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The Economic Effects of Highway Widening: Tolled Lanes vs. General-Purpose Lanes – Using an Integrated Impact Model

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Abstract

Highway expansion projects in large metropolitan areas are usually contentious. What are the full effects of highway capacity gains and who wins and who loses? This research elaborates our earlier network impact modeling work in two important directions. First, we extend our modeling capability to include highway lanes that are tolled. Second, we apply the new model to an important prototype application, the (recently) private 10-mile segment of California SR91. The possible widening of this route via extra tolled or extra general-purpose lanes has been the subject of considerable controversy. We show that our approach can shed light on key elements of such controversies and, thereby, possibly reduce political conflict and misunderstanding. We also show that whereas congestion tolls are widely presumed to be efficient, the efficiency outcomes are complex when only a very small part of the network is tolled.

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Disclosure

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Introduction

Our group has an interest in modeling the regional economic impacts of highway and other infrastructure projects. We have been particularly interested in treating the full effects of highway capacity gains and losses. The research reported here builds on our earlier work but elaborates it in two important directions. First, we have extended our modeling capability to include highway lanes that are tolled. Second, we apply the new model to an important prototype application, the (recently) private 10-mile segment of California SR91. The possible widening of this route via extra tolled or extra general-purpose lanes has been the subject of considerable controversy. A non-compete provision in the franchise awarded to the California Private Transportation Company (CPTC) had stood in the way of public agencies' efforts to provide additional capacity in the corridor. We show that our approach can shed light on such controversies and, thereby, possibly reduce political conflict and misunderstanding. We also show that whereas congestion tolls are widely presumed to be efficient, the efficiency outcomes are complex when only a small part of the network is tolled.

In Section II we discuss the general attributes of the segment of the SR91 that includes the tollway. In Section III we outline the workings of our model, SCPM2. Section IV discusses data inputs for the model's application to the analysis of hypothetical highway widening. Section V reports model results and Section VI offers some conclusions

California's SR91 Express Lanes

The SR91 Express Lanes were California's first private toll highway project. It was developed under enabling legislation passed by the California legislature in 1989. A franchise was eventually awarded to the California Private Transportation Company who financed, built, and operated two tolled lanes in each direction along 10 miles of the SR91's unused median strip between the SR91/SR55 Junction in Anaheim and the Orange/Riverside County Line. Development costs are estimated to have been $135 million. These lanes opened to traffic on December 27 of 1995. Drivers pay electronically via windshield-mounted transponders, a widely used Texas Instruments technology called FasTrak that also serves as a California bridge toll standard, and are billed monthly.

The SR91 toll lanes are an example of value pricing, i.e., of providing travelers with an opportunity to pay a premium for access to a higher level of service (Small 2001). This context provides toll facilities with an attractive policy dimension, but introduces a host of questions ranging from modeling to the politics of congestion.

CPTC developed, refined, and applied state-of-the–art pricing and photo-enforcement software and hardware and demonstrated that these perform well. Tolls varied from $0.60 to $3.20 in 1998, depending on traffic flow conditions, and the toll schedule was periodically adjusted so that 65-mph average speeds could be maintained. Most recently, peak-hour tolls went as high as $8**.** Given the target 25-minute time savings, this implies a high valuation of travel time for peak-period toll users. Three-person or larger carpools received free access on the Express Lanes.

Recent volumes on the Express Lanes were greater than 30,000 trips per day, 14 percent of weekday SR91 corridor use. Peak-hour use was 1,400-1,600 vehicles per hour per lane. Yet, capping a controversy over how corridor capacity should be expanded to respond to growing demand, the lanes were recently sold to the Orange County Transportation Authority (OCTA) for $207 million, with ownership transfer occurring in early 2003. Now OCTA and the California Department of Transportation (Caltrans, District 12) will have the flexibility to add to capacity or change the mix of toll and free lanes. To our knowledge, the type of analysis reported below was not done. Detailed results of user surveys are described at http://www.path.berkeley.edu/~leap/TTM/Demand_Manage/pricing.html. Many of the cited descriptive data are from Caltrans' final evaluation report published in 2000 and available at http://www.ceenve.calpoly.edu/sullivan/SR91/sr91.htm.

The Southern California Planning Model (SCPM)

Regional economists and regional planners often rely on interindustry models. The details of intersectoral linkages in these models are useful for exploring regional economic structure. However, this approach has not permitted an adequate treatment of transportation costs, not all of which are transacted because most roads are publicly provided.

This problem has been addressed at the national level by the Bureau of Transportation Statistics effort to create Transportation Satellite Accounts (Han and Fang, 2000).

Such spatial elaborations require explicit treatment of the resources consumed by flows between origin-destination pairs. While explicit representation of the transportation network is usually less important in multiregional approaches, it is another matter at the intrametropolitan level, where congestion dominates line-haul costs. Along with the explicit treatment of transport costs, we have developed sub-metropolitan area level disaggregations of a regional economic model. Richardson *et al*. (1993) developed the Southern California Planning Model-1 (SCPM1), combining a metropolitan level input-output model with a Garin-Lowry model to spatially allocate induced economic impacts. This model operationalized spatial input-output analysis at the intrametropolitan level. SCPM1 could allocate impacts in terms of jobs or the dollar value of output to the area's 308 sub-regional (municipal) zones. It did not treat the transportation network explicitly. Congestion effects were ignored, and transportation flows were exogenous.

The Southern California Planning Model (SCPM1) and its successors have been developed for the Los Angeles metropolitan region. The study area includes Los Angeles, Orange, Riverside, San Bernardino and Ventura counties. The area covers almost 34,000 square miles. The 2000 population of the five-county area was over 16.3 million.

In 2000, the urbanized portions of the five-county area extended to 1,668 square miles; population density in the urbanized area was about 7,068 people per square mile, the highest in the U.S. The urbanized area is described in terms of the Southern California Association of Government's (SCAG's) 1996 system of 3,192 traffic analysis zones (TAZs; reduced to 1,464 TAZs in the exercise that follows). The corresponding regional highway network includes 88,649 links.

Table 1 provides some recent aggregate data describing the region. The total households in the area were 5.35 million in 2000. The nonfarm employment in the SCAG region was over 5.11 million in 1999. The employment distribution across industry sectors is: 34.3 percent in services, 16.4 percent in manufacturing, 13.3 percent in government, 9.6 percent in retail, and 7.3 percent in FIRE. International exports from the five-county area have been reported to be $35.7 billion in 1996 (Exporter Location Series, US Bureau of the Census); our analysis suggests, however, that this may be a significant underestimate.

Table 1: Socio-Economic Profile, Los Angeles Five-County Area

County	Population	Households	Private Non-Farm Employment	Median Household Income	Mean Commute Time (mins.)	Land Area (sq. mi.)
Year	2000	2000	1999	1999	2000	
Los Angeles	9,519,338	3,133,774	3,747,755	$42,189	29.4	4,061
Orange	2,846,289	935,287	1,330,960	$58,820	27.2	789
Riverside	1,545,387	506,218	366,358	$42,887	31.2	7,207
San Bernardino	1,709,434	528,594	440,958	$42,066	31.0	20,052
Ventura	753,197	243,234	224,817	$59,666	25.4	1,845
Five-County Area	16,373,645	5,347,107	6,110,848	$45,957*	29.1	33,954

* Weighted mean; median not available.

Source: http://quickfacts.census.gov/qfd/

Integrating a transportation network into SCPM1 provides important opportunities. Distance decay relationships (destination choice) can be endogenized, permitting an improved spatial allocation of indirect and induced economic impacts. Also, this integration makes it possible to better account for the economic consequences of changes in transportation network capacity, such as the prospect of widening portions of SR91.

Recent work resulted in the development of SCPM2, which treats the transportation network explicitly, endogenizing otherwise exogenous matrices describing the travel behavior of households, achieving consistency across network costs and origin-destination requirements, and endogenizing indirect and induced economic impacts over zones (Cho, et al 2001).

