of the potential intermediate stop locations. This model is a standard regression model, as follows:

Number of Trips To Intermediate Stops = 0.375*retail + 0.120*eduhealth + 4.651*othserv + 0.281*totschenroll - 0.388*profmanag + 0.232*pubadmin

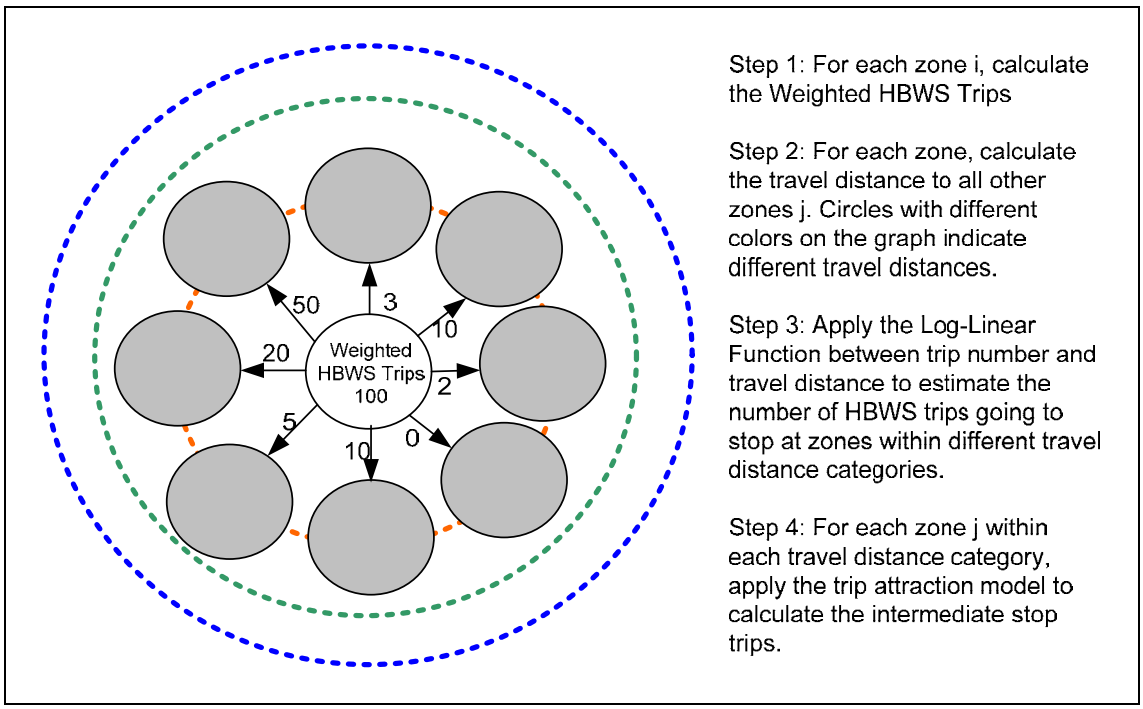
where, retail = number of retail employees;
eduhealth = number of education and health employees;
othserv = number of other service employees;
totschenroll = K-12 and preschool students enrollment;
profmanag = the number of professional and management employees; and
pubadmin = the number of public administration employees.

The R-square of this model is 0.30. All independent variables are significant to the 95 percent confidence level.

Intermediate Stop Model Application

Figure 5-1 presents an overview of the model implementation plan, with a four-step process to identify the location of the intermediate stops. These steps are described in more detail below:

Figure 5-1. OVERVIEW OF INTERMEDIATE STOP MODEL IMPLEMENTATION STEP



Step 1: Input the total number of home-based work strategic trips. This is the control total of home-based work strategic trips. There are about 2.5 million total home-based work strategic trips in the SCAG region.

Step 2: Categorize travel distances. Travel distances are input from the distance matrices developed in the primary trip distribution models.

Step 3: Apply the log-linear home-based work strategic trip model to estimate the number of trips that will make stops at zones with each travel distance category. For each zone pair (origin and the intermediate stop), calculate the number of home-based work strategic trips using the log-linear distance decay function. Zones that are closer to the origin zone will have more intermediate stops.

Step 4: Within each travel distance category, apply the home-based work strategic attraction model to allocate the home-based work strategic trips to specific locations.

