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A METHOD FOR ESTIMATING DAYTIME POPULATION BY SMALL AREA GEOGRAPHY

Abstract: The distribution of resident population in the San Diego region is well documented. However, most people spend a great deal of their time other than where they live. Twice each day a massive shift in the population distribution takes place, resulting in crowded activity centers and nearly deserted residential neighborhoods. Daytime population distribution is important to planners and public officials as it impacts a wide range of issues from water demand and sewage disposal to the routing of hazardous materials. Using data from surveys and computer models, the San Diego Association of Governments has developed a method for estimating both current and future daytime population by small geographic units.

INTRODUCTION

The distribution of U.S. resident population in regions is well documented. A variety of sources, from the Federal Census to local telephone books indicate where people live. However, in a mobile society of bedroom communities and urban employment centers, where we live and where we actually are during the day are often quite different. Twice each weekday, a major shift in the distribution of population takes place. This is evidenced by peak hour traffic jams, crowded shopping center parking lots, and nearly deserted residential neighborhoods.

The distribution of daytime population is critical to both planners and public officials because it impacts such a wide range of issues. For example, sewage disposal requirements and the demand for water are radically affected by the shift. Per-capita crime statistics are also affected by the daytime population distribution. Crime rates for a particular geographic area are often expressed as a ratio of incidents to population. The population, however, refers to residents, not the number of people actually

in that area during the day. Consequently, crime rates may be overstated for areas of low resident population, such as central cities. This statistical bias is reversed in the suburbs, where daytime population is relatively low.

The routing of hazardous or dangerous materials is affected in the same manner. If the material is being transported in the daytime, and the goal or policy is to route it through the least populated areas, daytime population figures become crucial. Disaster preparedness measures also must account for variations in resident and daytime populations. Evacuation routes and emergency services are greatly affected depending on the time of day (and hence the location of the population) an event may occur.

Many daytime population data products available from private vendors are simply variations of place-of-work employment files. SANDAG has developed a better method for estimating current and future daytime population for the San Diego region. The method uses trip forecasting knowledge to account for people leaving and arriving in small areas throughout the day. In theory, the method is transferable to other regions, however a great deal of background data and a reliable Geographic Information System would be required.

DATA SOURCES

The data used to produce subarea estimates of daytime population were derived from three separate elements in the SANDAG work program: the 1986 Travel Behavior Survey, the regional and subarea transportation models and the long-range Regional Growth Forecast. Each is incorporated into SANDAG's Geographic Information System.

Travel Behavior Survey

The 1986 Travel Behavior Survey was conducted between February and June of 1986. It was the third such study in the San Diego region. As with the surveys of 1966 and 1977, it had three purposes: 1) to calibrate and enhance the regional and subarea transportation models, 2) to create a comprehensive data base for short-range transportation system management projects, and 3) to monitor trends in travel behavior.

The 1986 survey involved extensive data collection from 2,754 randomly selected households, as well as roadside interviews of drivers leaving and entering the San diego urbanized area at five cordon stations.

The households were interviewed by telephone in two stages. The first stage consisted of general demographic questions such as household size, number of vehicles owned, age, sex, income and employment status. Travel Diaries were then mailed to the household, in which all persons were asked to keep a careful record of their trips during the assigned Travel Day. A trip was defined as any one-way travel by any mode from a starting point (origin) to an ending point (destination) for a specific purpose. The following day, the household was re-contacted and the travel data were collected over the phone. Trip ends were then geocoded to the 753 Traffic Analysis Zones (TAZ's) in the region and the land use at each trip end was recorded. TAZ's are subdivisions of census tracts. Origin and destination data from the survey were used to estimate trips leaving and arriving a geographic area as explained below.

Transportation Models

SANDAG develops and maintains computer models to perform both regional and subarea transportation analyses. The models interact with the ARC/INFO data base management system to store and edit the data and to produce computer plots of the model results. One component of the transportation modeling system is the Trip Generation Model. Its purpose is to estimate the current and future number of daily person trip ends produced in or attracted to each TAZ considering demographic shifts over time and differences across the region. For example, the Travel Behavior Surveys show that high income households produce more than twice as many trips as low income households.

The model generates trip Productions and Attractions by TAZ for five trip types: Home-Work, Home-Shop, Home-Other, Other-Work and Other-Other. No directionality is implied by the trip type names; a trip originating at home and destined for work and a trip originating at work and destined for home are both Home-Work trips. Trips are generated by both residents and visitors. Trips may begin and end within the region (internal-internal), begin or end outside the region (internal-external) or simply pass through (external-external).

Productions and Attractions (P's and A's) should not be confused with origins and destinations. For home-based trips, (Home-Work, Home-Shop and Home-Other), the Production is defined as the "home" end of the trip. "Work", "shop" and "other" are the Attraction ends. The "other" end of the Other-Work trips is defined as the Production and the "work" end is the Attraction. Other-Other trips are split evenly into Productions and Attractions. Productions and Attractions are balanced by trip type at the

regional level, however TAZ's that are predominately residential will generate mostly Productions, while commercial or industrial zones will generate mostly Attractions.