The current research extended the model so that network segments that are tolled can be included. The current version of the model, SCPM2.5, relies on a constrained optimization model that combines traffic assignment and trip distribution. A path-flow version of this model is

$$Z = \min Z(\mathbf{x},\mathbf{q}) = \sum_a \int_0^{x_a} t_a(w) \quad dw + \sum_p \left(\frac{1}{\beta^p} \sum_r \sum_s q_{rs}^p \cdot \ln\left(q_{rs}^p\right) \right) \tag{1}$$

subject to

$$f_{rs}^{pk} \geq 0 \qquad \forall\, p,\, k,\, r, s \tag{2}$$

$$q_{rs}^p \geq 0 \qquad \forall p,\, r, s \tag{3}$$

$$\sum_k f_{rs}^{pk} = q_{rs}^p \qquad \forall\, p, r, s \tag{4}$$

$$x_a = \sum_p \sum_{rs} \sum_k f_{rs}^{pk} \cdot \delta_{a,k}^{rs} \quad \forall\, a \tag{5}$$

where

t_a = link performance function of link *a*.
x_a = flow on link *a*.
q_{rs}^p = trip rate of type *p* between OD pair *r*-*s*.
f_{rs}^{pk} = flow of trip type *p* on path *k* connecting OD pair *r*-*s*.
u_{rs} = travel time between OD pair *r*-*s*.
$\delta_{a,k}^{rs}$ = 1 if link *a* is on path *k* between OD pair *r*-*s*, 0 otherwise.

Trips are disaggregated into nine types of personal trips (*m*), and freight trips from four industrial sectors (*n*).

m: 1 = home-to-work, 2 = work-to-home,
3 = home-to-shop, 4 = shop-to-home,
5 = home-to-other, 6 = other-to-home,
7 = work-to-other, 8 = other-to-work,
9 = other-to-other,

n: 1 = Mining,
2 = Manufacturing (non-durable),
3 = Manufacturing (durable),
4 = Transportation,
5 = Communications and Utilities

The economic impact on industry *n* in zone *r* is

$$V_r^n = V_r^{n,D} + V_r^{n,I} + V_r^{n,U}$$

where,

$V_r^{n,D}$ = Given net direct impact on industry *n* in zone *r*
$V_r^{n,I}$ = Net indirect impact on industry *n* in zone *r*

$$V_r^{n,I} = \frac{\exp\left(\alpha^n + \beta^n \cdot u_{sr}\right)}{\sum_z \exp\left(\alpha^n + \beta^n \cdot u_{sz}\right)} \cdot V^{n,I} \cdot \left(\frac{V_s^{n,D}}{V^{n,D}}\right)$$

$V_r^{n,U} =$ Net induced impact on industry n in zone r

$$V_r^{n,U} = JHS \cdot \left(JHW\right)^T \cdot \frac{\exp\left(\alpha^n + \beta^n \cdot u_{sr}\right)}{\sum_z \exp\left(\alpha^n + \beta^n \cdot u_{sz}\right)} \cdot V^{n,U} \cdot \left(\frac{V_s^{n,D}}{V^{n,D}}\right)$$

$$JHW = \frac{q_{rs}^{m=1}}{\sum_r q_{rs}^{m=1}},\ q_{rs}^{m=1} = \text{Journey home-to-work matrix}$$

$$JHS = \frac{q_{rs}^{m=3}}{\sum_s q_{rs}^{m=3}},\ q_{rs}^{m=3} = \text{Journey home-to-shop matrix}$$

The solution algorithm for SCPM2.5 is shown and discussed in Appendix A.

Data Inputs

Spatially disaggregated modeling requires the preparation of input data at fine levels of geographic detail. Most model input data were collected at the census block level, the base unit for all census data. We assembled detailed spatial and aspatial information for the study area, including Census 2000 population data, SCAG 1997 employment data providing employment by four-digit SIC category by street address, USGS 1-meter resolution air photos, and similar sources. Along with baseline data on the region, exogenous impacts on economic and transportation systems from hypothetical SR91 expansions are suggested.

Because the expansion of SR91 is still a hypothetical project, there are no data on the exact expansion boundaries. However, it is possible to identify the housing and business units likely to be along the freeway alignment by referring to USGS air photos. Unfortunately, the available USGS air photos were taken several years ago and do not provide up-to-date land use information. It was also problematic to match the air-photos with the alignment of the freeway because they are represented in different GIS projection systems. We relied on field inspections to update the land uses shown by the USGS air-photos to obtain up-to-date information on the land uses most likely to be impacted. From our field inspections it was determined that 266 housing units are likely to be impacted by a hypothetical freeway expansion project. Most of these are located in low-density residential areas. All of them are in the city of Anaheim. No businesses were found to be located in the likely impact area of the freeway expansion because all existing business are set back from the alignment.

Predicting the destination settlements of the relocating households involved two steps. First, an empirically established distribution function was used to generate moving distances (Clark 2002). The mean move was estimated to be 6.28 miles. Second, most likely move-in locations for each impacted household were determined by identifying the center of the census block with average housing unit price closest to that of the census block from which the household would move. This means that each move-out household is relocated to a place with a housing unit price similar to the original residence. Some households might decide to trade up or down. Others might decide to move out of the region. There are no data available on this possibility, so we assumed and modeled a quasi-equilibrium response.

The number of move-out and move-in households in each census block was used together with county, city, TAZ, congressional district and school district information to generate input data for the SCPM runs. As households are relocated, their expenditures, including property and sales taxes**,** are also relocated. Based on available data, it is possible to determine the median housing value, household income, sales tax rate, property tax rate and other inputs to SCPM. Detailed input data development procedures are shown in Appendix B.

Model Results, Hypothetical Expansion of SR91 Capacity

Highway Network Effects

Network flow estimates are shown in Tables 3 and 4. Table 3 provides baseline and scenario results, reporting network delay costs and tolls paid. Tolls paid are a transfer from users to owners. However, total user costs are the sum of delay costs and tolls, and it is this total cost to which users respond. About 17 percent of the estimated baseline passenger-car-equivalents on the entire network consist of freight shipments.

We consider and report on two facility expansion scenarios combined with six operating options for a total of twelve scenarios, plus 5 operating options for the existing facility. Tolls on SR91 vary by time of day. SCPM2 results are scaled to 24-hour periods. The analysis relies on a composite SR91 toll that approximates a weighted average charge across 24 hours.[1]

The two facility expansion scenarios are:

- add a toll lane in each direction, providing 4 general purpose lanes and 3 toll lanes in each direction (the 4+3 scenario), or
- add a general purpose lane in each direction, providing 5 general purpose lanes and 2 toll lanes in each direction (the 5+2 scenario).

[1] Only high-occupancy vehicles were allowed on the toll lanes. In this study, however, the toll lanes are not assumed to be HOV lanes, and vehicles were allowed to choose their route only based on the sum of delay cost and tolls.

Table 2: Annual Network Costs ($1,000)

Scenarios		Passenger		Freight		Sum		
	Toll	Delay Cost	Toll Paid	Delay Cost	Toll Paid	Delay Cost	Toll Paid	Total
4+2	$1	14,418,680	169,480	2,997,823	41,772	17,416,504	211,252	17,627,756
	$2[1]	14,433,917	153,478	3,024,640	14,693	17,458,556	168,171	17,626,727
	$3	14,462,734	125,423	3,030,641	8,789	17,493,376	134,213	17,627,588
	$4	14,495,565	91,448	3,033,802	5,476	17,529,367	96,924	17,626,291
	$5	14,535,631	51,479	3,037,384	1,799	17,573,015	53,278	17,626,293
	$6	14,587,478	-	3,039,334	-	17,626,812	-	17,626,812
4+3[2]	$1	14,377,372	210,437	2,992,311	47,246	17,369,684	257,683	17,627,367
	$2	14,421,121	166,114	3,023,568	15,744	17,444,689	181,857	17,626,547
	$3	14,454,085	134,062	3,029,880	9,540	17,483,965	143,602	17,627,568
	$4	14,491,957	95,037	3,033,788	5,476	17,525,745	100,513	17,626,257
	$5	14,535,619	51,480	3,037,206	1,967	17,572,825	53,446	17,626,271
	$6	14,587,467	-	3,039,324	-	17,626,791	-	17,626,791
5+2[2]	$1	14,423,509	164,429	2,998,337	41,234	17,421,846	205,663	17,627,509
	$2	14,502,937	84,780	3,022,475	16,880	17,525,412	101,660	17,627,072
	$3	14,544,779	42,289	3,034,614	4,687	17,579,394	46,975	17,626,369
	$4	14,571,935	14,783	3,038,355	918	17,610,290	15,701	17,625,990
	$5	14,586,856	-	3,039,166	-	17,626,023	-	17,626,023
	$6	14,587,368	-	3,039,323	-	17,626,691	-	17,626,691

