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# CSTDM09 - California Statewide Travel Demand Model

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Model Development

Parking Costs

Final System Documentation: Technical Note

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## Table of Contents

<b>1. Introduction .....</b>	<b>5</b>
<b>2. Parking Cost Structure .....</b>	<b>5</b>
<b>3. Parking Cost Model Development .....</b>	<b>8</b>
<b>3.1 Data Sources.....</b>	<b>8</b>
<b>3.2 Base Cost Model.....</b>	<b>16</b>
<b>3.3 Hourly and Daily Models .....</b>	<b>19</b>
<b>3.4. Application .....</b>	<b>21</b>
<b>3.4.1 Initial model results .....</b>	<b>21</b>
<b>4. Model Integration .....</b>	<b>26</b>
<b>5. Summary.....</b>	<b>27</b>

**Tables:**

<b>Table 1: Parking Cost Type Used in SDPTM by Tour Time Periods .....</b>	<b>7</b>
<b>Table 2: Industry Descriptions .....</b>	<b>17</b>
<b>Table 3: Parking Base Cost Model.....</b>	<b>18</b>
<b>Table 4: Hourly and Daily Cost Models .....</b>	<b>19</b>
<b>Table 5: Airports with Special Parking Costs .....</b>	<b>27</b>
<b>Table 6: Parking Base Cost Model.....</b>	<b>27</b>
<b>Table 7: Time Period to Parking Cost Type .....</b>	<b>28</b>
<b>Table 8: Hourly and Daily Cost Models .....</b>	<b>28</b>

**Figures:**

<b>Figure 1: Buffer Example, Zone 1005 .....</b>	<b>9</b>
<b>Figure 2: Progression of Parking Rates for Key Markets, Colliers Survey .....</b>	<b>10</b>
<b>Figure 3: Raw Parking Prices, North Beach (2009 Dollars) .....</b>	<b>11</b>
<b>Figure 4: Raw Prices Coded in Bins, North Beach (2009 Dollars) .....</b>	<b>12</b>
<b>Figure 5: TAZ Assignments and Average Prices, North Beach (2009 Dollars).....</b>	<b>13</b>
<b>Figure 6: Parking Costs in Los Angeles TAZ (2009 dollars).....</b>	<b>14</b>
<b>Figure 7: Parking Costs in San Francisco TAZ (2009 dollars) .....</b>	<b>15</b>
<b>Figure 8: Parking Base Cost Model Fit versus Observed (2000 Dollars) .....</b>	<b>18</b>
<b>Figure 9: Hourly Parking Cost Function.....</b>	<b>20</b>
<b>Figure 10: Daily Parking Cost Function .....</b>	<b>21</b>
<b>Figure 11: Histogram of Zones by Base Parking Cost Range, Model Year 2000 ...</b>	<b>22</b>
<b>Figure 12: 2000 Base Parking Costs, Greater Los Angeles.....</b>	<b>23</b>
<b>Figure 13: 2000 Base Parking Costs, LA Wilshire Blvd Corridor .....</b>	<b>23</b>
<b>Figure 14: 2000 Base Parking Costs, Bay Area .....</b>	<b>24</b>
<b>Figure 15: 2000 Base Parking Costs, San Francisco / Oakland / Berkeley .....</b>	<b>24</b>
<b>Figure 16: 2000 Base Parking Costs, Sacramento Area .....</b>	<b>25</b>
<b>Figure 17: 2000 Base Parking Costs, San Diego Area .....</b>	<b>25</b>

## 1. Introduction

This technical note describes the gathering of parking cost data for the California Statewide Travel Demand Model (CSTDM09). Parking costs are used in the Short Distance Personal Travel Model (SDPTM) and the Long Distance Personal Model (LDPTM), where they can have a significant impact on mode and destination choice.

## 2. Parking Cost Structure

A base cost is produced from a model considering the density of employment and population in and near the TAZ under consideration, and then specific parking costs are determined from this. Parking costs in the application of the CSTDM09 are calculated in year 2000 dollars. There are four kinds of parking costs:

- **Base parking cost** represents 1/20 of the monthly unreserved parking rate, i.e. the cost for 24 hour access to a parking garage for a month, but without a specifically assigned stall for the user. This is taken as the parking cost for all work and school choices in the SDPTM; it is assumed that the decision to purchase parking is a long term one, and that the cost would be amortized across the period of employment or enrollment. The base cost is calculated using a model to match observed data, and, as the name implies, is the basis for the calculation of the costs listed below.
- **Daily parking cost** represents the cost for parking in a parking garage for a full day, purchased one day at a time. This is typically around double the base parking cost; for instance, in 2008, unsecured monthly parking in the Oakland central business district (CBD) was \$192.50 on average, or \$9.63 as a base rate. Daily parking was \$18. Daily parking rates are used for the LDPTM, as the decision to park at an airport is a long term but irregular one. Similarly, daily costs are used for the SDPTM for long duration stops for purposes other than work or school; for instance, spending the day shopping downtown. Daily parking costs are calculated as a function of the base cost.
- **Hourly parking cost** represents the cost for parking in a parking garage for an hour, purchased on an hourly basis or less. This is typically somewhere between

a third and a fifth of the cost of daily parking; for instance, in the Oakland CBD in 2008, with daily parking of \$18, hourly parking was \$6 per hour. Hourly costs, multiplied appropriately, are used for short duration stops in the SDPTM. Hourly parking costs are calculated as a function of the base cost.

- **Special parking costs** represent specific parking charges that are added to the base cost. The key use of special parking costs are at airports for the LDPTM, but other special costs may be considered at hospitals and/or major postsecondary institutions. As the base cost is calculated on density, it can be thought of as implicitly representing a market-based parking cost, where dense areas demand more expensive parking structures and have higher demand for parking spaces. These special costs represent situations where parking cost is elevated from the market value due to institutional mandate as much as market conditions. This also permits the specification of parking costs as a policy input. Special costs are added to the base cost before the calculation of hourly or daily parking costs.

The decision as to whether to use hourly or daily parking costs for the SDPTM is based on the duration of the tour or stop under consideration. As the SDPTM deals with time periods, rather than explicit durations, time is assumed to be an hour within a single time period, two if the trip starts and ends in adjacent time periods and daily otherwise, with an extra hour added if the trip involves the longer midday time period. The following table shows the cost used in the model.

**Table 1: Parking Cost Type Used in SDPTM by Tour Time Periods**

		Starting time period				
Ending time period		Off-peak Early	AM Peak	Midday	PM Peak	Offpeak Late
	Off-peak Early	1 Hour				
	AM Peak	2 Hours	1 Hour			
	Midday	Daily	3 Hours	2 Hours		
	PM Peak	Daily	Daily	3 Hours	1 Hour	
	Off-peak Late	Daily	Daily	Daily	2 Hours	1 Hour

In the case where the hourly cost would be greater than the daily cost, which is for 3 hour parking in areas with a base parking cost of \$13 or more (in practice, very few zones), the daily cost is used instead.

Parking costs is free in TAZs with a total employment density less than 5,000 nonretail employees per square mile; these low density areas can typically provide free parking for their workers and visitors. Nonretail employees are used to avoid the model producing parking charges for areas such as shopping malls, which are somewhat dense in terms of employment, but provide ample free parking for their patrons. Downtown retail areas are still dense enough to exceed this threshold. For instance, the zone containing Arden Fair Mall in Sacramento (520) and the zone containing Union Square in San Francisco (1,035) both have high retail employment; 62% and 64% respectively. However, the nonretail employment density of Arden Fair Mall is 2,703/sq. mi, whereas the nonretail employment density of Union Square is 33,385/sq. mi, which would result in an expected parking charge. This can be overridden with a special parking cost if needed.