Regional Growth Forecast

Every three to five years, SANDAG produces a series forecast of population, housing and employment for the San Diego region. The land use elements of the region's 92 General and Community Plans are direct inputs to the forecast. The forecasting models allocate future activity primarily to vacant land which has an appropriate land use designation and access to the transportation network. Using ARC/INFO, forecast data are stored in the smallest geographic unit in SANDAG's Geographic Information System, the Master Geographic Reference Area, or MGRA. The 24,380 MGRA's in the system are the result of overlaying TAZ's, city boundaries, sphere of influence boundaries and a matrix of 2000' by 2000' gridcells. Storing data by MGRA allows the user to aggregate to standard nested geographies such as TAZ's, census tracts, subregional areas and major statistical areas, or to use the MGRA's to approximate the boundaries of any non-standard study area. As will be discussed, the storage of forecast data by MGRA also enables future daytime populations to be estimated for any geographic area.

METHODOLOGY

General

Two computer programs are used to calculate the daytime population distribution. The first, CALC.DAYPOP, estimates current and future daytime population by TAZ. The 753 TAZ's are the smallest of the nested geographic units in SANDAG's GIS, so the program also outputs estimates aggregated to the 380 census tracts, 41 subregional areas and seven major statistical areas in the region. The second program, CALC.DAYPOP.MGRA, takes the TAZ-level estimates and distributes them to the 24,380 MGRA's described above.

In general, both programs calculate daytime population in the same manner. They begin with the resident population and subtract out a portion of the departures (average daily person trips produced in a zone), and then add in a portion of the arrivals (trips attracted to a zone). This is done separately for each of the five trip types. TAZ-level P's and A's by trip type

are output from the Trip Generation Model. The portions are estimated from the travel survey data.

Estimating By TAZ

The method requires determining what portion of each TAZ's Productions should be subtracted and what portion of Attractions should be added to arrive at the daytime population. To do this, data from the 1986 Travel Behavior Survey were analyzed, and the resulting portioning factors are shown in Table 1. The idea was to produce estimates for peak daytime activity. Trip purpose was cross-tabulated with time of day (hour of arrival) and trip type. For each home-based trip type (Home-Work, Home-Shop and Home-Other), the highest accumulation of to-purpose activity was calculated by adding the arriving (to-purpose) trips and subtracting the departing (from-purpose) trips for each hour of the day beginning at 1:00am. Most trip types showed their peak accumulation (most people at their to-purpose location) at around 11:00am. For consistency, the 11:00am accumulation or percentage was used for all trip types. An accumulation was not calculated for non-home-based trip types (Other-Work and Other-Other) because both ends of these trip types are somewhere other than "home". Instead, the straight percentage of these types of trips during the 11:00 hour was used.

Table 1 shows the trip type factors which were used to portion the Productions and Attractions in both programs, and how they were derived.

TABLE 1
TRIP TYPE FACTORS

Home-Work:	to-work trips were 55.5% of H-W trips, there were 679,594 to-work trips, 11:00 accumulation was 539,517 "at work", 539,517 / 679,594 = 79.4%, H-W Factor = .555 * .794 (or .44067).
Home-Shop:	to-shop trips were 42.8% of H-S trips, there were 575,851 to-shop trips, 11:00 accumulation was 84,361 "at shopping", 84,361 / 575,851 = 14.6%, H-S Factor = .428 * .146 (or .062488).
Home-Other:	to-other trips were 48.8% of H-O trips, there were 1,469,930 to-other trips, 11:00 accumulation was 585,574 "at other", 585,574 / 1,469,930 = 39.8%, H-O Factor = .488 * .398 (or .194224).
Other-Work:	10.3% of O-W trips occur during the 11:00 hour, O-W Factor = .103
Other-Other:	10.0% of O-O trips occur during the 11:00 hour, O-O Factor = .10

Resident Population

Resident population, or "night" population includes all persons living in each TAZ plus an estimate of the number of people staying in hotels and motels. The Series 7 Regional Growth Forecast provided the number living in each TAZ for 1986, 1995, 2000 and 2010. It also provided current and future hotel employment in each TAZ. Using information from the San Diego Convention and Visitors Bureau, it was determined there are approximately 3.25 hotel guests for each hotel employee:

In 1986, total hotel employment was 16,901,
there were 31,638 hotel/motel rooms,
average hotel occupancy was 72.3%,
average party size was 2.4 persons, so,
hotel guests = 31,638 * .723 * 2.4 or 54,898.
54,898 / 16,901 = 3.25 guests per employee.