Notes: 1. Baseline

2. 4+3: 4 general purpose lanes and 3 toll lanes each direction; 5+2: 5 general purpose lanes and 2 toll lanes, each direction

Table 3: Increments in Annual Network Costs Relative to the Baseline ($1,000)

Scenarios		Passenger		Freight		Sum		
	Toll	Delay Cost	Toll Paid	Delay Cost	Toll Paid	Delay Cost	Toll Paid	Total
4+3	$1	-56,544	56,960	-32,328	32,553	-88,873	89,512	640
	$2	-12,795	12,636	-1,072	1,050	-13,867	13,686	-181
	$3	20,169	-19,415	5,240	-5,153	25,409	-24,569	840
	$4	58,040	-58,441	9,148	-9,218	67,188	-67,658	-470
	$5	101,703	-101,998	12,566	-12,727	114,269	-114,725	-456
	$6	153,551	-153,478	14,684	-14,693	168,234	-168,171	63
5+2	$1	-10,408	10,951	-26,303	26,541	-36,711	37,492	781
	$2	69,020	-68,697	-2,164	2,186	66,856	-66,511	345
	$3	110,863	-111,189	9,974	-10,007	120,837	-121,196	-358
	$4	138,018	-138,695	13,715	-13,776	151,733	-152,470	-737
	$5	152,940	-153,478	14,527	-14,693	167,466	-168,171	-705
	$6	153,451	-153,478	14,683	-14,693	168,134	-168,171	-37

Note: The assumed value of time per person is $6.5/hour. These calculations assume 1.1 persons per car, $35.5/truck hour, 2.0 PCEs per truck, and 365 days per year. Value of travel time assumptions are controversial. The Caltrans (2000) SR91 report notes that $6 to $14 per hour values were inferred from patterns of tollway use on the SR91. See also Small and Yan (2001) and Verhof and Small (1999).

The operating options are defined by varying the composite toll charged on the tolled lanes from values of $1 to $6.[2] Table 3 shows increments in network delay costs and tolls collected by alternative. Turning to the dollar values of impacts, annual reductions in network resulting from adding a toll lane are either $14 million or $89 million if the facility tolls are $2 and $1, respectively. With respect to general-purpose lanes, annual reductions in network delay are $37 million if the facility toll is kept to one dollar. For all higher tolls, there are increases in network delay in the range of $67 million to $168 million. For both of these cases, higher tolls on the facility cause system-wide increases in delay. The tolls improve level of service on the tolled facilities, but intensify demand for the general-purpose lanes and other parallel paths in the network.

Despite the presumed efficiency advantages provided by road tolls, adding SR91 capacity in the form of general-purpose lanes offers greater reductions in total network delay than does adding toll lanes. Thus, from a network perspective, adding tolls on selected facilities does not necessarily improve system performance. Tolls, while allowing for more efficient use of the tolled segment, also have the effect of diverting traffic to other parts of the network, causing other links carry greater volumes. This effect is amplified as these selective tolls are increased, with the highest tolls resulting in a loss of system efficiency relative to the baseline.

An average toll of $5 corresponds to 45 minutes if the passenger's value of time is $6.5 per passenger-hour. At this toll level, there are no system-wide benefits delivered by either facility alternative. These results seem counter-intuitive but such partial equilibrium effects often differ from general equilibrium effects. System-wide tolls can be set to maximize net revenues, throughput, or to minimize travel delay. Minimizing travel delay delivers efficiency improvements if decreases in total delay are sufficient to offset the administrative cost of collecting the tolls. Limited tolling may create efficiencies along a link, but unless all segments of the network are tolled, it is not clear that such a limited toll strategy will increase network efficiency. Traffic may be shifted to other routes. Indeed, this was one of the sources of the political controversy over the California Department of Transportations non-compete agreement with CPTC. This agreement precluded expansion of the SR91 general-purpose lanes.

Most of the early academic literature on congestion tolls concludes that they are efficient. In recent years, some theoretical attention has been directed to the question of second-best toll strategies that are consistent with value pricing options. In these circumstances, tolls are introduced incrementally on new or existing facilities competing with untolled links. This makes the level of congestion in untolled lanes an important variable or parameter, depending on whether the system of interest consists of the tolled facilities or the network (Verhoef, Nijkamp, and Rietveld 1996; Small and Yan 2001).

[2] The values of time for passengers ($6.5/ hour) and trucks ($35.5/ hour /PCE) were weighted according to system-wide delay costs generated by passenger cars and trucks. The composite toll was based on the weighted average ($8.41/hour/PCE). Thus, $1 corresponds to 7.1 minutes in the model.

The standard theoretical discussion examines various public and private objectives given a simple hybrid system consisting an origin-destination pair, and a toll facility competing with a single, parallel, untolled path. This approach makes it possible to investigate general principles and strategies.

The network simulations with our model involve modifying the volume delay functions for network links to include tolls. System cost is the product of link volumes and corresponding travel times summed over all the links in the network. Consider the simplified example provided in Figure 1. A fixed demand for travel is allocated over competing links a_1 and a_2. Equilibrium flows occur at congested travel time T. In the untolled case, system cost is the sum of shaded areas P and Q in Figure 2.