FIGURE 5-2
HOME-BASED WORK PERSON TRIP DISTRIBUTION (RSA TO RSA)
(2000 MODEL VS 2000 CTPP)

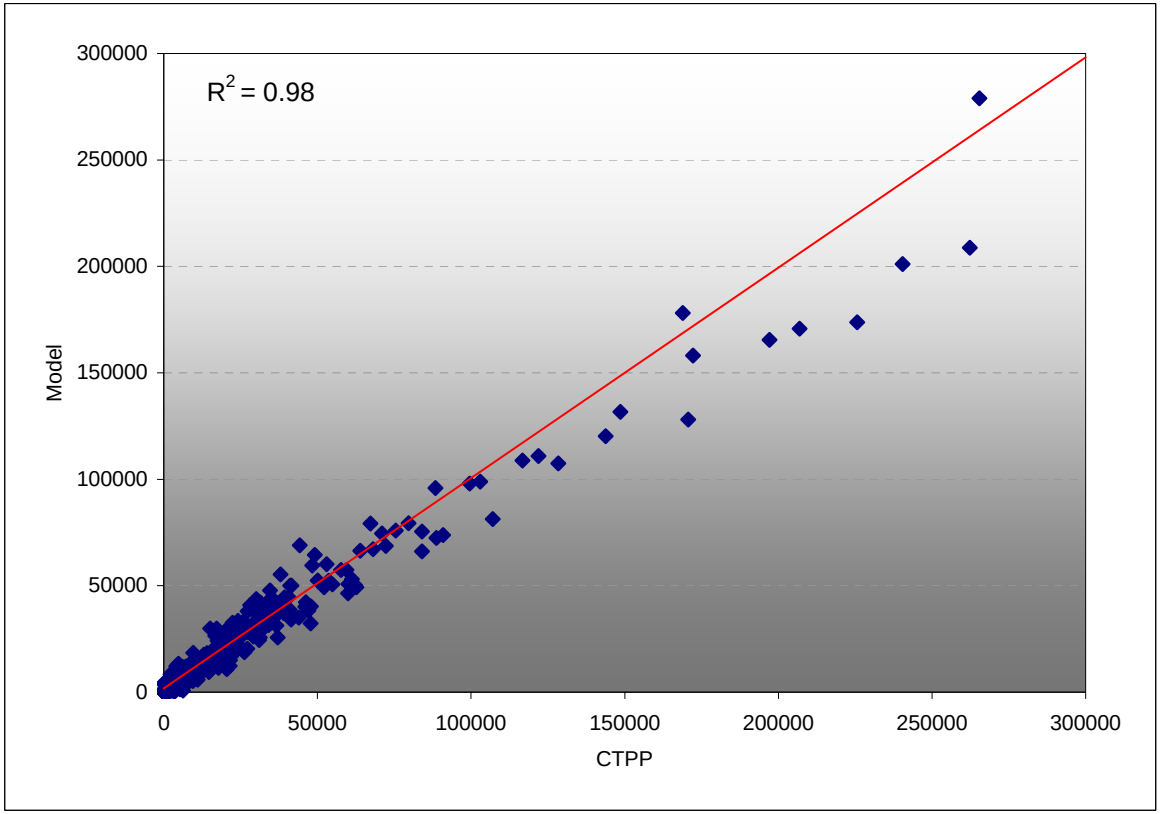
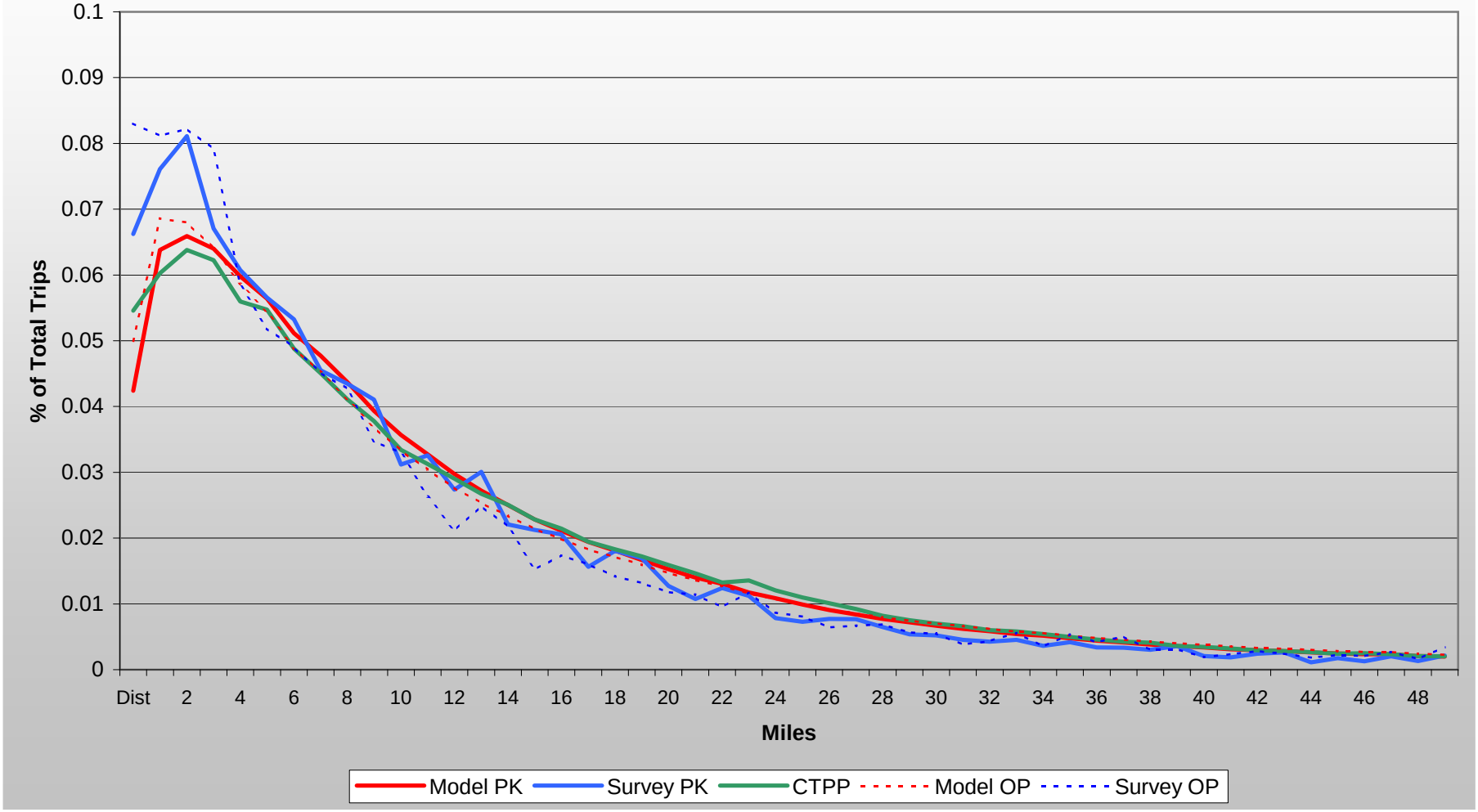