Calculating Daytime Population

Both programs calculate daytime population in the same manner. First, each TAZ's daytime population (DP) is set equal to its resident population. It is then kept as a running total as factored (portioned) Productions are first subtracted and then factored Attractions are added. This is done for each of the five trip types in each of the TAZ's as shown in equation 1:

$$DP_{TAZ} = RP_{TAZ} - \sum_{TT=1,5}(P_{TAZ,TT} * F_{TT}) + \sum_{TT=1,5}(A_{TAZ,TT} * F_{TT}) \qquad (1)$$

where: DP= Daytime Population,
RP= Resident Population,
P= Productions,
A= Attractions,
TT= Trip Type,
F= Trip type factor.

Estimating By MGRA

After the TAZ-level daytime population is calculated using the CALC.DAYPOP program, the data can be distributed to the Master Geographic Reference Areas using the program CALC.DAYPOP.MGRA. MGRA's are the smallest geographic unit in SANDAG's GIS, and are subdivisions of TAZ's. Once at the MGRA level, current and future daytime population can be extracted to approximate any user-defined study area. The CALC.DAYPOP.MGRA program works by either proportioning the Productions and Attractions from the TAZ to the MGRA level, or recalculating P's and A's for each MGRA based on population, households and employment. Proportioning of a TAZ's P's and A's is used for those trip types whose P's and A's are based on just resident population or just one type of employment. For the other trip types, the MGRA P's and A's need to be recalculated based on the person trip generation rates of households and the various employment types found in each MGRA within each TAZ. (See Tables 2 and 3.) The MGRA P's and A's are then factored using the same trip type factors as the TAZ-level program, and daytime population by MGRA is calculated in the same subtract-and-add manner described above. Trip types are proportioned or recalculated as follows:

Productions:	
Home-Work	Proportioned by resident population.
Home-Shop	Proportioned by resident population.
Home-Other	Proportioned by resident population.
Other-Work	Recalculated from person trip rates.*
Other-Other	Recalculated from person trip rates.*

Attractions:	
Home-Work	Proportioned by total employment.
Home-Shop	Proportioned by retail employment.
Home-Other	Recalculated from person trip rates.*
Other-Work	Proportioned by total employment.
Other-Other	Recalculated from person trip rates.*

(* See Tables 2 and 3.)

As in the Trip Generation Model, separate sets of person trip generation rates are used for the 16 TAZ's identified as comprising the San Diego City Central Business District (CBD). Tables 2 and 3 list the person trip generation rates used for recalculating an MRGA's P's and A's.

TABLE 2
PERSON TRIP PRODUCTION RATES

	----CBD----		---Non-CBD--	
	O-W	O-O	O-W	O-O
Households	0.143	0.425	0.486	1.171
Retail Employment	1.889	1.000	1.012	2.167
Service Employment	0.786	0.714	0.395	1.238
Government Employment	0.500	0.500	0.371	1.227
Other Employment	0.120	0.120	0.133	0.254

TABLE 3
PERSON TRIP ATTRACTION RATES

	----CBD----		---Non-CBD--	
	H-O	O-O	H-O	O-O
Households	0.143	0.143	0.478	0.374
Retail Employment	0.222	1.222	1.840	3.765
Service Employment	0.571	1.143	2.252	1.933
Government Employment	1.333	0.833	8.303	2.136
Other Employment	0.400	0.120	0.413	0.438

In general, each MGRA is processed by trip type in the following manner. First, P's and A's are proportioned from the TAZ or recalculated. Then they are factored by trip type as in the TAZ-level program. Daytime population is kept as a running total:

Productions

H-W, H-S, H-O: Proportion= MGRA population / TAZ population

$$DP = RP - (P_{TAZ} * Proportion * F_{TAZ,TT}) \quad (2)$$

O-W, O-O: Calculate by households and each employment type:

$$DP = RP - (HH_{MGRA} \text{ or } EMP_{MGRA,TYPE} * Trip\ Rate * F_{TAZ,TT}) \quad (3)$$

Attractions

H-W, O-W: Proportion= MGRA Total Emp / TAZ Total Emp

$$DP = RP + (A_{TAZ} * Proportion * F_{TAZ,TT}) \quad (4)$$

H-S: Proportion= MGRA Retail Emp / TAZ Retail Emp

$$DP = RP + (A_{TAZ} * Proportion * F_{TAZ,TT}) \quad (5)$$

H-O, O-O: Calculate by households and each employment type:

$$DP = RP + (HH_{MGRA} \text{ or } EMP_{MGRA,TYPE} * Trip\ Rate * F_{TAZ,TT}) \quad (6)$$

where:
DP= Daytime Population,
RP= Resident Population,
P= Productions,
A= Attractions,
F= Trip Type Factor,
TT= Trip Type,
HH= Households,
EMP= Employment. (Type refers to retail, service, etc.)

Summary of Findings

Table 4 lists current and projected resident and daytime population for the 37 subregional areas (SRA's) in the urbanized portion of the San Diego region. Map 1 shows the configuration of SRA's. Twenty-five SRA's had a net loss of population during the daytime in 1986, while 12 gained population. The same basic pattern holds true in 2010, with 24 losing population and 13 showing an increase. Throughout the period, the Kearny Mesa and Central San Diego SRA's show the largest daytime gains.