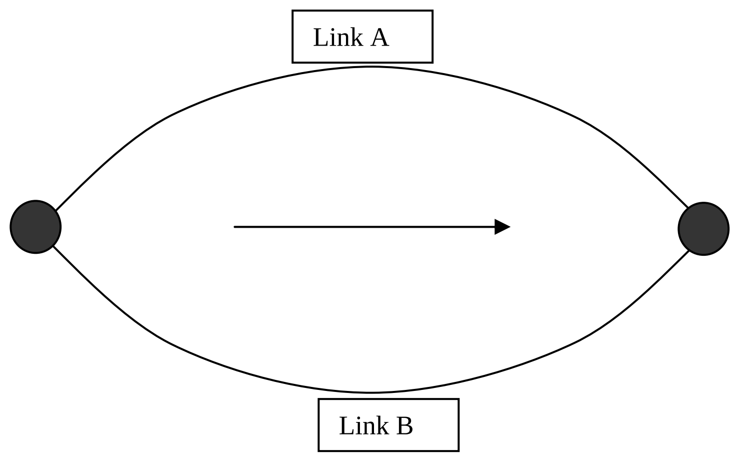

Figure 1. Simple Network System with One Zone-Pair and Two Competing Links

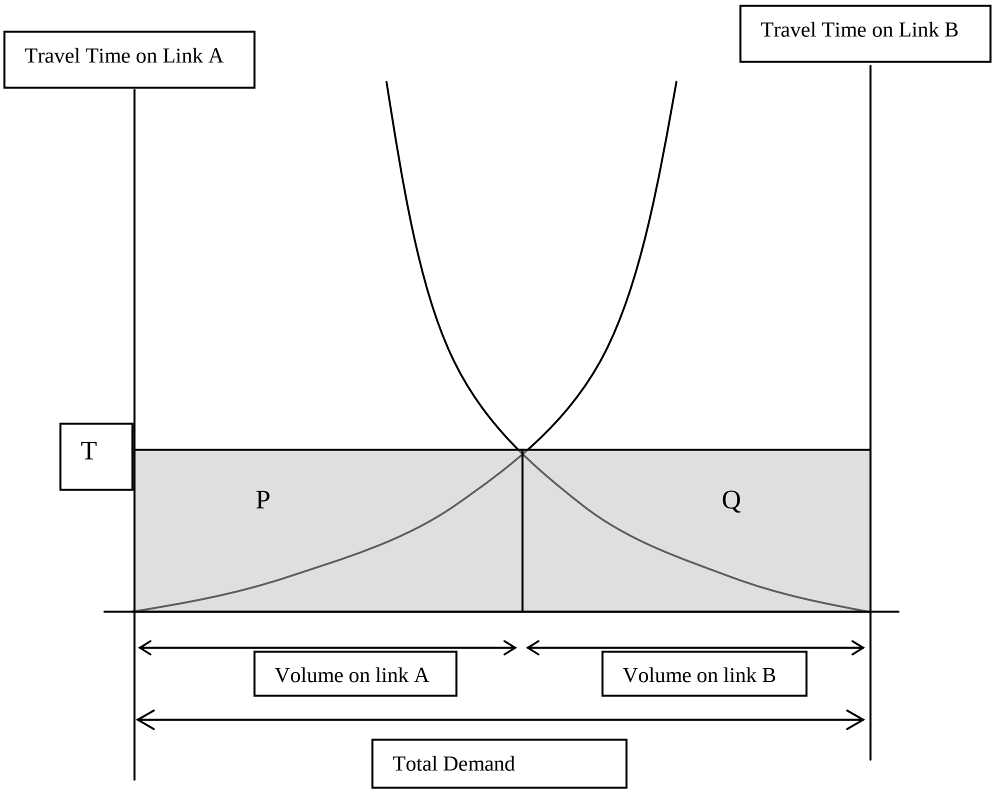

Figure 2. Performance of the Simple Network without Tolls

Time has value. For modeling purposes, imposing a toll on a link is equivalent to modifying the volume-delay function for the link so that all vehicles on the link experience a corresponding increase in travel time. In the case of an ideal toll, this resets average cost to marginal cost. If a toll is applied to link A, the existing volume delay function shifts upward by a value corresponding to the toll.

In this example, the toll on link a_1 is set to keep its congestion on this link low by *shifting* the demand away to link a_2, with no attention to the increased congestion on the untolled link. This formulation may explain many of the results of the simulation, which show that some toll levels have negative network-wide impacts. Yet, this is probably the correct approach because it accounts for the political controversy that caused public officials to purchase the private segment of SR 91.

If travel demand is fixed in this simple system, the new equilibrium travel time T' in Figure 3 is greater than T in Figure 2. As a result, total system cost increases relative to the untolled case. Area P_1' is the system cost due to congestion on a_1. Area P_2' is the revenue provided to the owner of toll road, expressed in units of time.

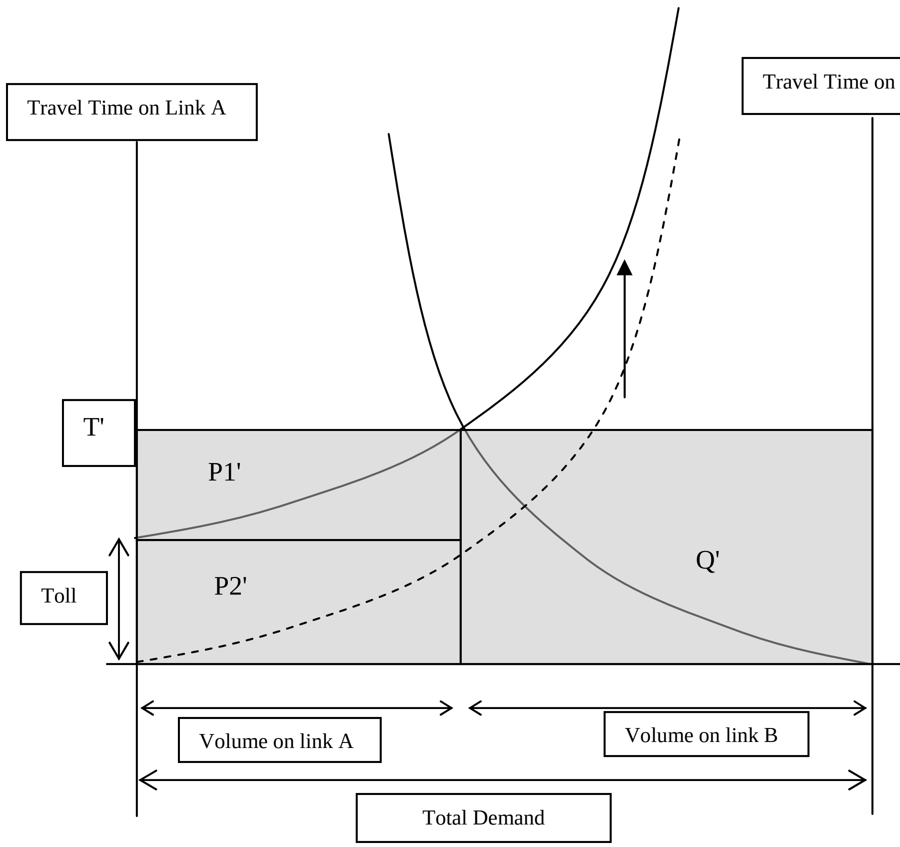

Figure 3. Performance of the Simple Network System with Toll on Link a_1

Our examination of the SR91 toll facilities treats these in the context of the real world, SCPM network described above. While we are able to simulate flows and changes in flows, we do not identify optimal tolls. Nevertheless, similar to the cited literature, our analysis of network flows suggests that efficiency gains will not necessarily be achieved by selective tolling. Selective tolls again produce a second-best result whereby more efficient use of a particular link occurs at the expense of performance throughout the rest of the system. The more congestion there is on untolled facilities, the greater the possible efficiency loss from value tolls. This has substantial policy relevance, because tolls are inevitably introduced on a facility-by-facility basis. Further, private interests have the greatest incentive to risk their capital on the construction of new facilities when congestion on competing routes is high. The modeling consequences highlighted here include the importance of being able to compare the system effects of adding tolled versus untolled capacity. Our results show that large-scale facility investment decisions require that this be done in the context provided by a model of the complete network.

Household Relocation Effects

The aggregate regional effects of household relocation are minor. See Table 4. Approximately $24 million in annual household expenditures are removed from the path of the highway expansion and are relocated throughout the region. Aggregate impacts are small. The importance of these calculations is to show spatial redistribution effects. We have been able to calculate the direct, indirect, and induced impacts of the relocations by traffic analysis zone. These and total net impacts in terms of thousands of dollars of income for 1,464 TAZs are mapped in Figures 4a through 4d.

Direct impacts result from displaced households. Negative impacts occur in locations adjacent to the freeway right of way. Positive impacts are more widely distributed as households relocate according to an empirically established distribution function (Clark et al.'s 2002).

Indirect, induced, and total impacts are much more widely dispersed. SCPM2 has the unique capability to estimate these complex spatial effects. A regional input-output model estimates aggregate indirect and induced impacts from positive and negative direct impacts respectively. These impacts are then spatially disaggregated according to activity patterns, represented by passenger and freight O-Ds, while these O-Ds are adjusted by the disaggregated impacts (See Appendix A for details). SCPM2 results are sector-specific, but are here reported in terms of total dollars.

Table 4: Summary Economic Impacts of Residential Relocation, One-Lane Expansion of SR91 in Each Direction ($1,000s of 1999 dollars)

$1000	Positive	Negative	Net
Direct	14,405	-14,421	-16
Indirect	3,621	-3,635	-15
Induced	5,834	-5,823	12
Total Impacts	23,860	-23,879	-19

Note: Negative impacts are generated at residents' move-out relocations. Positive impacts are generated at residents' move-in relocations.

Most of the (net) negative direct impacts are allocated along the SR91 corridor toward the SR91/SR55 junction. Most of the zones with positive net impacts are concentrated within a 10-mile radius, adjacent to the zones with direct negative impact (see Figure 4a). Indirect impacts, which are allocated based on work trip patterns, are located in zones within a 15-miles radius from the center of the direct impacts. Induced effects were allocated even further from the SR91. Figure 4c shows that most of the zones with (net) negative induced impact are found from Orange and San Bernardino Counties while zones in Los Angeles County were experiencing positive impacts. Figure 4d shows total net impact for a representative case, two tolled lanes plus five untolled lanes in each direction with a $2 toll. Results for the other scenarios are similar.

Applying SCPM makes it possible to support a detailed cost benefit analysis of individual projects. We have already calculated the annual network benefit of various capacity options. The model can also be used to calculate the spatial and sectoral incidence of construction expenditures, as well as the spatial and sectoral incidence of alternative approaches to financing the project. This joint treatment of benefits and costs in substantial spatial and sectoral detail allows a discussion of equity as well as efficiency consequences.