### 3. Parking Cost Model Development

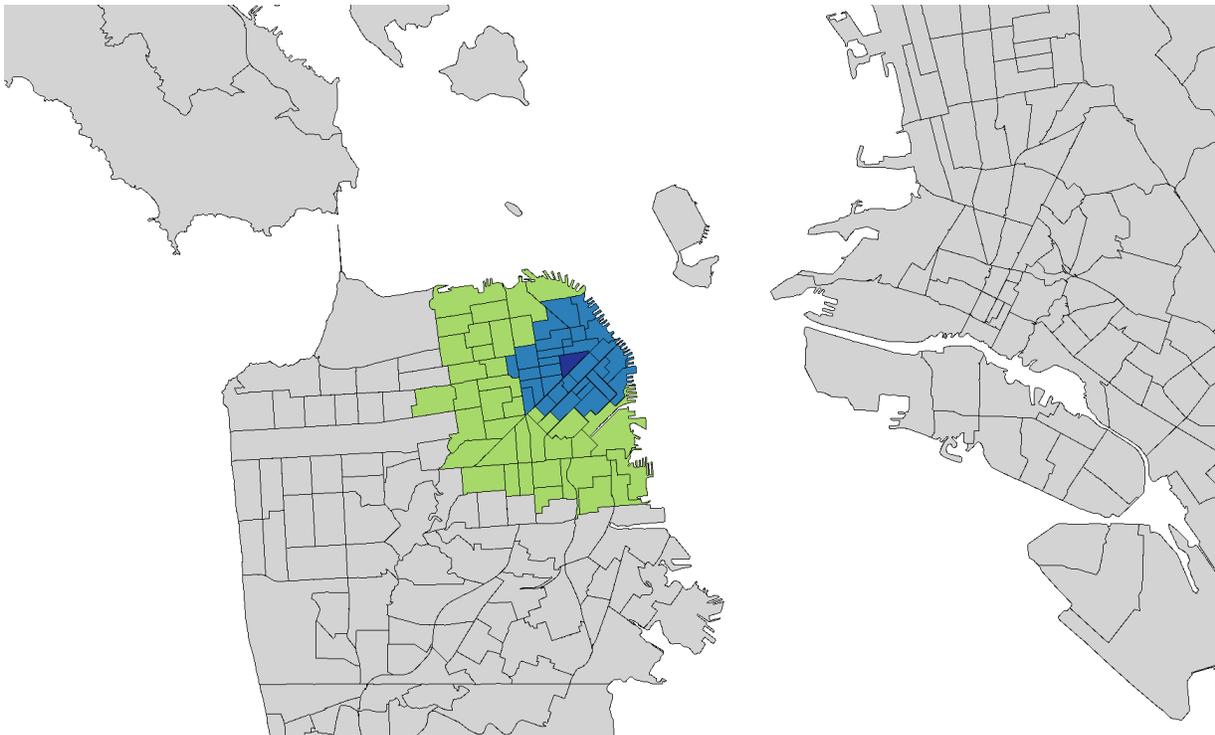
The core parking cost model attempts to produce the base cost of parking (1/20 of the monthly cost), using certain zonal properties. Additional functions are used to derive the hourly and daily costs of parking, given the base cost. The base cost model produces base parking costs in the year 2000, i.e. with year 2000 dollars.

#### 3.1 Data Sources

The main source for the zonal properties was the 2000 Census Transportation Planning Package (CTPP), which provides employment by industry at the block group level. This was aggregated up to the CSTDM09 zone system. A buffering system was used to provide employment densities for 1 mile and 2.5 miles. There were three steps:

1. The straight-line distance was found between each pair of zone centroids. For each zone, the zones with centroids within the cutoff distance (e.g. 1 mile) were selected. A Python script was used to do this, although a GIS operation could also select these zones.
2. For all of these selected zones, the total area was calculated.
3. The total employment for these selected zones was divided by the area to produce density.

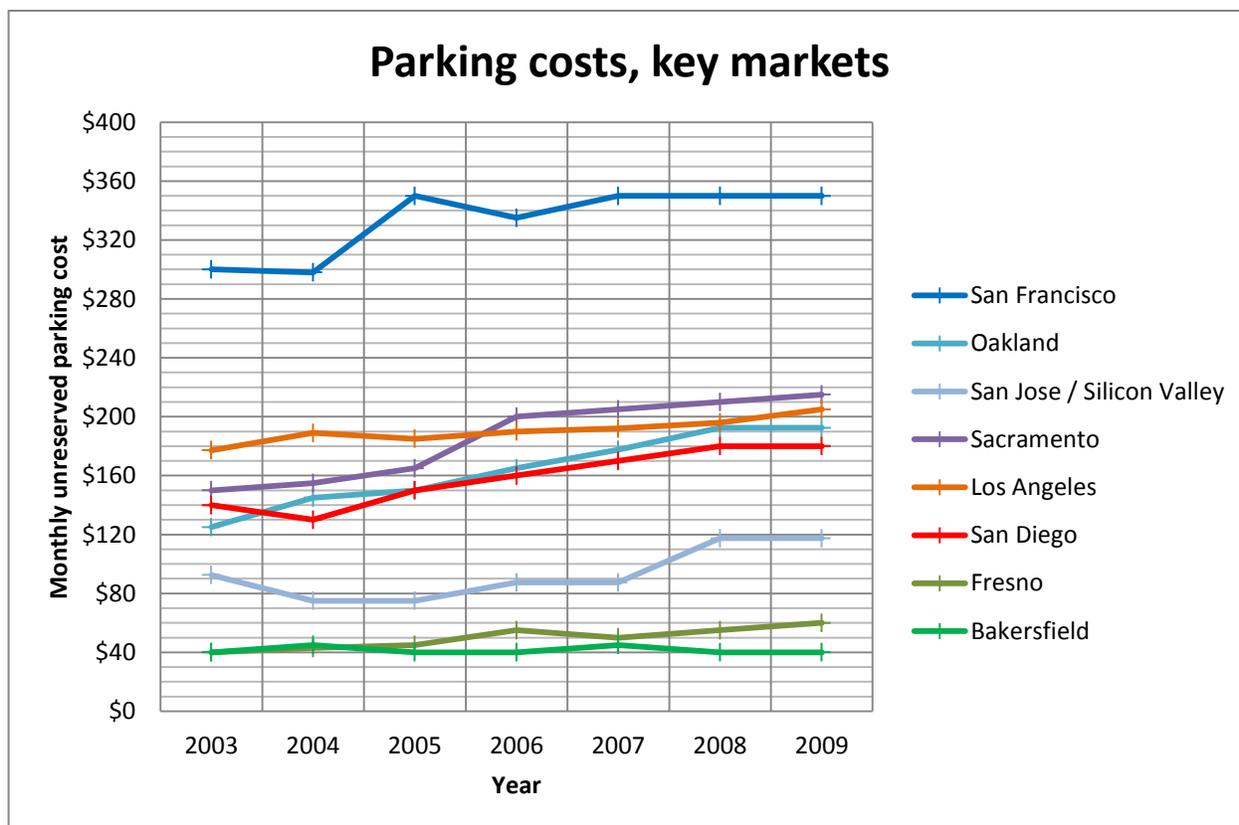
This buffering technique has the benefit of working at the zonal level, but handling the relatively large CSTDM09 zones and removing water. An example is shown in Figure 1 below for zone 1005 in downtown San Francisco; blue zones are within 1 mile (the dark blue is zone 1005 itself), and green are within 2.5 miles.



**Figure 1: Buffer Example, Zone 1005**

For parking costs, the primary data source was Colliers annual CBD Parking Rate Survey. The Colliers survey, which is published on an annual basis from 2003 to the present, provides a variety of prices for parking in CBD areas throughout North America. The California metropolitan areas in this data set, which were all used for the model, were Bakersfield, Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, San Jose, Santa Rosa and Walnut Creek. A selection of zones in the CBD area was used for each of these metros.

The Colliers data has continuously tracked monthly reserved, monthly unreserved and daily parking prices; in recent years, hourly was added. The 2003 to 2009 time series data were linearly extrapolated backwards to produce year 2000 base cost prices. The changes in some of the markets are shown in Figure 2 below. Note that the prices here are current year prices, so the linear extrapolation covers both market changes and inflation.