Between them, they account for more than 50 percent of the net daytime gain of all SRA's. This is due to their relatively low resident population and substantial employment base.

In 1986, daytime population in the University SRA, a portion of which is commonly referred to as the "Golden Triangle", is more than twice the size of its resident population--an increase of 123 percent. This is due to students and faculty traveling to the University of California, the existence of several high-rise office buildings, and two regional shopping centers. By 2010, the daily increase rises to 134 percent.

The net losses recorded between residential and daytime population were more evenly distributed among SRA's. A loss of population during the day indicates these areas are primarily bedroom communities without major employment centers. From 1986 through 2010, the SRA showing the largest numeric loss of daytime population is Southeast San Diego, losing almost 40,000 persons in 1986 and 54,000 by 2010. The Harbison-Crest SRA loses the greatest percentage of its population during the day--36 percent in 1986 and 54 percent by 2010.

Maps 2 and 3 depict the 1986 population density (persons per square mile) by census tract for resident and daytime population respectively. They indicate that densely populated residential areas generally have close access to freeways and major arterials. Areas of high density daytime population tend to be even more immediately concentrated around major transportation arteries. In 1986 there were only two census tracts with a resident population density in excess of 20,000 persons per square mile. In the daytime, however, there were 11, including seven over 30,000 and 2 over 70,000. By the year 2010, there will be 24 census tracts with a daytime density over 20,000 persons per square mile. Maps 4 and 5 show the change in census tract population density between night and daytime for 1986 and 2010.

CONCLUSION

An analysis of the results of this method has shown that it provides what appears to be a reasonable portrayal of the daytime population distribution in the San Diego region. It is difficult to assess its accuracy, though, because little comparative data are available. However, SANDAG's employment files, activity center files, traffic generators and census data all support the results. While in theory this method is transferable to other regions, reliable travel behavior statistics to use as input are expensive to obtain.

REFERENCES

San Diego Association of Governments, 1986 Travel Behavior Surveys, Volume I, Results of Surveys, May, 1987.

San Diego Association of Governments, 1986 Travel Behavior Surveys, Volume II, Technical Documentation, September, 1987.

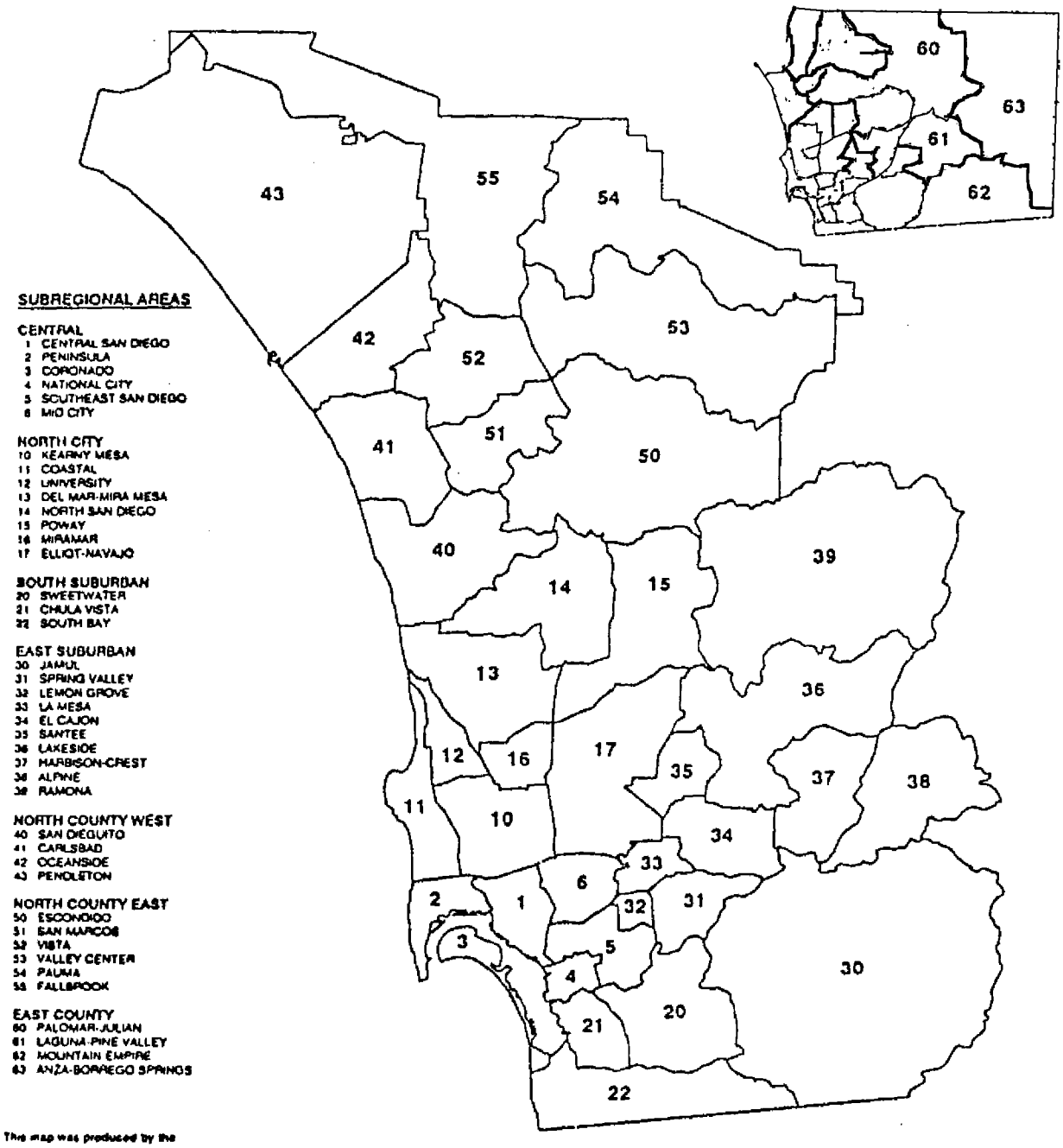
San Diego Association of Governments, Regional Transportation Models, July, 1988.