FIGURE 5-3
TRIP LENGTH FREQUENCY DISTRIBUTION - HOME-BASE WORK TRIPS
(MODEL, SURVEY, AND CTPP)



TRIP DISTRIBUTION RESULTS AND FINDINGS

Figure 5-2 compares home-based work person trip distribution between 2000 model and 2000 CTPP. Figure 5-3 shows the comparison of trip length frequency distribution for home-based work trips between model, survey and CTPP.

Tables 5-2 through 5-6 present summary statistics resulting from the trip distribution process for the Year 2003 Model Validation run. The Tables are summaries of trip tables in Production-Attraction (P&A) format. P&A format differs from origin-destination format in that the return trips, such as those from work-to-home, are actually credited as home-to-work trips. On a daily basis, half of the trips in those tables move from the zone of production to the zone of attraction and the other half of the trips move from the zone of attraction to the zone of production. Table 5-2 presents distribution results for home-based work trips, and Table 5-6 presents a summary of all trips.

The Year 2003 person-trip distribution model estimated inter-county travel patterns consistent with validations of previous Regional Transportation Models. The Year 2003 Model estimated that approximately 89.8 percent of the home-work trips generated in Los Angeles County had destinations within the Los Angeles County. Orange County retained 79.6 percent of its Year 2003 estimated home-work trips and Ventura County's estimated intra-county home-work trip percentage was 74.3 percent. San Bernardino County's estimated intra-county work trip percentage was 62.2 percent, while Riverside County's intra-county home-work trip percentage was estimated at 68.6 percent.

Table 5-7 presents average travel time statistics for the distribution of trips in the Year 2003 Model. The overall average AM peak period home-based work trip time from the Year 2003 Model is 27.8 minutes. The overall average mid-day home-based work trip time from the Year 2003 Model is 24.2 minutes. Figure 5-4 displays the average travel time to downtown Los Angeles from 6:00 A.M. to 9:00 A.M.

Table 5-2

YEAR 2003 HOME-BASED WORK PERSON TRIP DISTRIBUTION

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**83,846** ***98.02%***	31 ***0.04%***	18 ***0.02%***	1,577 ***1.84%***	64 ***0.07%***	1 ***0.00%***	85,537 ***100.00%***
Los Angeles	73 ***0.00%***	**5,721,749** ***89.78%***	437,270 ***6.86%***	30,437 ***0.48%***	103,564 ***1.62%***	80,179 ***1.26%***	6,373,271 ***100.00%***
Orange	44 ***0.00%***	382,879 ***17.92%***	**1,699,960** ***79.58%***	25,971 ***1.22%***	25,894 ***1.21%***	1,494 ***0.07%***	2,136,243 ***100.00%***
Riverside	2,527 ***0.25%***	80,273 ***7.93%***	92,129 ***9.10%***	**694,147** ***68.58%***	142,529 ***14.08%***	633 ***0.06%***	1,012,238 ***100.00%***
San Bernardino	429 ***0.04%***	201,533 ***18.62%***	75,220 ***6.95%***	130,165 ***12.03%***	**673,013** ***62.19%***	1,788 ***0.17%***	1,082,147 ***100.00%***
Ventura	2 ***0.00%***	139,856 ***24.98%***	3,023 ***0.54%***	367 ***0.07%***	939 ***0.17%***	**415,725** ***74.25%***	559,912 ***100.00%***
Total Attractions	**86,922** **0.77%**	**6,526,321** **58.02%**	**2,307,621** **20.51%**	**882,664** **7.85%**	**946,002** **8.41%**	**499,819** **4.44%**	**11,249,349** **100.00%**

Table 5-3

HOME-BASED WORK PERSON TRIP DISTRIBUTION (CTPP, TRAVEL SURVEY AND MODEL)

From\To	Source	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
Imperial	CTPP (2000)	97.98%	0.17%	0.05%	1.66%	0.14%	0.00%
	Travel Survey (2001)	96.91%	0.49%	0.51%	1.89%	0.19%	0.00%
	Model (2003)	99.59%	0.01%	0.01%	0.39%	0.01%	0.00%
Los Angeles	CTPP (2000)	0.01%	93.74%	4.12%	0.24%	1.07%	0.82%
	Travel Survey (2001)	0.18%	92.93%	4.90%	0.34%	0.82%	0.82%
	Model (2003)	0.00%	91.02%	6.20%	0.33%	1.23%	1.21%
Orange	CTPP (2000)	0.01%	13.85%	84.52%	0.85%	0.71%	0.05%
	Travel Survey (2001)	0.02%	18.85%	78.87%	1.23%	0.97%	0.06%
	Model (2003)	0.01%	19.90%	78.01%	0.95%	1.03%	0.09%
Riverside	CTPP (2000)	0.08%	6.37%	9.01%	73.91%	10.59%	0.04%
	Travel Survey (2001)	0.02%	5.94%	11.67%	72.26%	9.82%	0.29%
	Model (2003)	1.10%	10.48%	10.55%	63.63%	14.15%	0.09%
San Bernardino	CTPP (2000)	0.03%	16.91%	4.42%	7.89%	70.65%	0.09%
	Travel Survey (2001)	0.00%	16.60%	4.71%	7.72%	70.98%	0.00%
	Model (2003)	0.19%	20.71%	7.76%	11.11%	60.08%	0.16%
Ventura	CTPP (2000)	0.00%	20.17%	0.24%	0.05%	0.09%	79.44%
	Travel Survey (2001)	0.04%	17.74%	0.39%	0.09%	0.17%	81.57%
	Model (2003)	0.00%	25.85%	0.46%	0.05%	0.11%	73.54%
SCAG REGION	CTPP (2000)	**0.63%**	**59.03%**	**19.90%**	**7.39%**	**8.58%**	**4.48%**
	Travel Survey (2001)	**0.78%**	**59.52%**	**19.01%**	**7.83%**	**8.60%**	**4.27%**
	Model (2003)	**0.74%**	**59.95%**	**20.18%**	**6.94%**	**7.85%**	**4.36%**