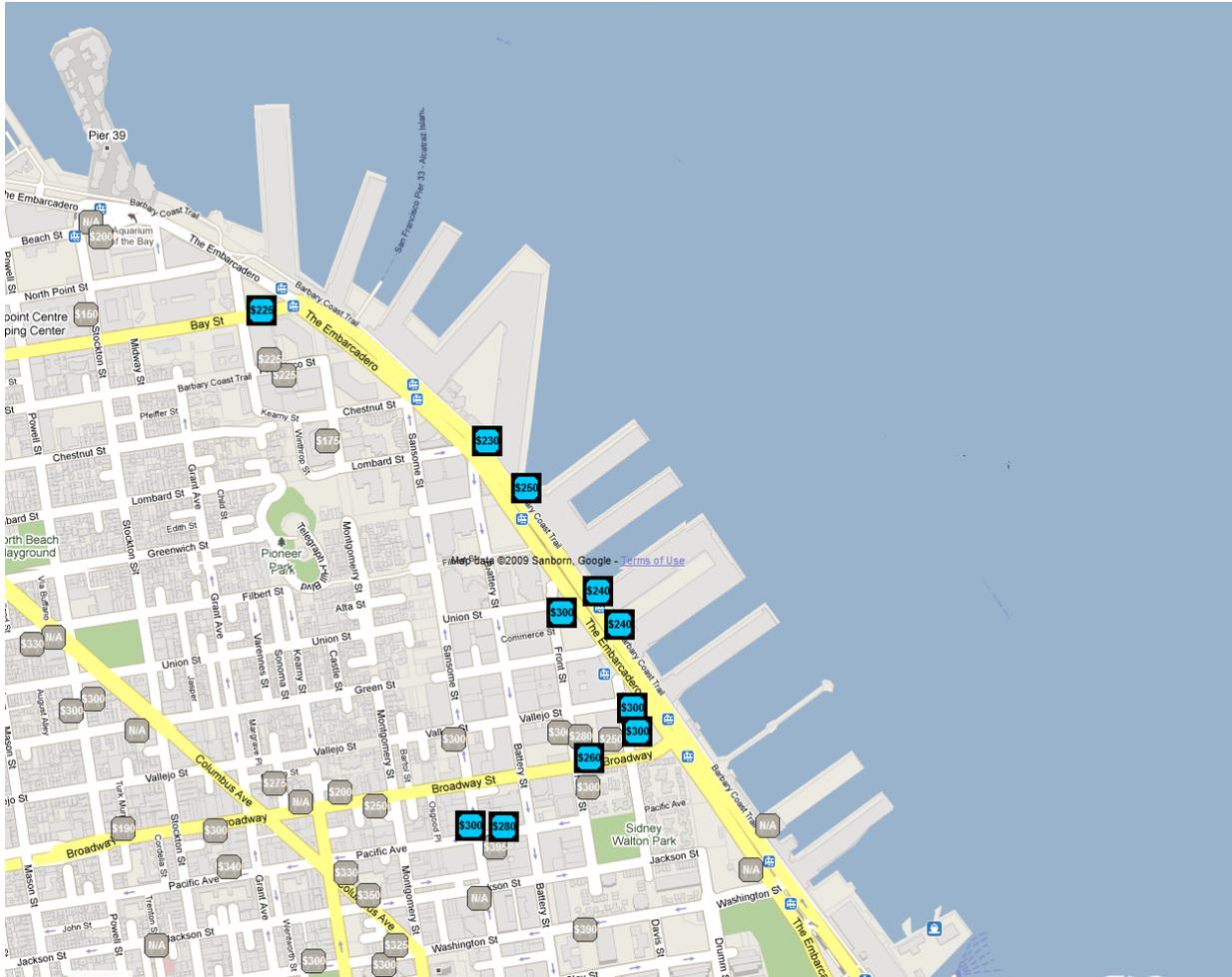


**Figure 2: Progression of Parking Rates for Key Markets, Colliers Survey**

For the two largest parking markets, San Francisco and Los Angeles CBDs, a finer-grained set of data was used. The website [www.bestparking.com](http://www.bestparking.com) aggregates parking rates at garages throughout these two CBD areas, covering a broad section of San Francisco, (roughly east of Van Ness Avenue and north of 16<sup>th</sup> Street) and the core of the Los Angeles CBD (roughly bounded by the Santa Monica, Santa Ana and Harbor Freeways, with S San Pedro street to the east). These data are current (as of the end of 2009), and in year 2009 dollars.

The individual parking garages monthly rates were first color-coded with a series of dots, representing \$50 ranges in San Francisco and \$25 ranges in Los Angeles, where the parking rates were much lower. A zone map was superimposed, and the number of garages in each band was counted for each zone. The average of these observations was taken as the monthly parking rate in the zone. The Figure 3, 4, and 5 provides a

visual representation of this process for the North Beach area of San Francisco. Note that these prices are in year 2009 dollars; they are adjusted later.



**Figure 3: Raw Parking Prices, North Beach (2009 Dollars)**

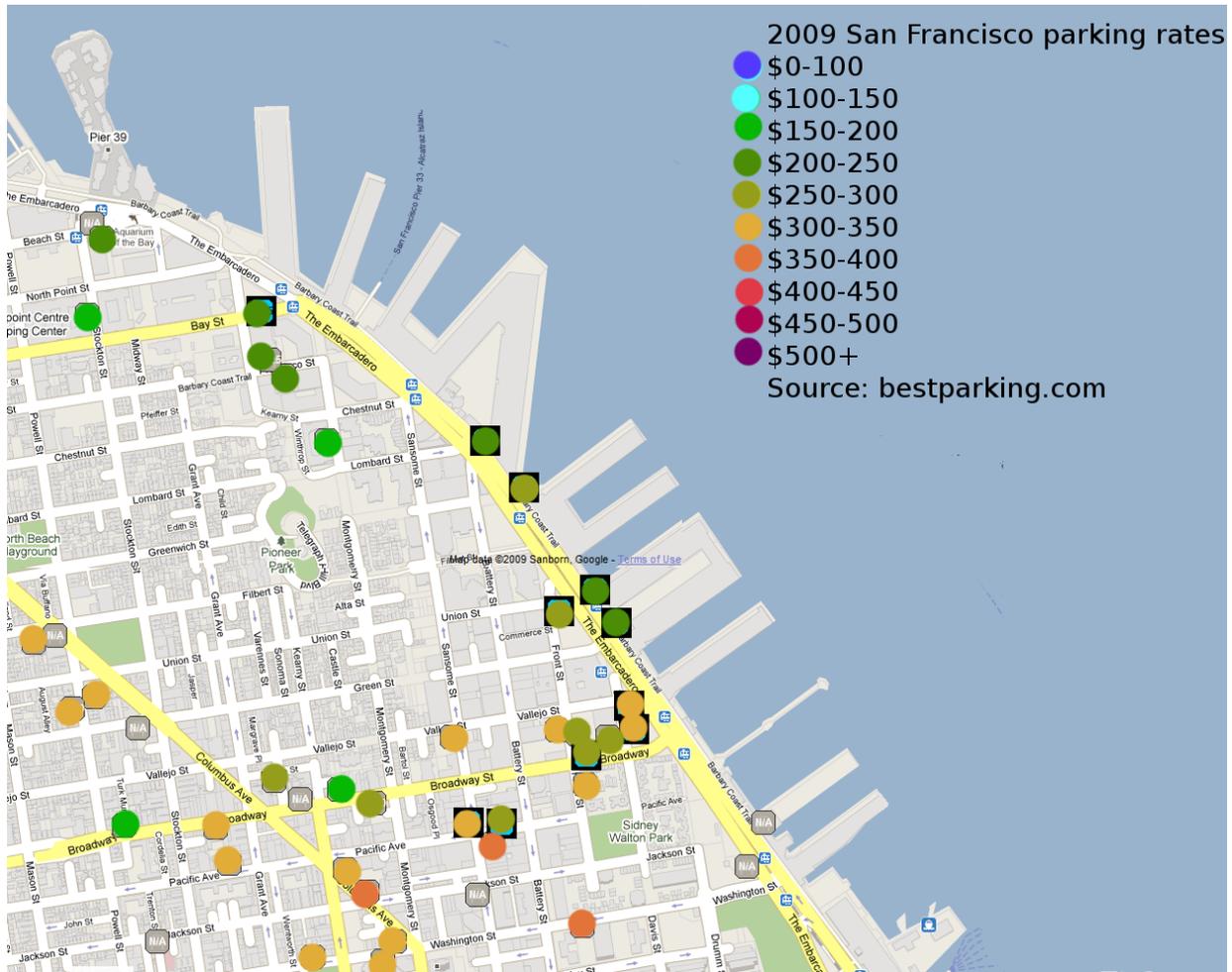
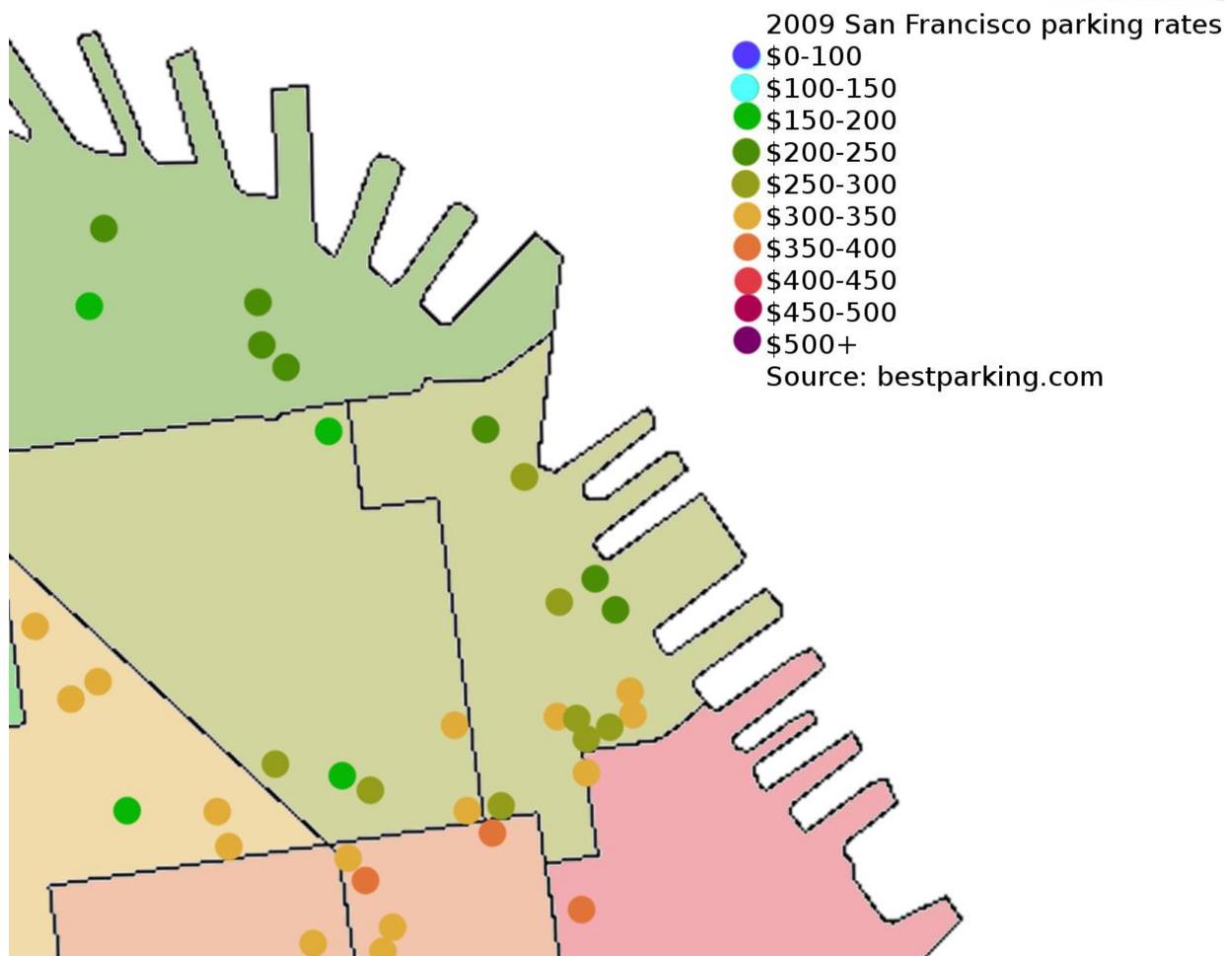
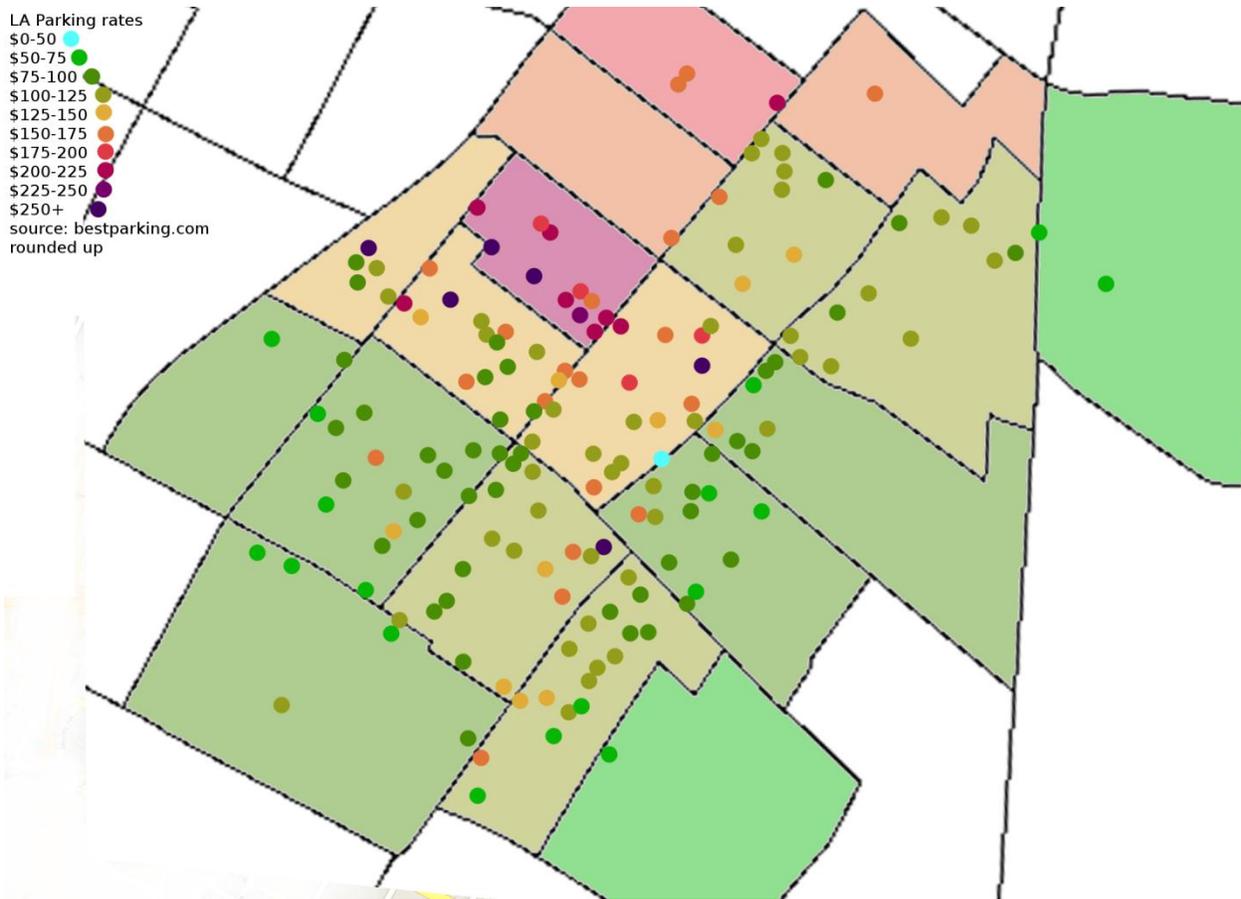