TABLE 4
CHANGES IN RESIDENTIAL AND DAYTIME POPULATION
BY SUBREGIONAL AREA
1986 AND 2010

SUBREGIONAL AREA	1986 RESIDENT POP.*	1986 DAYTIME POP.	1986 CHANGE (NUMBER)	1986 CHANGE (PERCENT)	2010 RESIDENT POP.*	2010 DAYTIME POP	2010 CHANGE (NUMBER)	2010 CHANGE (PERCENT)	1986-2010 RESIDENT % CHANGE	1986-2010 DAYTIME % CHANGE
1 CENTRAL SAN DIEGO	150,432	223,530	73,098	48 6%	182,136	294,165	112,029	61 5%	21 1%	31 6%
2 PENINSULA	78,493	116,027	37,534	47 8%	84,017	147,278	63,261	75 3%	7 0%	26 9%
3 CORONADO	28,344	30,823	2,479	8 7%	35,817	38,635	2,818	7 9%	26 4%	25 3%
4 NATIONAL CITY	55,887	61,841	5,954	10 7%	56,142	74,972	18,830	33 5%	0 5%	21 2%
5 SOUTHEAST SAN DIEGO	125,392	85,580	-39,812	-31 8%	148,938	95,280	-53,658	-36 0%	18 8%	11 3%
6 MID-CITY	126,645	105,837	-20,808	-16 4%	140,030	115,122	-24,908	-17 8%	10 6%	8 8%
10 KEARNY MESA	154,094	234,344	80,250	52.1%	194,719	335,896	141,177	72 5%	26 4%	43 3%
11 COASTAL	86,167	84,632	-1,535	-1.8%	98,180	102,493	4,313	4 4%	13 9%	21 1%
12 UNIVERSITY	35,343	78,816	43,473	123.0%	63,238	147,651	84,413	133 5%	78 9%	87 3%
13 DEL MAR-MIRA MESA	74,206	75,627	1,421	1.9%	153,500	155,544	2,044	1 3%	106 9%	105 7%
14 NORTH SAN DIEGO	42,565	33,803	-8,762	-20 6%	95,667	67,812	-27,855	-29 1%	124 8%	100 6%
15 POWAY	53,351	41,779	-11,572	-21.7%	86,488	74,434	-12,054	-13 9%	62 1%	78 2%
16 MIRAMAR	3,201	10,096	6,895	215 4%	3,143	20,482	17,339	551.7%	-1 8%	102 9%
17 ELLIOTT-NAVAJO	87,002	63,579	-23,423	-26.9%	100,563	72,471	-28,092	-27 9%	15 6%	14 0%
20 SWEETWATER	36,551	31,356	-5,195	-14 2%	108,082	64,463	-43,619	-40 4%	195 7%	105 6%
21 CHULA VISTA	90,795	85,140	-5,655	-6 2%	93,225	101,929	8,704	9 3%	2 7%	19 7%
22 SOUTH BAY	97,752	78,437	-19,315	-19 8%	165,519	156,765	-8,754	-5 3%	69 3%	99 9%
30 JAMUL	7,504	5,284	-2,220	-29.6%	17,222	11,358	-5,864	-34 0%	129 5%	115 0%
31 SPRING VALLEY	62,032	44,929	-17,103	-27 6%	97,421	69,135	-28,286	-29 0%	57 0%	53 9%
32 LEMON GROVE	26,239	22,640	-3,599	-13 7%	32,547	27,665	-4,882	-15 0%	24 0%	22 2%
33 LA MESA	54,540	57,467	2,927	5.4%	61,466	74,759	13,293	21 6%	12.7%	30 1%
34 EL CAJON	106,589	107,448	85	0 8%	121,855	138,570	16,715	13.7%	14 3%	29 0%
35 SANTEE	48,894	37,890	-11,004	-22.5%	65,997	57,173	-8,824	-13 4%	35 0%	50 9%
36 LAKESIDE	43,445	28,153	-15,292	-35 2%	63,167	35,193	-27,974	-44 3%	45 4%	25 0%
37 HARBISON CREST	11,145	7,156	-3,989	-35 8%	19,697	8,973	-10,724	-54 4%	76 7%	25 4%
38 ALPINE	7,659	5,415	-2,244	-29.3%	14,449	6,692	-7,757	-53 7%	88 7%	23 6%
39 RAMONA	20,691	15,098	-5,593	-27 0%	48,097	26,880	-21,217	-44 1%	132 5%	78 0%
40 SAN DIEGUITO	69,637	57,939	-11,698	-16 8%	99,404	72,251	-27,153	-27 3%	42 7%	24 7%
41 CARLSBAD	59,905	51,305	-8,600	-14.4%	130,581	101,838	-28,743	-22 0%	118 0%	98 5%
42 OCEANSIDE	93,721	77,927	-15,794	-16.9%	162,222	131,598	-30,624	-18 9%	73 1%	68 9%
43 PENDLETON	31,325	41,609	10,284	32 8%	29,929	44,467	14,538	48 6%	-4 5%	6 9%
50 ESCONDIDO	101,602	94,541	-7,061	-6.9%	181,938	156,722	-25,216	-13 9%	79 1%	65 8%
51 SAN MARCOS	29,800	33,978	4,178	14.0%	84,143	77,546	-6,597	-7 8%	182 4%	128 2%
52 VISTA	58,601	47,846	-10,755	-18.4%	95,615	76,882	-18,733	-19.6%	63 2%	60 7%
53 VALLEY CENTER	12,141	8,395	-3,746	-30 9%	25,883	13,180	-12,703	-49 1%	113 2%	57.0%
54 PAUMA	3,686	2,967	-719	-19.5%	8,880	4,241	-4,639	-52 2%	140.9%	42 9%
55 FALLBROOK	29,063	25,059	-4,004	-13.8%	54,622	37,514	-17,108	-31.3%	87.9%	49 7%