Table 5-4

YEAR 2003 HOME-BASED NON-WORK PERSON TRIP DISTRIBUTION

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**250,603** ***98.50%***	143 ***0.06%***	80 ***0.03%***	3,295 ***1.30%***	305 ***0.12%***	4 ***0.00%***	254,430 ***100.00%***
Los Angeles	828 ***0.00%***	**15,974,361** ***94.78%***	514,821 ***3.05%***	57,577 ***0.34%***	178,772 ***1.06%***	127,772 ***0.76%***	16,854,131 ***100.00%***
Orange	712 ***0.01%***	479,521 ***9.57%***	**4,437,350** ***88.52%***	45,877 ***0.92%***	43,865 ***0.88%***	5,320 ***0.11%***	5,012,645 ***100.00%***
Riverside	8,791 ***0.29%***	126,643 ***4.19%***	105,352 ***3.49%***	**2,581,281** ***85.41%***	197,900 ***6.55%***	2,104 ***0.07%***	3,022,069 ***100.00%***
San Bernardino	1,593 ***0.05%***	273,738 ***8.49%***	82,460 ***2.56%***	170,181 ***5.28%***	**2,693,733** ***83.51%***	3,881 ***0.12%***	3,225,586 ***100.00%***
Ventura	49 ***0.00%***	141,269 ***10.35%***	6,174 ***0.45%***	1,389 ***0.10%***	2,834 ***0.21%***	**1,213,287** ***88.89%***	1,365,001 ***100.00%***
Total Attractions	**262,575** **0.88%**	**16,995,675** **57.16%**	**5,146,236** **17.31%**	**2,859,600** **9.62%**	**3,117,409** **10.48%**	**1,352,368** **4.55%**	**29,733,863** **100.00%**

Table 5-5

YEAR 2003 NON-HOME BASED PERSON TRIP DISTRIBUTION

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**109,612** ***98.75%***	43 ***0.04%***	24 ***0.02%***	1,184 ***1.07%***	135 ***0.12%***	1 ***0.00%***	110,998 ***100.00%***
Los Angeles	96 ***0.00%***	**9,179,368** ***93.33%***	365,459 ***3.72%***	52,218 ***0.53%***	144,201 ***1.47%***	93,608 ***0.95%***	9,834,952 ***100.00%***
Orange	54 ***0.00%***	362,951 ***10.76%***	**2,919,988** ***86.54%***	47,685 ***1.41%***	41,917 ***1.24%***	1,683 ***0.05%***	3,374,279 ***100.00%***
Riverside	2,474 ***0.17%***	49,617 ***3.31%***	44,901 ***3.00%***	**1,276,600** ***85.26%***	123,326 ***8.24%***	461 ***0.03%***	1,497,380 ***100.00%***
San Bernardino	299 ***0.02%***	138,937 ***9.03%***	41,827 ***2.72%***	125,245 ***8.14%***	**1,230,898** ***80.02%***	1,090 ***0.07%***	1,538,297 ***100.00%***
Ventura	1 ***0.00%***	93,675 ***12.49%***	1,659 ***0.22%***	484 ***0.06%***	1,125 ***0.15%***	**653,133** ***87.08%***	750,077 ***100.00%***
Total Attractions	**112,537** **0.66%**	**9,824,591** **57.43%**	**3,373,859** **19.72%**	**1,503,416** **8.79%**	**1,541,603** **9.01%**	**749,976** **4.38%**	**17,105,982** **100.00%**