Figure 4: Raw Prices Coded in Bins, North Beach (2009 Dollars)

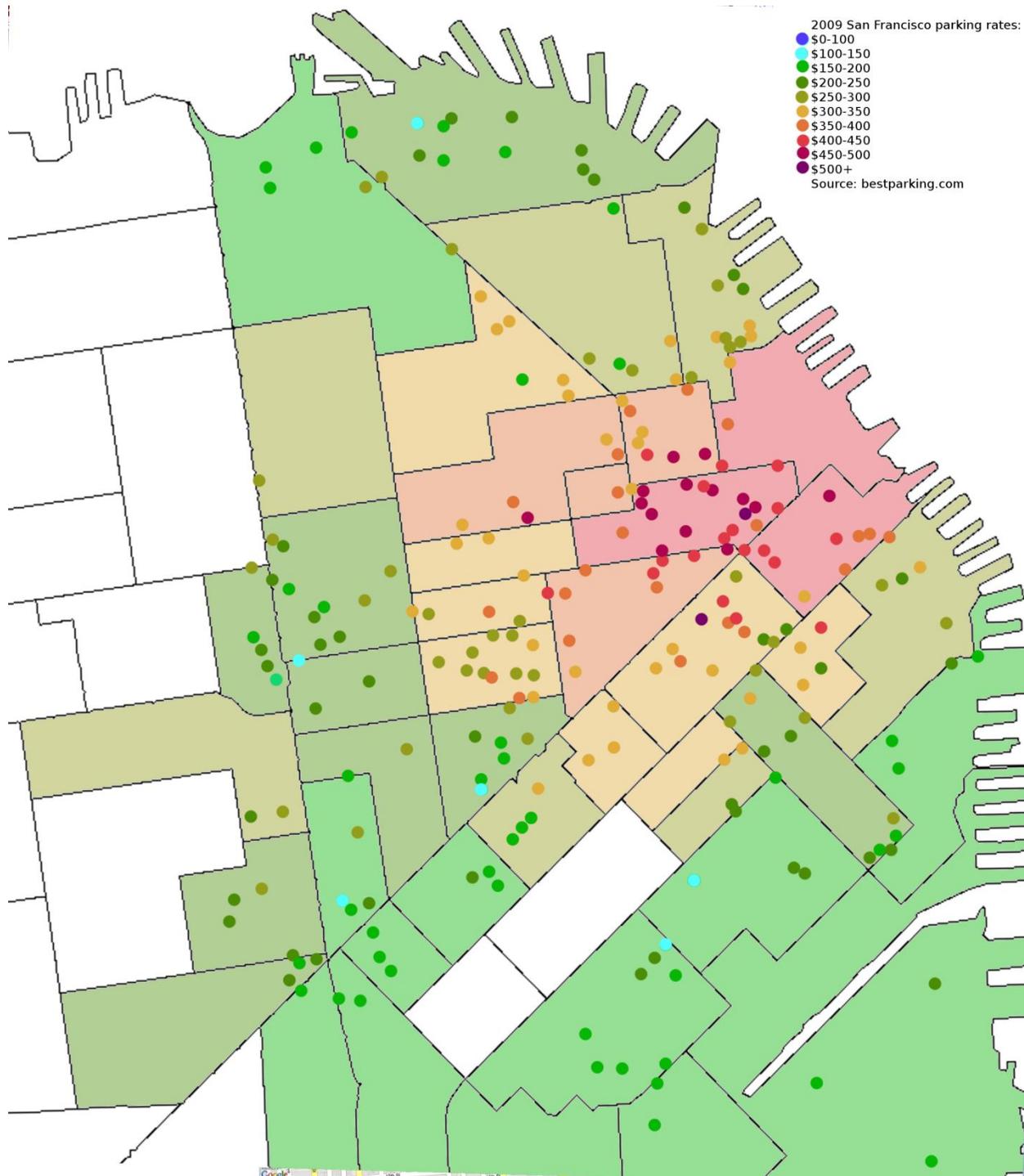


**Figure 5: TAZ Assignments and Average Prices, North Beach (2009 Dollars)**

This produced a total of 42 zonal observations in San Francisco, with monthly parking rates ranging from \$175 to \$448, and 18 in Los Angeles, with monthly rates between \$62.50 and \$215. These are shown in Figures 6 and 7 below; note that the scales are different (the light orange represents \$125-149.99 in LA, but \$300-349.99 in SF, for instance). These parking rates were then adjusted to year 2000 dollars for inclusion in the base cost data set. The Colliers series for San Francisco and Los Angeles revealed that the (linearly extrapolated) year 2000 prices were 0.8 of the 2009 prices, so this factor was used to scale the parking rates.