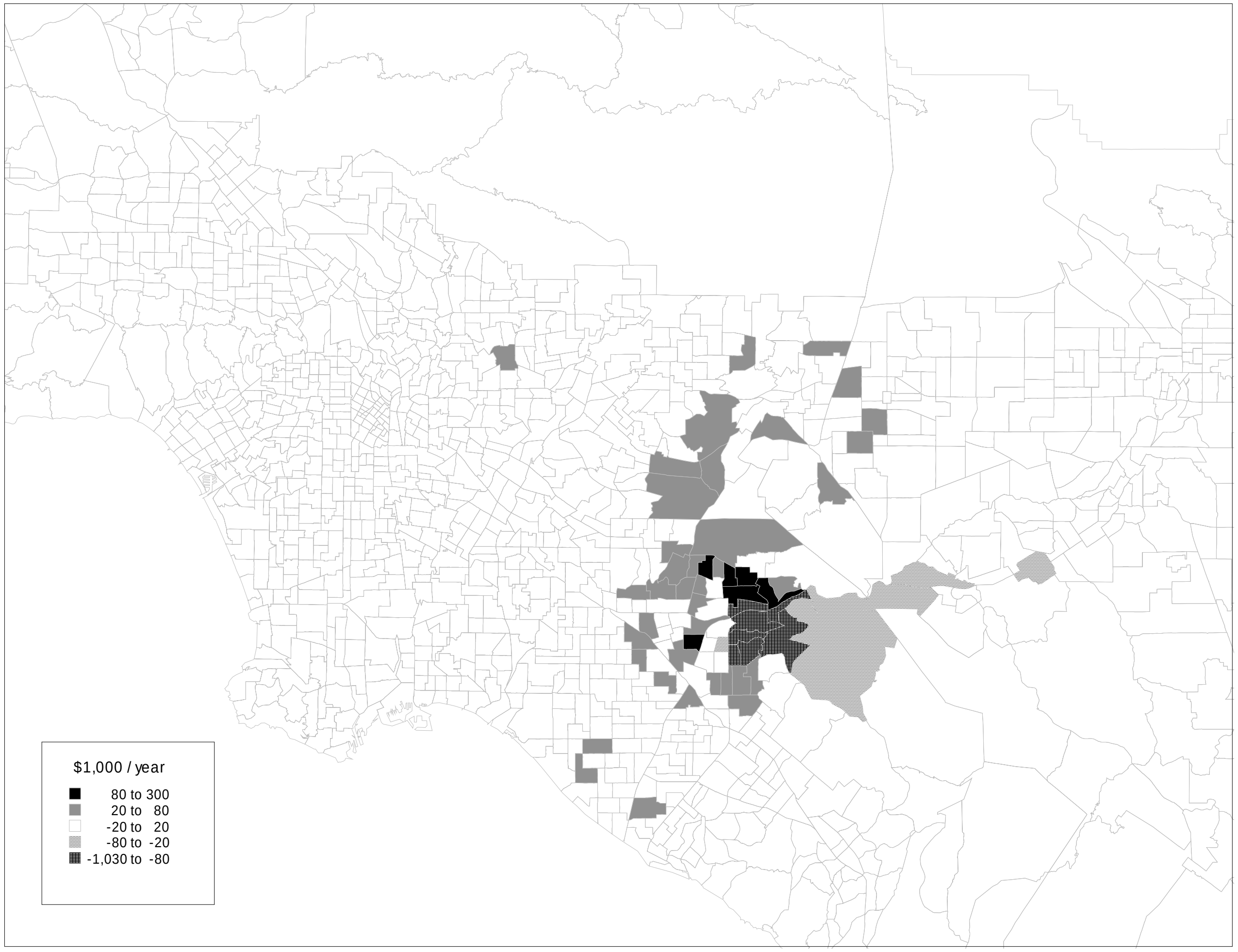

Figure 4a. Net Direct Impacts by Traffic Analysis Zone: Scenario 4+3, Toll = $2

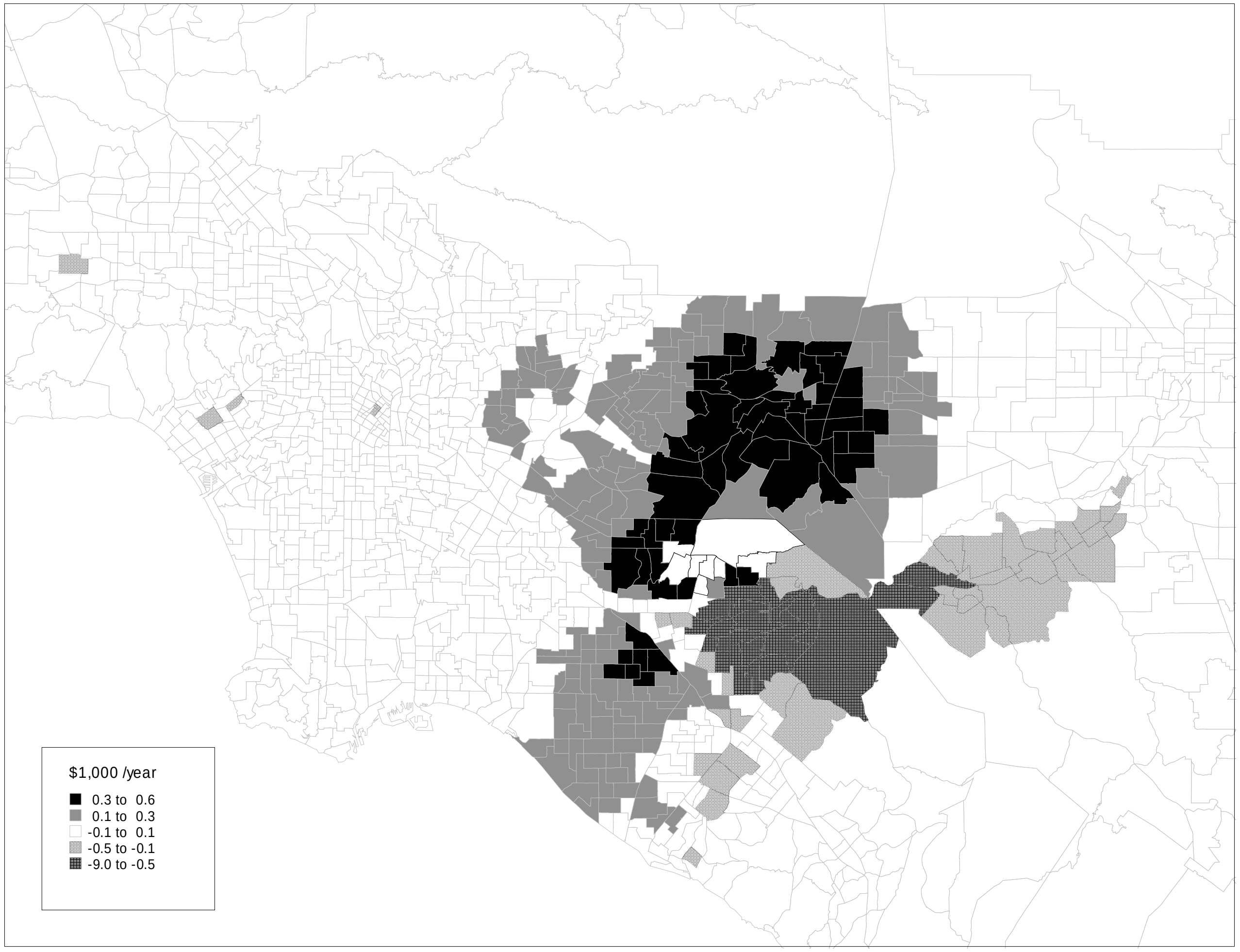

Figure 4b: Net Indirect Impacts by Traffic Analysis Zone: Scenario 4+3, Toll = $2