Table 5-6

YEAR 2003 TOTAL PERSON TRIP DISTRIBUTION

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**444,061** ***98.47%***	217 ***0.05%***	122 ***0.03%***	6,056 ***1.34%***	504 ***0.11%***	5 ***0.00%***	450,965 ***100.00%***
Los Angeles	998 ***0.00%***	**30,875,478** ***93.39%***	1,317,551 ***3.99%***	140,232 ***0.42%***	426,536 ***1.29%***	301,559 ***0.91%***	33,062,354 ***100.00%***
Orange	810 ***0.01%***	1,225,351 ***11.64%***	**9,057,299** ***86.07%***	119,533 ***1.14%***	111,676 ***1.06%***	8,498 ***0.08%***	10,523,166 ***100.00%***
Riverside	13,792 ***0.25%***	256,533 ***4.64%***	242,381 ***4.38%***	**4,552,028** ***82.29%***	463,754 ***8.38%***	3,198 ***0.06%***	5,531,686 ***100.00%***
San Bernardino	2,321 ***0.04%***	614,208 ***10.51%***	199,507 ***3.41%***	425,591 ***7.28%***	**4,597,644** ***78.65%***	6,758 ***0.12%***	5,846,030 ***100.00%***
Ventura	52 ***0.00%***	374,800 ***14.01%***	10,856 ***0.41%***	2,240 ***0.08%***	4,898 ***0.18%***	**2,282,145** ***85.31%***	2,674,991 ***100.00%***
Total Attractions	**462,034** **0.80%**	**33,346,587** **57.41%**	**10,827,716** **18.64%**	**5,245,680** **9.03%**	**5,605,014** **9.65%**	**2,602,162** **4.48%**	**58,089,193** **100.00%**

Table 5-7

YEAR 2003 AVERAGE PERSON TRIP LENGTHS BY COUNTY

AM-Peak Period:

County	Trip Purpose	Home-Based Work	Home-Based Non-Work	Home-Based School	Other-Based Others	Work-Based Others
Imperial	Time (Minutes)	13.57	8.80	5.96	7.45	12.37
	Distance (miles)	9.39	6.11	3.85	4.82	8.55
Los Angeles	Time (Minutes)	27.54	16.16	9.39	15.60	22.27
	Distance (miles)	12.48	7.49	4.23	7.12	10.34
Orange	Time (Minutes)	23.85	15.43	8.08	14.55	20.47
	Distance (miles)	11.86	7.82	3.95	7.30	10.47
Riverside	Time (Minutes)	32.55	21.74	9.34	16.38	25.17
	Distance (miles)	18.22	12.55	5.38	9.60	15.01
San Bernardino	Time (Minutes)	34.79	20.78	8.42	17.39	26.82
	Distance (miles)	19.93	12.05	4.78	10.15	15.95
Ventura	Time (Minutes)	25.86	16.14	6.68	13.47	21.34
	Distance (miles)	14.46	8.97	3.58	7.57	12.23
All	**Time (Minutes)**	**27.80**	**17.03**	**8.91**	**15.48**	**22.40**
	Distance (miles)	**13.67**	**8.60**	**4.33**	**7.67**	**11.24**

Midday Period:

County	Trip Purpose	Home-Based Work	Home-Based Non-Work	Home-Based School	Other-Based Others	Work-Based Others
Imperial	Time (Minutes)	12.98	8.83	5.36	7.62	9.14
	Distance (miles)	9.23	6.29	3.51	5.23	6.17
Los Angeles	Time (Minutes)	23.64	13.79	7.50	13.74	17.28
	Distance (miles)	12.79	7.34	3.73	7.28	9.08
Orange	Time (Minutes)	21.79	13.82	6.50	13.43	16.18
	Distance (miles)	12.49	7.83	3.45	7.54	9.14
Riverside	Time (Minutes)	28.34	19.03	7.99	16.50	17.78
	Distance (miles)	19.10	12.72	4.76	10.99	11.75
San Bernardino	Time (Minutes)	30.10	18.38	7.09	17.77	19.57
	Distance (miles)	20.59	12.23	4.16	11.83	12.90
Ventura	Time (Minutes)	23.16	14.66	5.65	13.59	15.21
	Distance (miles)	15.06	9.26	3.17	8.54	9.71
All	**Time (Minutes)**	**24.24**	**14.81**	**7.24**	**14.25**	**17.15**
	Distance (miles)	**14.14**	**8.57**	**3.82**	**8.13**	**9.61**