**Figure 6: Parking Costs in Los Angeles TAZ (2009 dollars)**



**Figure 7: Parking Costs in San Francisco TAZ (2009 dollars)**

A small number of additional parking costs were taken from Cruising for Parking, (D. Shroup, Transport Policy 13, 2006), which listed hourly off-street parking rates ca. 2001

in a few secondary centers, such as Long Beach, Pasadena, and Berkeley. These were converted to the base cost using the inverse of the hourly model as described above.

The monthly rates from both Colliers and the discrete bestparking.com data were converted to the base cost for estimation purposes, yielding a total of 116 observations.

### **3.2 Base Cost Model**

The base cost model is a linear regression, determining a zone's base cost in year 2000 dollars using intrinsic properties of the zone. Throughout the model, densities and proportions are used, so that the model is consistent regardless of the zone system or time horizon. Employment is divided into three types, by NAICS industry code, as shown in Table 2 below.

**Table 2: Industry Descriptions**

Category	NAICS code	Description
Retail	44-45	Retail Trade
	71	Arts, Entertainment, and Recreation
	72	Accommodation and Food Services
Service	51	Information
	52	Finance and Insurance
	53	Real Estate and Rental and Leasing
	54	Professional, Scientific, and Technical Services
	55	Management of Companies and Enterprises
	56	Administrative and Support and Waste Management and Remediation Services
	61	Educational Services
	62	Health Care and Social Assistance
	81	Other Services (except Public Administration)
	92	Public Administration
Other	11	Agriculture, Forestry, Fishing and Hunting
	21	Mining, Quarrying, and Oil and Gas Extraction
	22	Utilities
	23	Construction
	31-33	Manufacturing
	42	Wholesale Trade
	48-49	Transportation and Warehousing
	n/a	Military employment, all industries

Table 3 documents the parameters of the linear regression model of parking base cost.

**Table 3: Parking Base Cost Model**

Parameter	Value	T-stat
Constant	0.0714	0.08
Total employment density, 1 mi. buffer	1.500E-05	1.66
Total employment density, 2.5 mi. buffer	1.296E-04	5.97
Population density (zone)	1.953E-05	2.07
Retail employment density (zone)	5.000E-05	2.80
Service employment density (zone)	1.197E-05	3.05
Proportion of employment in retail & service	2.487	2.13

The base cost model has an  $R^2$  of 0.816, which is a good fit, as shown in the Figure 8 below. The parameters, excluding the constant, are all significant at the 90% confidence interval, with five of the six significant at the 95% confidence interval.



**Figure 8: Parking Base Cost Model Fit versus Observed (2000 Dollars)**

### 3.3 Hourly and Daily Models

The hourly and daily parking costs are derived from the base parking cost. The observed data used were the observations in the Colliers data set of monthly unreserved, daily and hourly garage parking for the available metropolitan areas in California. Because hourly parking was only added to the dataset in 2007, there was limited available data. To help remedy this, the 2007 to 2009 parking costs for other cities in the Western U.S. (Seattle, Bellevue, Portland, Boise, Denver and Phoenix) were added. The resulting data set had 48 hourly observations and 82 daily observations; 19 of each came from the other Western cities.

For both hourly and daily parking costs, the power functional form ( $\text{cost} = m \times \text{base}^n$ ) was found to have the best fit, although daily costs were concave downward and hourly were concave upward. The upward slope on the hourly cost seems to reflect the scarcity of parking effecting both the long stay and short stay markets in the cores. There is significant dispersion in the data; parking markets are idiosyncratic, and location-specific factors not represented here clearly affect the hourly parking cost in unpredictable ways. Additional data, and additional explanatory variables may help improve model fits in the future. The daily cost may be influenced into bending downward by cost pressures in the inexpensive metropolitan areas from cheap daily parking at the fringes of downtown, which hourly parking is more immune from. As a rule of thumb, daily parking costs were roughly double the base parking cost (which is the notional “daily” cost of monthly parking), where the hourly costs were roughly half the daily cost. The fits were reasonable for the limited data, and the models are shown in Table 4 and Figures 9 and 10.

**Table 4: Hourly and Daily Cost Models**

Model	Scale	Exponent	Num. obs.	R <sup>2</sup>
Hourly	0.3958	1.1806	48	0.7225
Daily	5.4733	0.5502	82	0.6385