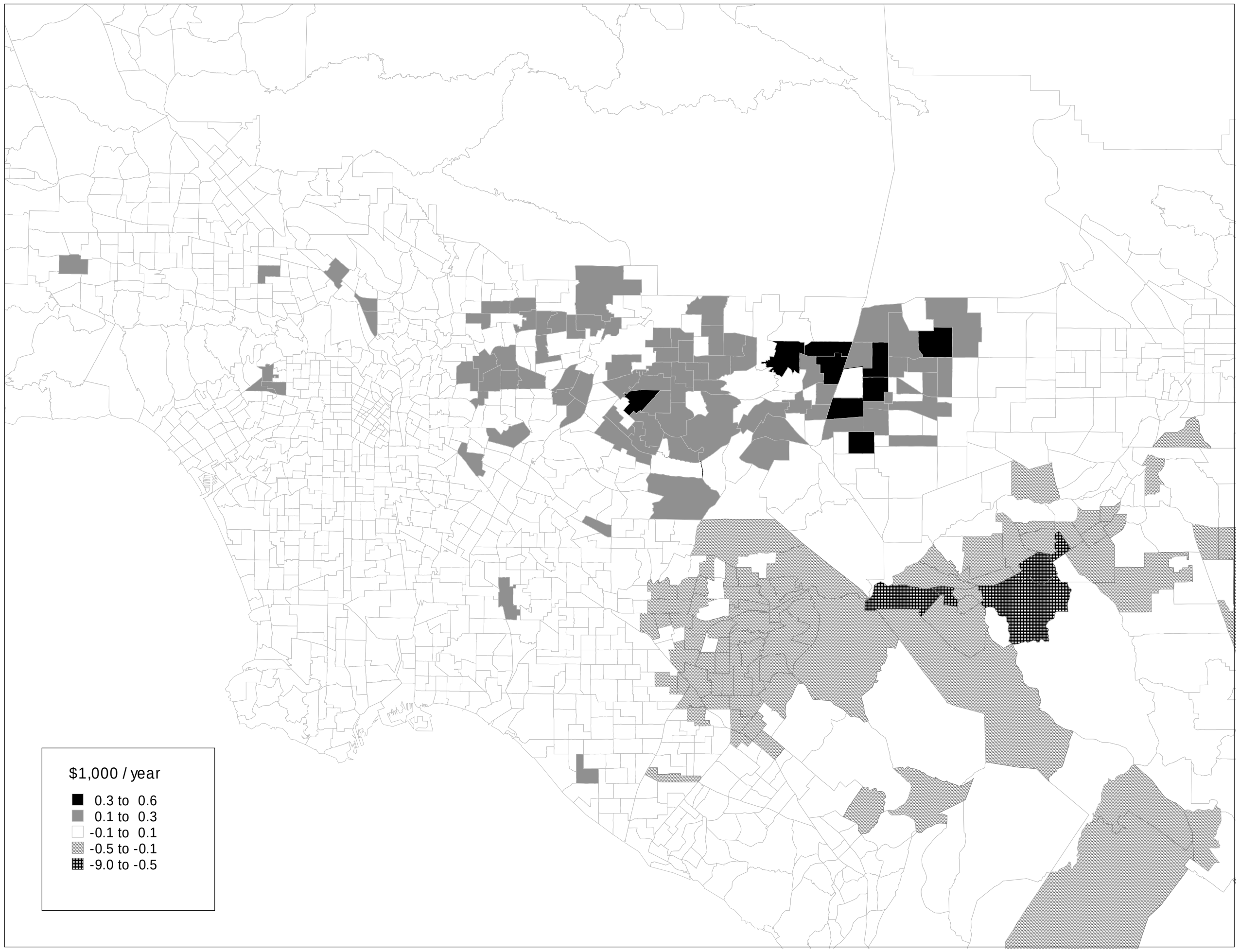

Figure 4c. Net Induced Impacts by Traffic Analysis Zone: Scenario 4+3, Toll = $2

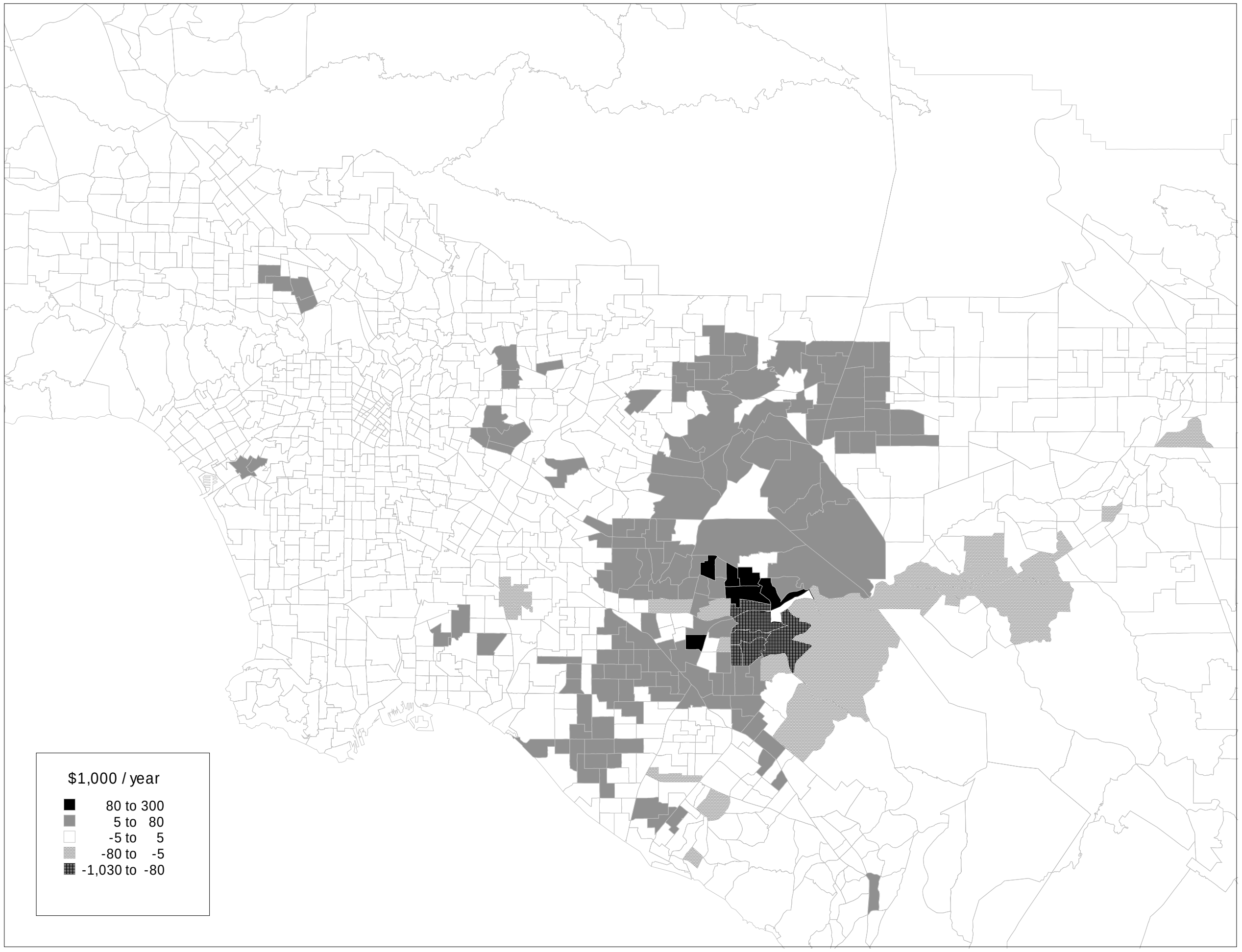

Figure 4d. Total Net Impacts by Traffic Analysis Zone: Scenario 4+3, Toll = $2

Conclusions

Our analysis has met several objectives.

1. We have elaborated a network model to account for the effects of tolls on selected freeway lanes.

2. We have integrated the network model with a spatially detailed economic model of the regional economy.

3. We have applied the model to the hypothetical case of highway widening on a segment of California's SR91, comparing the network-wide effects of adding tolled vs general-purpose lanes. The application included substantial data gathering and analysis so that a single integrated model can be used to analyze:

    a. The economic effects of household displacement,

    b. The network effects of various highway widening and tolling alternatives,

    c. The detailed spatial impacts of highway construction activities (calculated but not shown in this report).[3]

4. We have found that system-wide network effects of adding tolled lanes on just a small link of that network reveals a complex set of results. Adding a new tolled lane may with a high enough toll have negative overall network performance consequences. In contrast, adding a general-purpose lane in the SR91 corridor has more benign consequences. This result is consistent with the events that led public officials purchase the private segment of SR91. It is also consistent with findings from recent theoretical investigations of second-best pricing. Flows on congested, untolled, parallel routes benefit from the addition of untolled facilities. We extend this discussion to an examination of impacts throughout the Los Angeles network. Most research on value pricing has necessarily been of a partial equilibrium nature, and does not consider network effects. Our finding strongly suggests that substantially more research should be done at the network level.