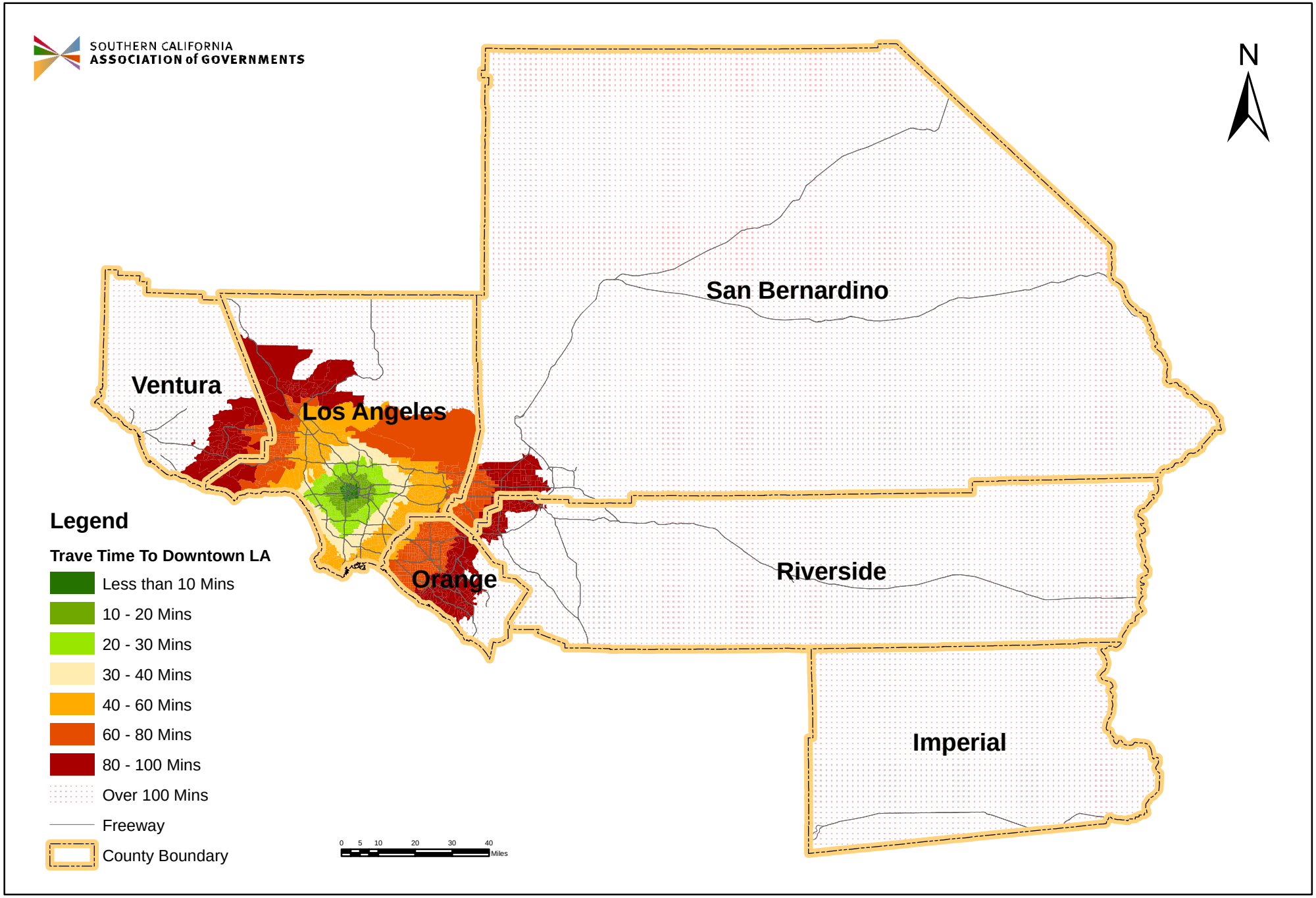


FIGURE 5-4
AVERAGE TRAVEL TIME TO DOWNTOWN LOS ANGELES (PEAK PERIOD)