* Resident population plus estimated hotel population

Map 1
SUBREGIONAL AREAS



SUBREGIONAL AREAS

CENTRAL
1 CENTRAL SAN DIEGO
2 PENINSULA
3 CORONADO
4 NATIONAL CITY
5 SOUTHEAST SAN DIEGO
6 MID CITY

NORTH CITY
10 KEARNY MESA
11 COASTAL
12 UNIVERSITY
13 DEL MAR-MIRA MESA
14 NORTH SAN DIEGO
15 POWAY
16 MIRAMAR
17 ELLIOT-NAVAJO

SOUTH SUBURBAN
20 SWEETWATER
21 CHULA VISTA
22 SOUTH BAY

EAST SUBURBAN
30 JAMUL
31 SPRING VALLEY
32 LEMON GROVE
33 LA MESA
34 EL CAJON
35 SANTEE
36 LAKESIDE
37 HARBISON-CREST
38 ALPINE
39 RAMONA

NORTH COUNTY WEST
40 SAN DIEGUITO
41 CARLSBAD
42 OCEANSIDE
43 PENDLETON

NORTH COUNTY EAST
50 ESCONDIDO
51 SAN MARCOS
52 VISTA
53 VALLEY CENTER
54 PAUMA
55 FALLBROOK

EAST COUNTY
60 PALOMAR-JULIAN
61 LAGUNA-PINE VALLEY
62 MOUNTAIN EMPIRE
63 ANZA-BORREGO SPRINGS

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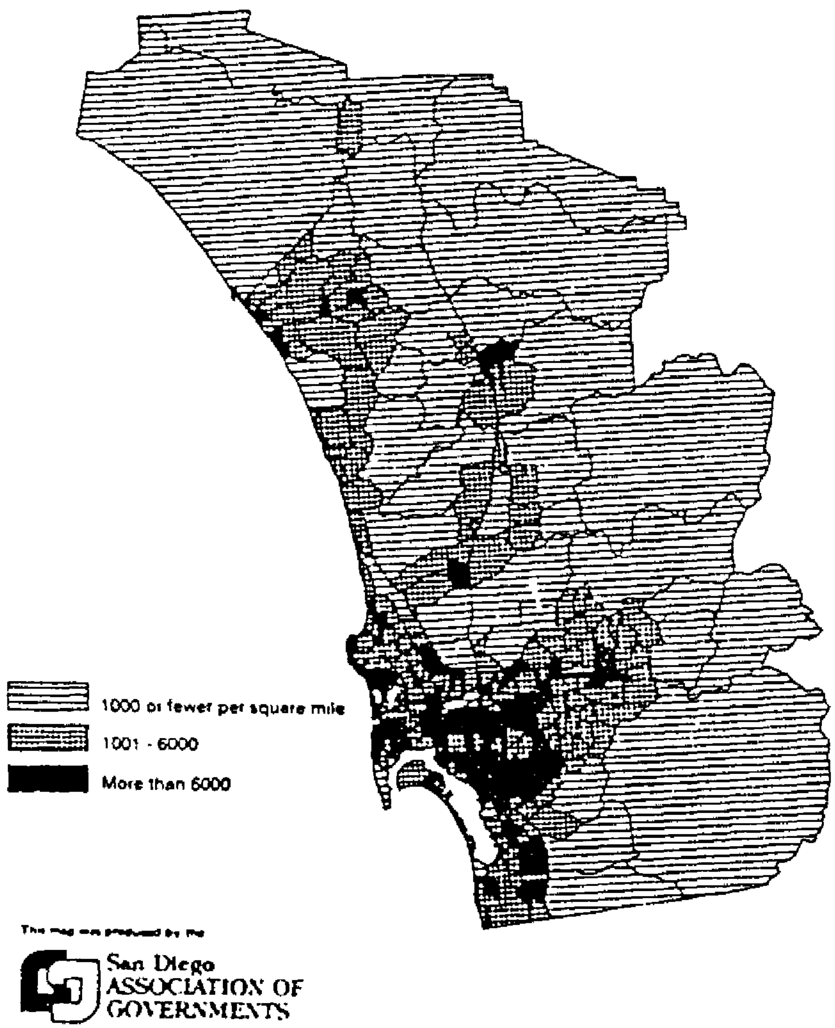
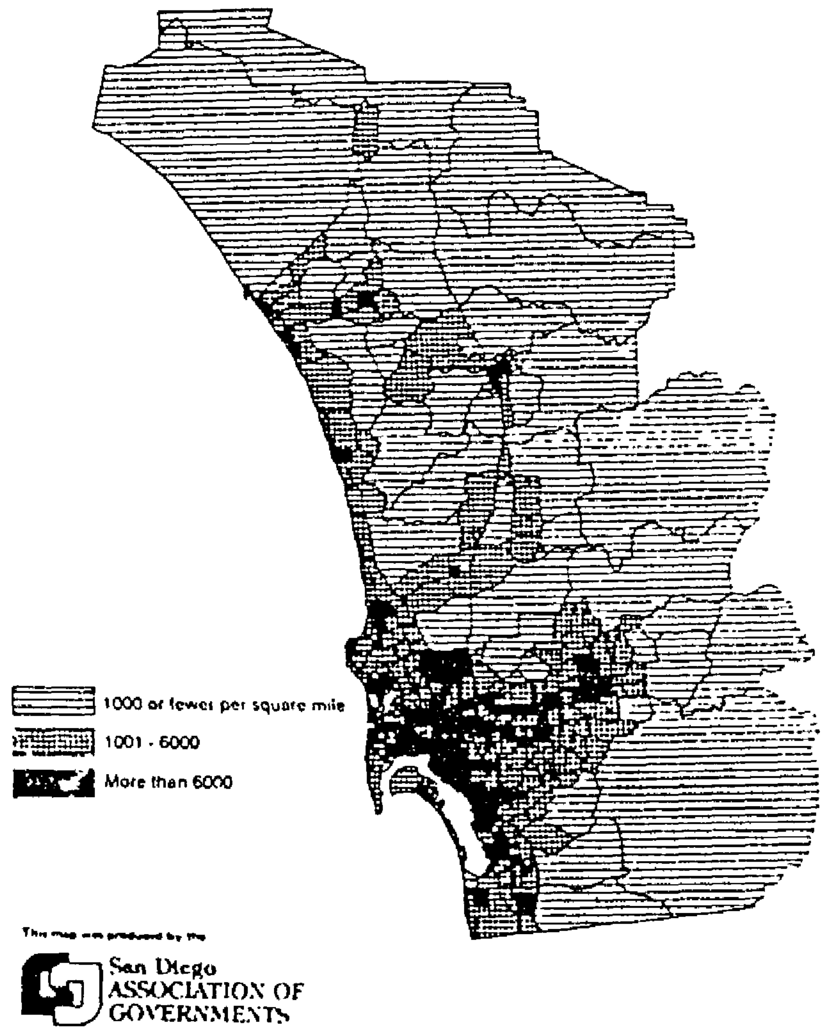
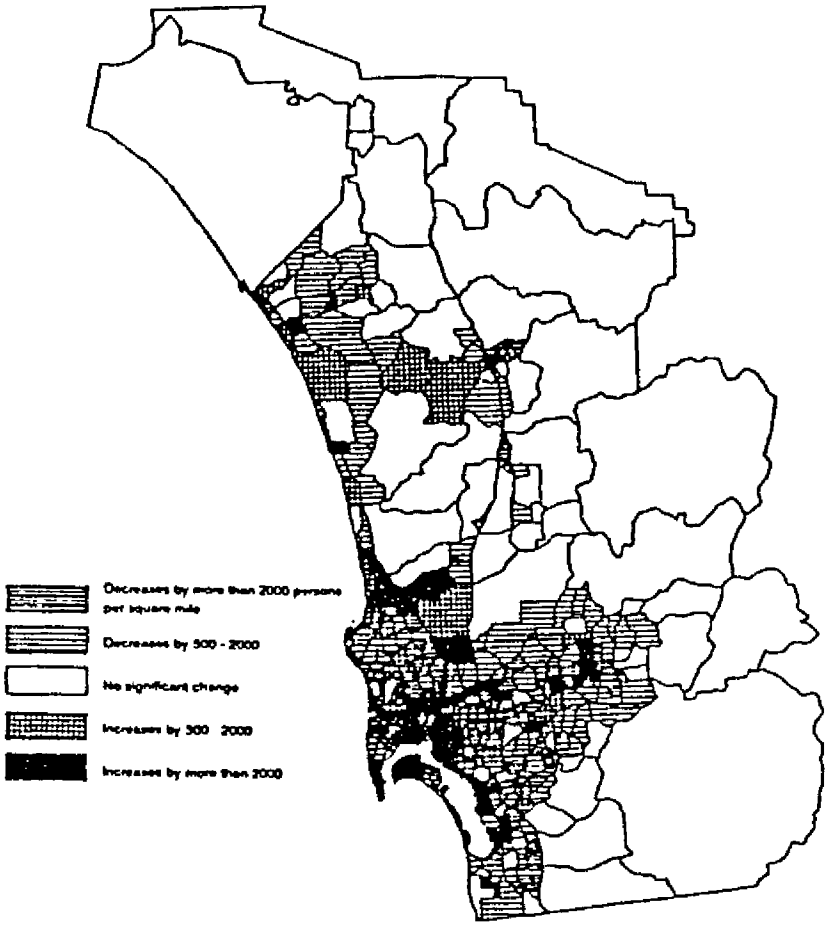
MAP 2
RESIDENTIAL (NIGHT) POPULATION DENSITY
BY CENSUS TRACT
1986