On the premise that all politics are local, we suggest that our analysis of distributional impacts is useful to policy analysts. While we are able to identify costs and benefits, we are also able to estimate which communities bear the costs and which gain the benefits. Whereas network studies in regional highway analyses are common, none to our knowledge, include the comprehensive results from an integrated model shown here.

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[3] The estimation of the multiplier impacts is a straightforward application of the regional input-output model. Also, these impacts are neither costs nor benefits so they are not shown here. Appendix C shows how to calculate the direct effects that would drive the model. We have adopted the “translator” approach of the earlier Regional Science Research Institute input-output models to Implan. Appendix C shows the how the various Implan sectors would respond to one dollar spent on highway widening.

Implementation

We suggest that our detailed analysis of distributional impacts is useful to policy analysts. While we are able to identify costs and benefits, we are also able to estimate which communities bear the costs and which gain the benefits. Whereas network studies in regional highway analyses are common, none to our knowledge, include the comprehensive results from an integrated model shown here. There are inevitably many other freeway widening controversies. Applying our methodology may be useful as a way to inform the debates surrounding these.

On the technical side, most previous research on value pricing has necessarily been of a partial equilibrium nature that does not consider network effects. The complexity of network effects shown in our simulations strongly suggests that substantially more research should be done at the network level.

Appendix A: SCPM2.5 Solution Algorithm

SCPM 2.5 is a distribution-assignment combined model for multi-trip purposes. Trip generation for freight movement is also endogenized in the model. It is implemented with a secant algorithm with a successive average method for linear combination between iterations.

Exogenous variables

- Positive and negative direct impacts (in dollars) by zone and by sector, and corresponding to indirect and induced effects by sector respectively, V_r^D, V^I, V^U

  (For simplicity in presentation, the index for industrial sector *n* was ignored)
- Baseline attraction and production for both of personal and freight trips in PCEs, $\mathbf{O}_r^p$, $\mathbf{D}_s^p$
- Distance decay functions, α^p, β^p for both of persons(m) and freight(n) trips
- Conversion factors to estimate PCEs from monetary terms for freight, γ^p

Algorithm

- Step 0: Initialization

  - Set iteration index $k = 0$
  - Initialize the trip rates for iteration k, ${}^k q_{rs}^p = 0$
  - Initialize link traffic volume, ${}^k x_a = 0$
  - Calculate the initial zone-to-zone travel time k = 0, u_{rs}, based on free-flow travel times
  - Initial impact allocation over the zones for iteration k,

    $${}^k V_r^I = V^I \frac{V_r^D}{\sum_z V_z^D} \text{, and } {}^k V_r^U = V^U \frac{V_r^D}{\sum_z V_z^D}$$

  - Total impacts by zone for iteration k, ${}^k V_r = V_r^D + {}^k V_r^I + {}^k V_r^U$

- Step 1: Calculation of changes in origin and destination of intermediate freight movement
  - Set iteration index $k := k+1$
  - If $k > \mathrm{K}$ then stop algorithm for the predefined iteration limit K

  - Freight movement

    $${}^k O_r^z = \mathbf{O}_r^z + \gamma \cdot \sum_j b_{ij} \cdot {}^{k-1} V^z$$

$$ {}^{k}D_s^z = \mathbf{D}_s^p + \gamma \cdot \sum_j a_{ij} \cdot {}^{k-1}V^z $$

- F-factor for the use of allocation indirect and induced impacts

$$ {}^{k}F^z = \frac{{}^{k}O_F^z + {}^{k}D_F^z}{\sum_z ({}^{k}O_F^z + {}^{k}D_F^z)} $$

- Step 2: Distribution of Trips
  - Auxiliary OD of trip type *p* in iteration k, ${}^{k}v_{rs}^p$

$$ {}^{k}v_{rs}^p = {}^{k}O_r^p \cdot {}^{k}D_s^p \cdot \mathrm{K}_{rs}^p \cdot \exp\left(\alpha^p + \beta^p u_{rs}\right) $$

  - Update ODs

    $\lambda = 1/k$

    ${}^{k}q_{rs}^p = (1-\lambda) \cdot {}^{k-1}q_{rs}^p + \lambda \cdot {}^{k}v_{rs}^p$

  - Compute the matrices

    ${}^{k}JHW$, ${}^{k}JHS$ from ${}^{k}q_{rs}^{m=1}$ (H-W), and ${}^{k}q_{rs}^{m=3}$ (H-S)

- Step 3: Update link volume and travel time
  - Auxiliary link volume ${}^{k}y$

    by all-or-nothing assignment using ${}^{k}q_{rs}^p$,and external travels

  - Update link volumes

    $\lambda = 1/k$

    link volume ${}^{k}x = (1-\lambda) * {}^{k-1}x + \lambda * {}^{k}y$

  - Update link travel time

    Link travel time = link performance function (${}^{k}x$)

- Step 4: Updating zone-to-zone travel time,

  ${}^{k}u_{rs}$ = travel time on the shortest path with current link travel time

- Step 5: Distribution of indirect impacts

$$ {}^{k}V_r^I = \frac{\exp\left(\alpha^p + \beta^p \cdot u_{sr}\right)}{\sum_z \exp\left(\alpha^p + \beta^p \cdot u_{sz}\right)} \cdot V^I \cdot \left(\frac{V_s^D}{V^D}\right) $$

  - Repeat the process for both of positive and negative impacts and sum them together to derive net impacts, $\left| \sum_{+,-} {}^{k}V_r^I \right|$

- Step 6: Distribution of induced impacts

$$V_r^{n,U} = JHS \cdot (JHW)^T \cdot \frac{\exp(\alpha^n + \beta^n \cdot u_{sr})}{\sum_z \exp(\alpha^n + \beta^n \cdot u_{sz})} \cdot V^{n,U} \cdot \left(\frac{V_s^{n,D}}{V^{n,D}} \right)$$

  - Repeat the process for both of positive and negative impacts and sum them together to derive net impacts, $\left| \sum_{+,-} {}^k V_r^U \right|$

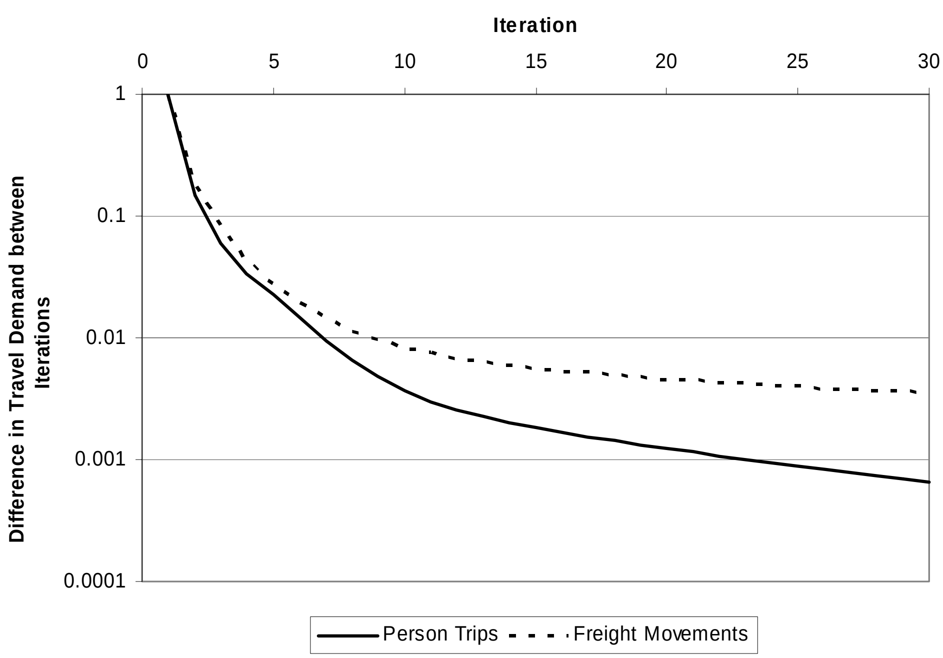
- Step 7: Total impacts over zones

$${}^kV_r = \left|V_r^D\right| + \left|{}^kV_r^I\right| + \left|{}^kV_r^U\right|$$

Go to step 1

Empirically, the algorithm efficiently generates equilibrium trip rate, traffic conditions, and economic impact allocations. The following graph shows gaps between OD matrices generated between iterations for a severely seismically stressed transportation system (Cho, et al, 2001).