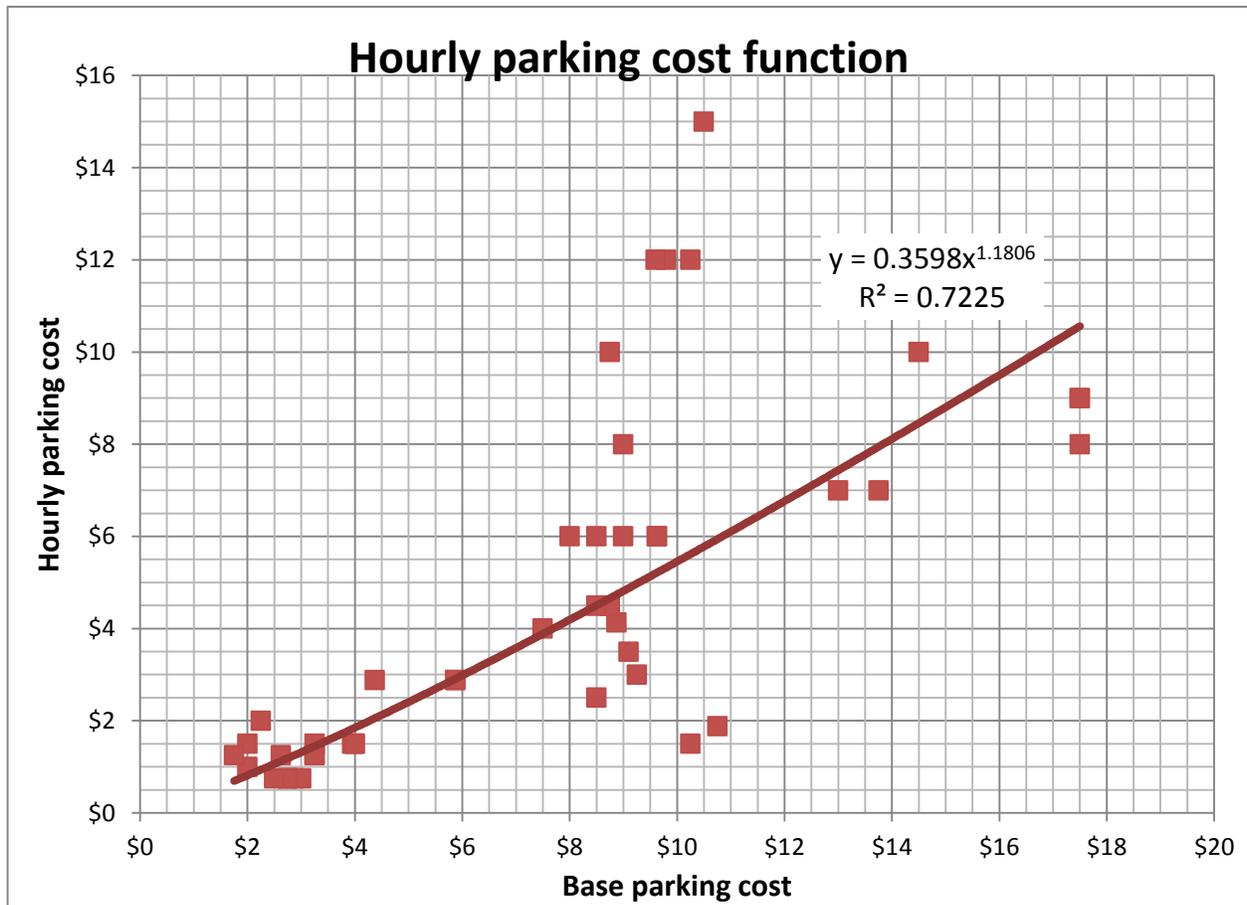


Figure 9: Hourly Parking Cost Function

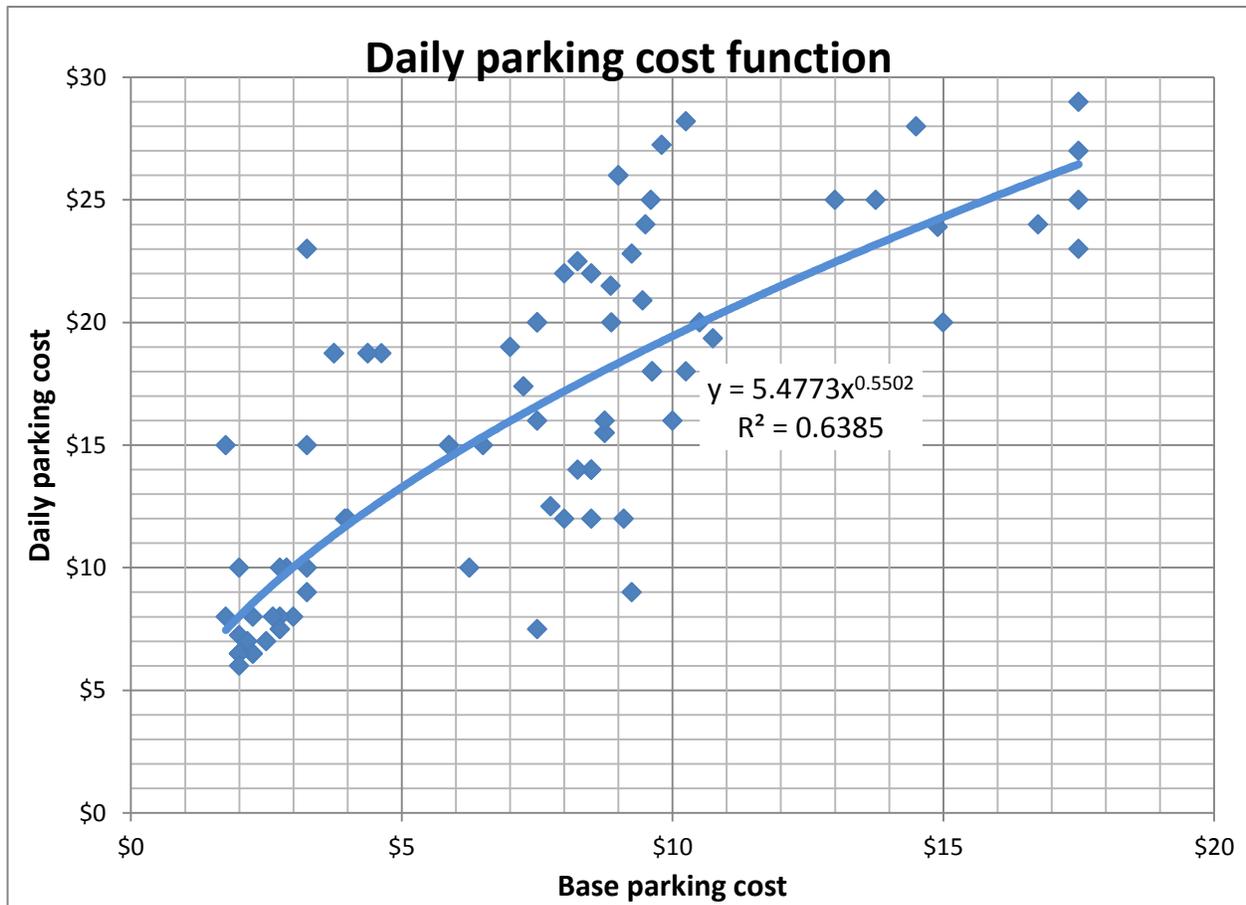
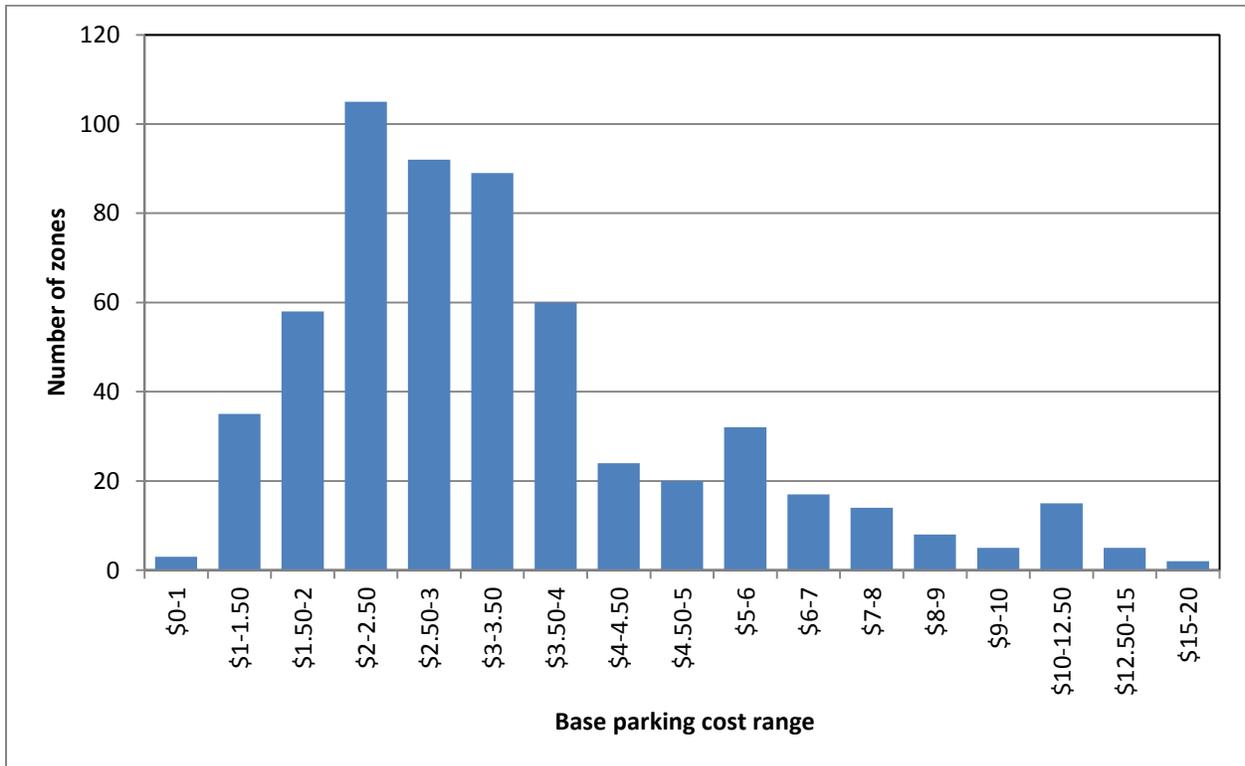


Figure 10: Daily Parking Cost Function

### 3.4 Application

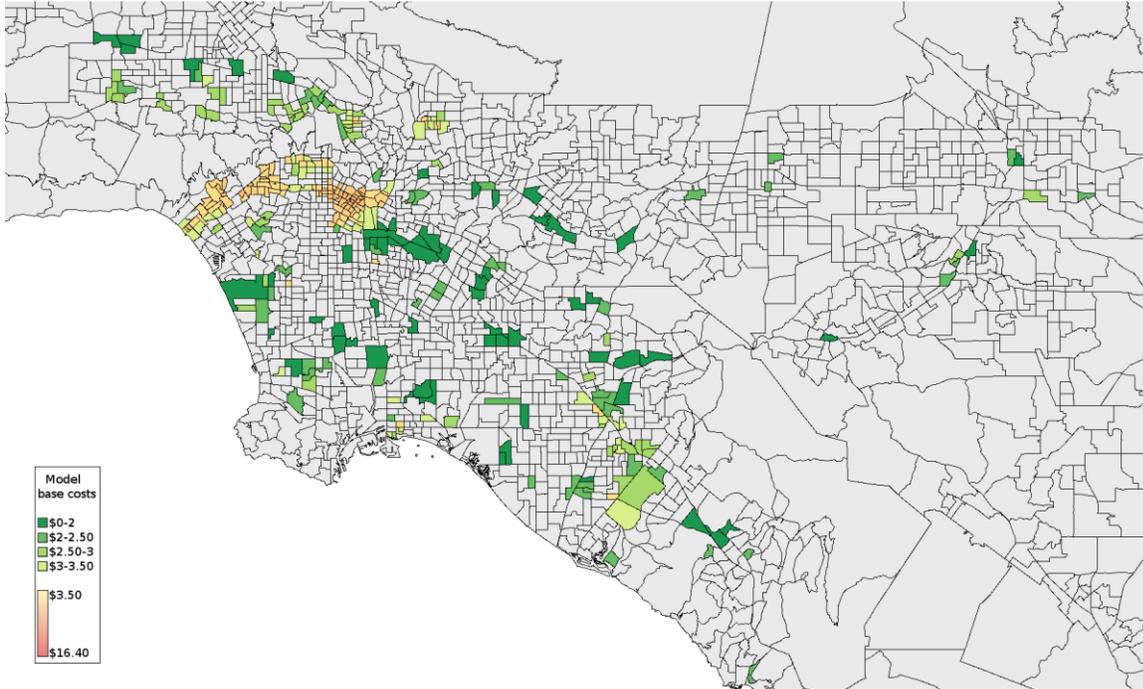
#### 3.4.1 Initial model results

The base cost model, as estimated, was applied to the year 2000 data for the state of California. With the cutoff for parking charges set to zones with greater than 5,000 nonretail jobs per square mile, a total of 584 of the 5131 zones had parking charges. Noting that the base cost model produces values in year 2000 dollars, the average base parking cost was \$3.63, which corresponds to a monthly rate of \$72.57. The average base parking cost was \$2.99. The detailed distribution of zones by parking price is shown in Figure 11 below. The model produces similar results for the 2008 employment data, with somewhat higher parking costs (as employment and employment density has increased in certain areas).