MAP 3
DAYTIME POPULATION DENSITY
BY CENSUS TRACT
1986



MAP 4
NIGHT TO DAYTIME POPULATION DENSITY CHANGE
BY CENSUS TRACT
1986



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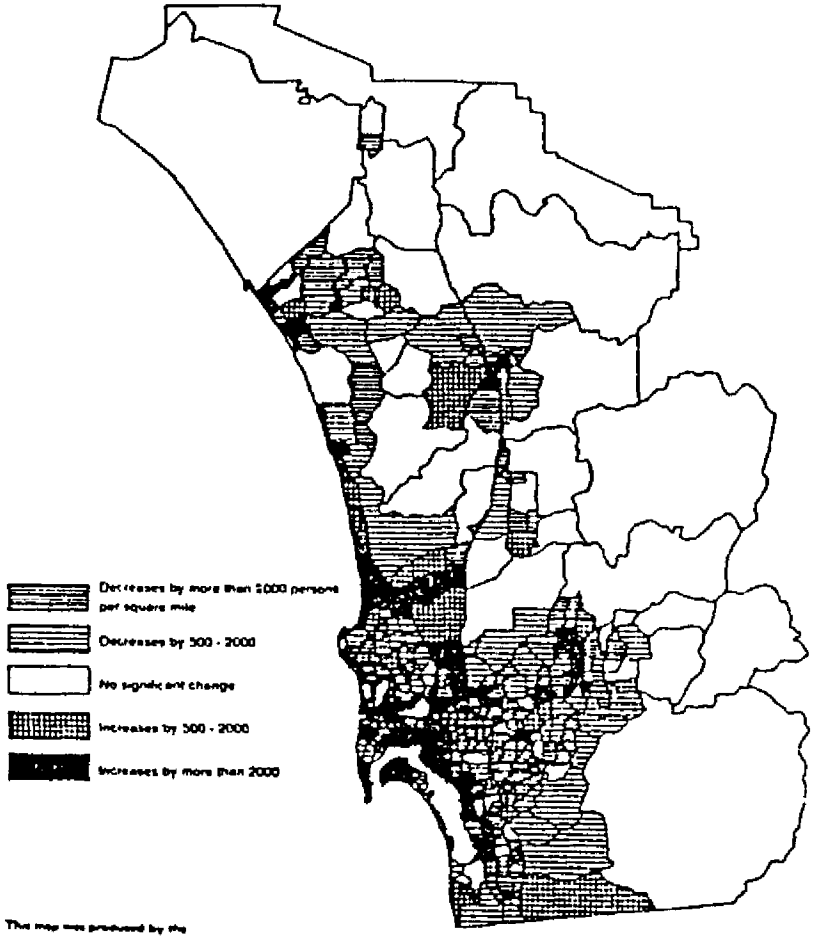
MAP 5
NIGHT TO DAYTIME POPULATION DENSITY CHANGE
BY CENSUS TRACT
2010



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