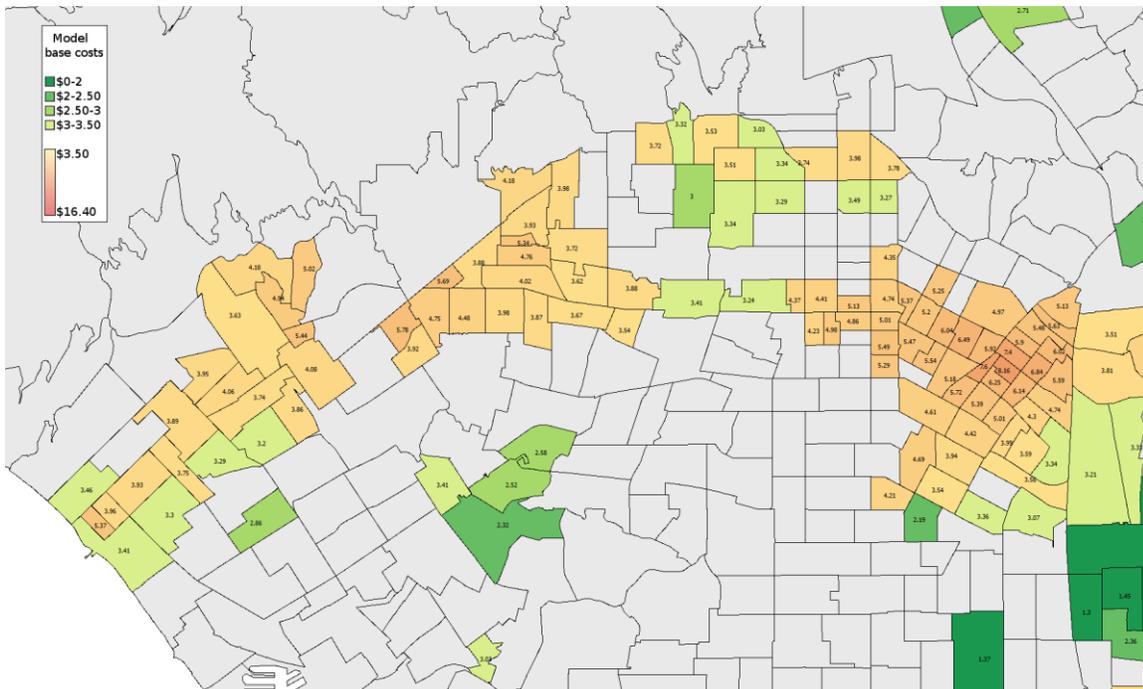


**Figure 11: Histogram of Zones by Base Parking Cost Range, Model Year 2000**

The following series of maps (Figures 12 to 17) show the distribution and values of year 2000 model base parking costs.



**Figure 12: 2000 Base Parking Costs, Greater Los Angeles**



**Figure 13: 2000 Base Parking Costs, LA Wilshire Blvd Corridor**

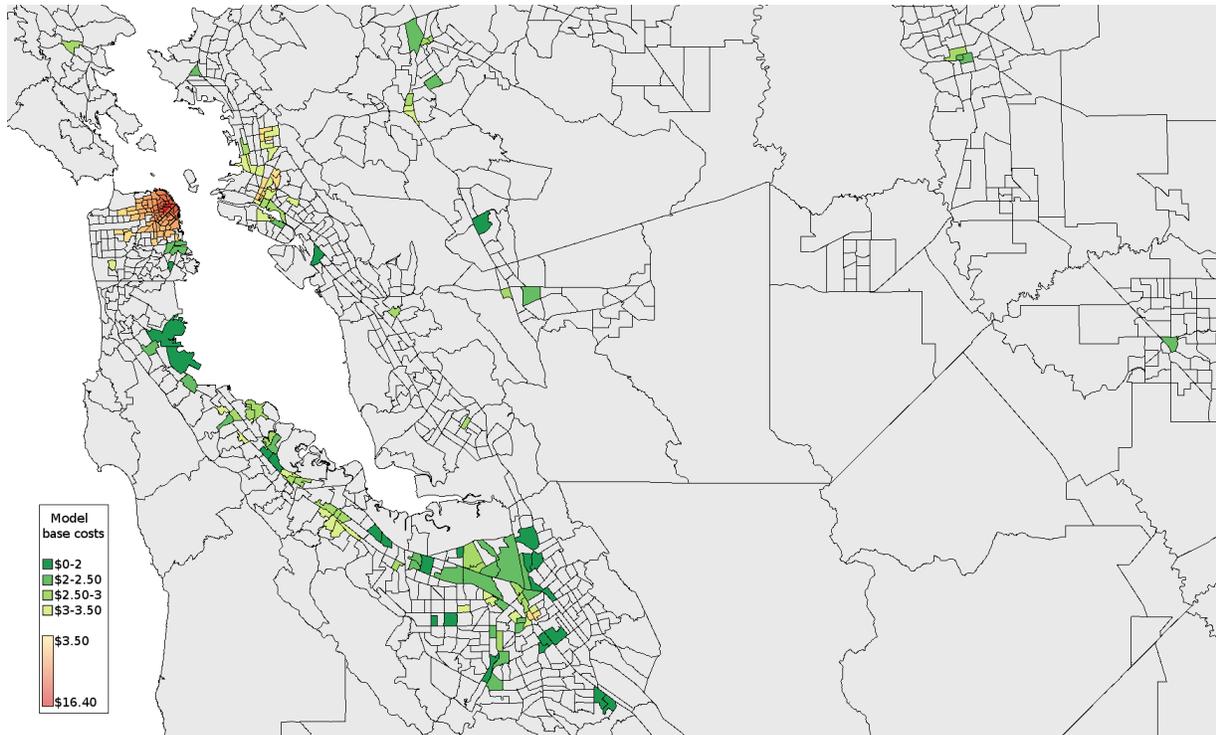


Figure 14: 2000 Base Parking Costs, Bay Area

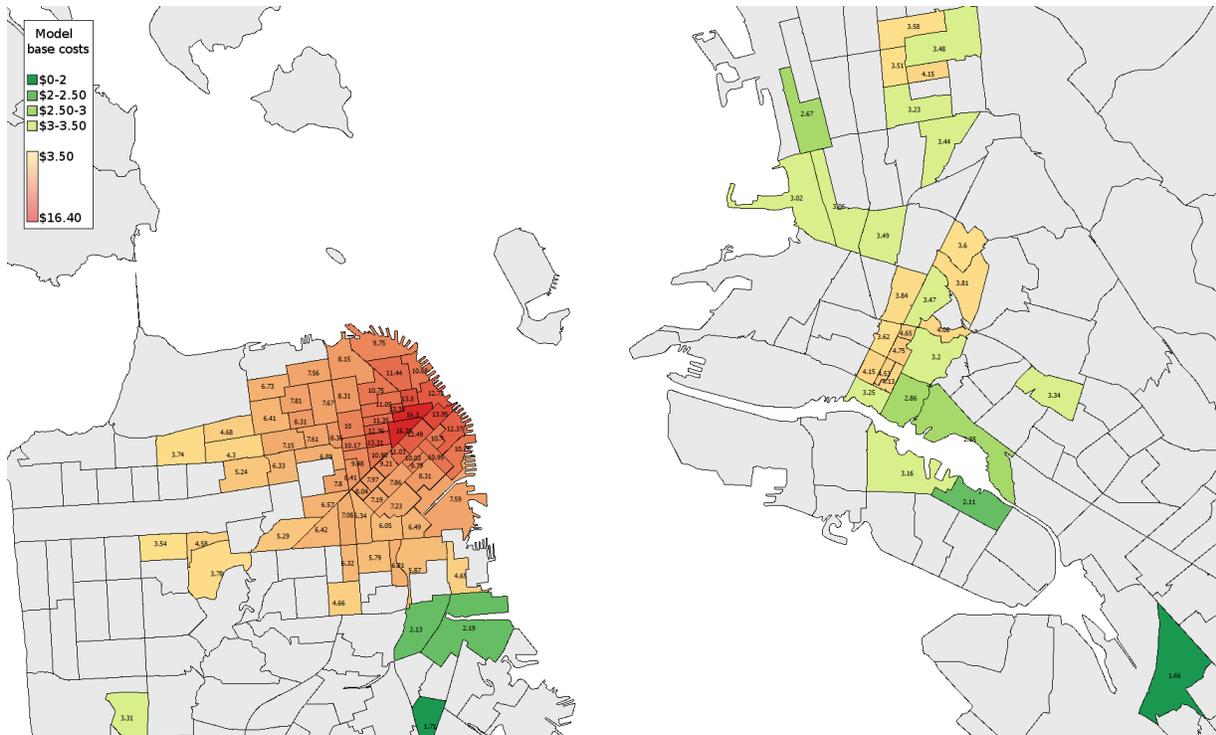
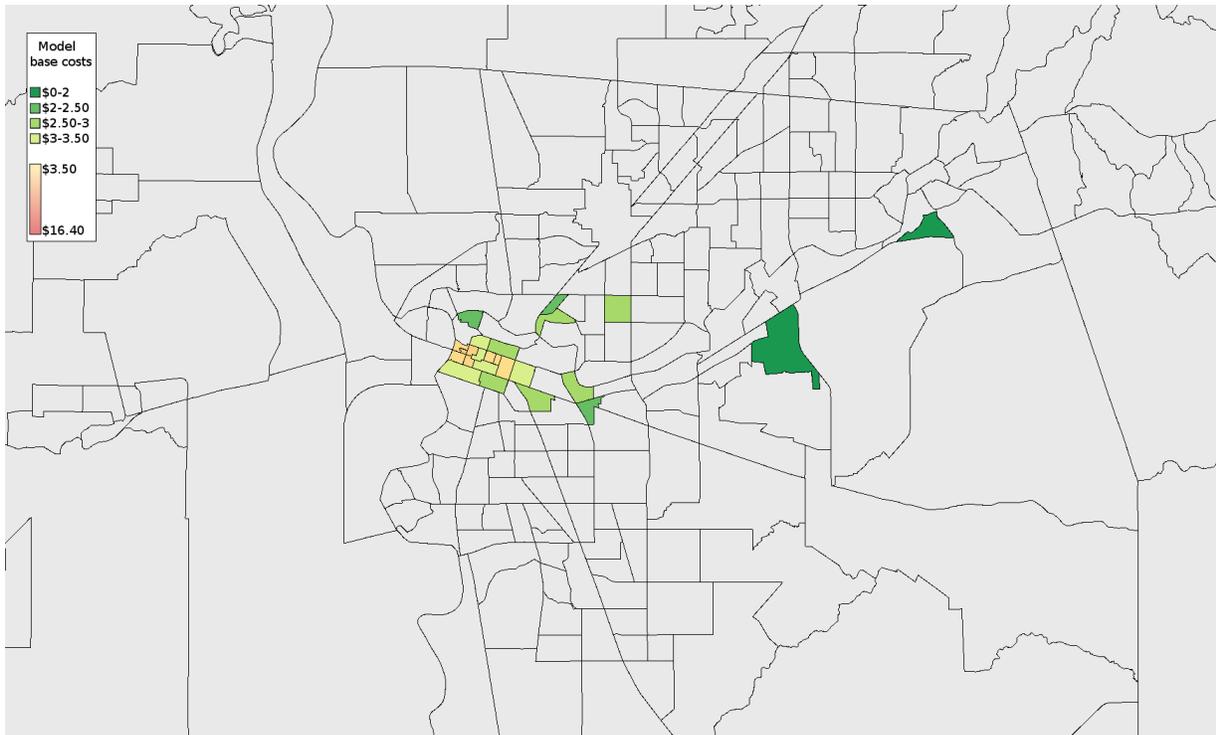
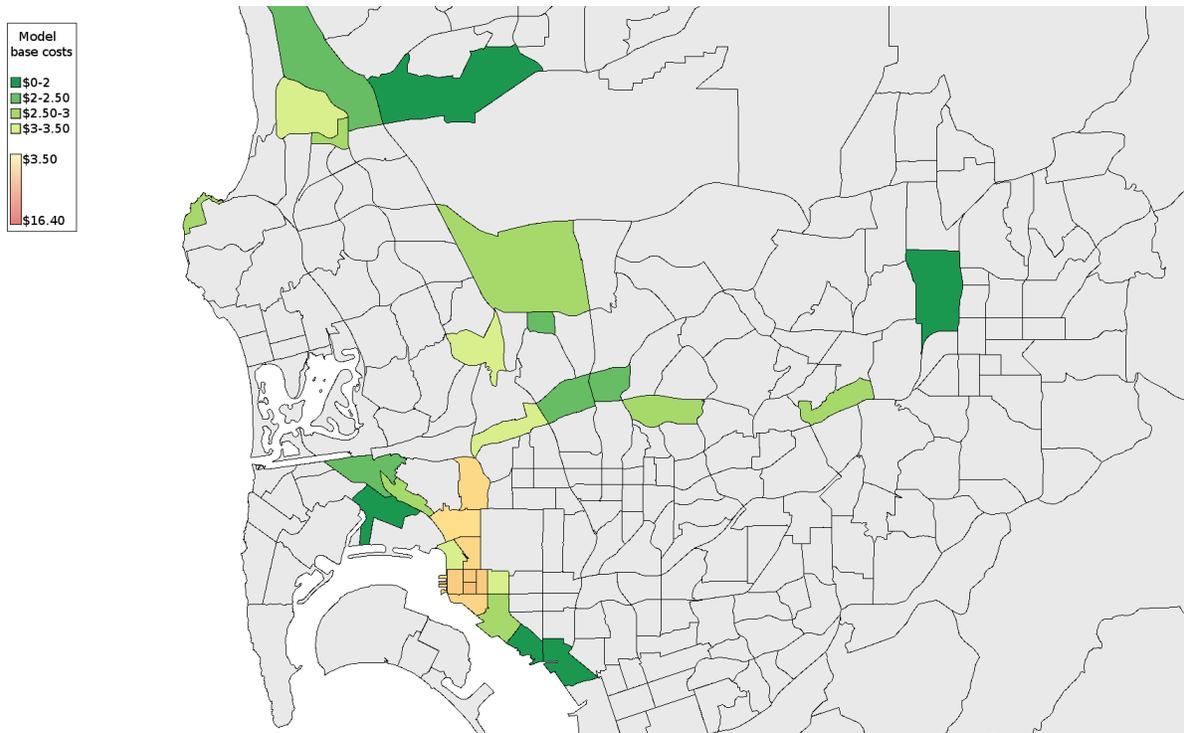


Figure 15: 2000 Base Parking Costs, San Francisco / Oakland / Berkeley



**Figure 16: 2000 Base Parking Costs, Sacramento Area**



**Figure 17: 2000 Base Parking Costs, San Diego Area**

Centers not highlighted in the previous maps with parking charges (typically one zone in the downtown; up to three for larger cities) are Stockton, Modesto, Fresno, Visalia, Porterville and Bakersfield in the Central Valley; Santa Cruz, Monterey, Salinas, San Luis Obispo, Santa Barbara and Goleta on the coast; Ventura, Thousand Oaks, Oceanside and Escondido in the SCAG/SANDAG regions, and Santa Rosa, Napa and Fairfield in the ABAG/SACOG regions.

#### **4. Model Integration**

Parking costs are calculated using the above models; the base cost is calculated first, then the daily and hourly costs are derived from these. These calculations are done in the zonal properties preparation script in the standard model run. Special parking costs can be added in the base zonal properties file. There are two fields that can be used to add special costs; Park\_Add\_Base and Park\_Add\_Day.

If a value is specified in Park\_Add\_Base, then the amount specified (in dollars) is added to the base parking cost as well as to all other parking costs developed from the base. If a value is specified in Park\_Add\_Day, then that amount (in dollars) is added to the daily parking cost as well as a consistent amount to the hourly parking costs. The base parking cost is not affected. Park\_Add\_Base can be used to change parking costs on a blanket basis, to test policies or to specify areas of additional parking cost that apply to all users. Park\_Add\_Day adds parking costs to Other trips and tours visiting a zone, but not Work or School. This is useful for areas such as airports where parking charges apply to visitors but not to staff. Eight airports currently have parking charges developed from Web searches for parking cost data; the others were in TAZ that also included other land uses where parking would be expected to be free for all users. The airports with additional parking charges are summarized in table 5 below.

**Table 5: Airports with Special Parking Costs**

TAZ	Airport	Daily Cost
602	SMF	\$9.50
1481	OAK	\$25.50
1811	SJC	\$22.50
2406	FAT	\$10.00
3370	SBA	\$12.00
4540	LAX	\$19.00
5246	ONT	\$10.00
6403	SAN	\$18.00

## 5. Summary

There are four parking costs present in the CSTDM09 model. They are:

- **Base parking cost**, which represents 1/20 of the cost of a monthly reserved space, and is used in the SDPTM for work and school travel. Produced by a model based on zonal and buffered densities, which produces year 2000 base parking costs. The model is a linear regression as described in Table 6 below.

**Table 6: Parking Base Cost Model**

Parameter	Value	T-stat
Constant	0.0714	0.08
Total employment density, 1 mi. buffer	1.500E-05	1.66
Total employment density, 2.5 mi. buffer	1.296E-04	5.97
Population density (zone)	1.953E-05	2.07
Retail employment density (zone)	5.000E-05	2.80
Service employment density (zone)	1.197E-05	3.05
Proportion of employment in retail & service	2.487	2.13

- Hourly and daily parking costs**, which represent the cost to park for an hour in a garage and the cost of daily parking purchased by the day. They are used for trips in the SDPTM for purposes other than work or school, based on the time period an activity starts and ends in as shown below; the daily is also used as the parking cost in the LDPTM. See Table 7 below.

**Table 7: Time Period to Parking Cost Type**

		Starting time period				
Ending time period		Offpeak Early	AM Peak	Midday	PM Peak	Offpeak Late
	Offpeak Early	1 Hour				
	AM Peak	2 Hours	1 Hour			
	Midday	Daily	3 Hours	2 Hours		
	PM Peak	Daily	Daily	3 Hours	1 Hour	
	Offpeak Late	Daily	Daily	Daily	2 Hours	1 Hour

Hourly and daily costs are produced by power regression (cost = scalexbase cost<sup>exponent</sup>) from the base parking cost produced in the previous model. The parameters are listed in Table 8 below.

**Table 8: Hourly and Daily Cost Models**

Model	Scale	Exponent	Num. obs.	R <sup>2</sup>
Hourly	0.3958	1.1806	48	0.7225
Daily	5.4733	0.5502	82	0.6385

- Special parking costs** are additional costs added to the base parking cost (and then carried over to the hourly and daily costs by those models). They represent specific parking costs above the market value. Currently, there are a small number special costs in the model, only applied to major airports.