Figure A.1 – Differences in Travel Demand Iterations



- Comparison to User Equilibrium Flows

Because the algorithm applies a successive averaging method to update trip rates (OD) and volumes between iterations, the step size is not estimated but predefined.

SCPM2.1 volume: after 30 iteration of baseline condition
User equilibrium volume: After 30 iterations of user equilibrium model with baseline network capacity, and travel demand that was generated from SCPM2.1 (30 iterations)

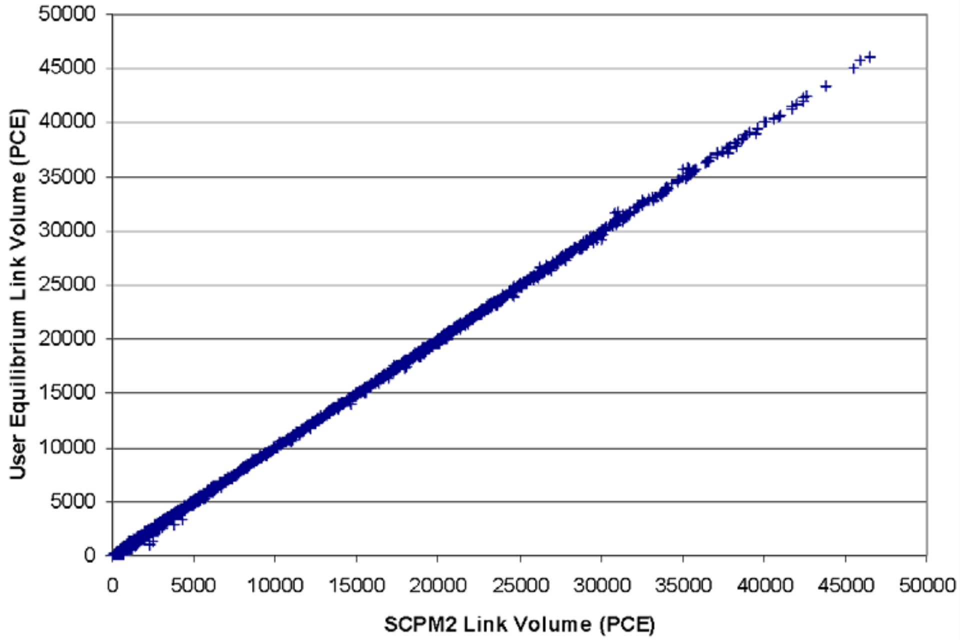


Figure A.2. Calculated Link Volume Comparisons

User Equilibrium volume =	-7.77427	+	0.996042 *	SCPM2.1 volume
	t=-16.7714		t=12983.0	
	p=9.598E-63		p=0.000	

R^2 = 0.999868, F=1.69E8, p=0.000

Appendix B: Detailed Data Inputs and Data Derivation Procedures

Table B.1: The Locations of Move-Out Households

COUNTY	CITY	TAZID	MOVEOUTHHS	CONGRESSDISTRICT	SCHOOLDISTRICT	MEDIANHOMEVAL
ORA	Anaheim	1105	73	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	65	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	38	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	32	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	24	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	34	41	ORANGE UNIFIED	207997

Table B.2: The Locations of Move-In Households

COUNTY	CITY	TAZID	MOVEINHHS	CONGRESSDISTRICT	SCHOOLDISTRICT	MEDIANHOMEVAL
LA	Los Angeles	292	1	26	LOS ANGELES UNIFIED	173556
LA	Los Angeles	1466	1	32	LOS ANGELES UNIFIED	236581
LA	Burbank	331	1	27	BURBANK UNIFIED	290283
LA	San Dimas	503	1	28	BONITA UNIFIED	228951
LA	San Dimas	422	1	28	GLENDORA UNIFIED	228951
LA	San Dimas	465	1	28	BONITA UNIFIED	228951
LA	Claremont	429	1	28	CLAREMONT UNIFIED	228951
LA	Claremont	429	1	28	CLAREMONT UNIFIED	228951
LA	Rowland Heights	775	1	41	ROWLAND UNIFIED	207997
LA	Pomona	680	1	41	POMONA UNIFIED	207997
LA	Pomona	680	1	41	POMONA UNIFIED	207997
LA	Diamond Bar	732	1	41	WALNUT VALLEY UNIFIED	207997
LA	Walnut	622	2	28	ROWLAND UNIFIED	228951
LA	Walnut	622	1	28	WALNUT VALLEY UNIFIED	228951
LA	Rowland Heights	837	1	41	ROWLAND UNIFIED	207997
LA	Rowland Heights	837	1	41	ROWLAND UNIFIED	207997
LA	Temple City	485	1	28	TEMPLE CITY UNIFIED	228951
LA	San Gabriel	442	1	31	SAN GABRIEL UNIFIED	172600
LA	Monterey Park	648	1	31		172600
LA	Whittier	805	1	34		172658
LA	East La Mirada	964	1	39		240458
LA	Montebello	769	1	34	MONTEBELLO UNIFIED	172658
LA	Long Beach	1122	1	38	LONG BEACH UNIFIED	213736
LA	Long Beach	1136	1	38	LONG BEACH UNIFIED	213736
ORA	La Habra	973	1	39		240458
ORA	Brea	925	1	39		240458
ORA	Fullerton	1005	1	39		240458
ORA	Fullerton	1005	1	39		240458
ORA	Fullerton	1005	1	39		240458
ORA	Fullerton	1005	1	39		240458
ORA	Fullerton	999	1	39		240458

ORA	Fullerton	1061	1	39		240458
ORA	Fullerton	1049	1	39		240458
ORA	Fullerton	1049	1	39		240458
ORA	Fullerton	1049	1	39		240458
ORA	Fullerton	1054	2	39		240458
ORA	Fullerton	1013	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Fullerton	1013	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1013	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1012	3	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1012	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1054	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1040	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1050	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1014	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1014	1	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Placentia	1075	2	39	PLACENTIA-YORBA LINDA UNIFIED	240458
ORA	Yorba Linda	1031	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	3	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
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ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1031	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1055	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1055	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1055	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1055	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1055	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1027	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1027	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1027	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Placentia	1027	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1027	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1059	1	41	PLACENTIA-YORBA LINDA	207997

					UNIFIED	
ORA	Anaheim	1059	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
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ORA	Yorba Linda	1055	6	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA		1055	4	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1055	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1059	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Placentia	1059	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Placentia	1059	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	2	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1445	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1047	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Yorba Linda	1047	1	41	PLACENTIA-YORBA LINDA UNIFIED	207997
ORA	Anaheim	1105	2	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	9	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	1	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	1	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	1	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	2	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	1	41	ORANGE UNIFIED	207997
ORA	Anaheim	1105	6	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	5	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	1	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	3	41	ORANGE UNIFIED	207997
ORA	Anaheim	1070	5	41	ORANGE UNIFIED	207997

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ORA	Anaheim	1120	1	47	ORANGE UNIFIED	319560
ORA	Anaheim	1120	1	47	ORANGE UNIFIED	319560
ORA	Anaheim	1120	2	47	ORANGE UNIFIED	319560
ORA	Mission Viejo	1386	1	48	SADDLEBACK VALLEY UNIFIED	290277
ORA	Irvine	1316	2	47	IRVINE UNIFIED	319560
ORA	Irvine	1295	1	47	IRVINE UNIFIED	319560
ORA	Costa Mesa	1343	2	45	NEWPORT-MESA UNIFIED	288415
ORA	Costa Mesa	1336	1	45	NEWPORT-MESA UNIFIED	288415
ORA	Costa Mesa	1336	1	45	NEWPORT-MESA UNIFIED	288415
ORA	Santa Ana	1301	1	46	SANTA ANA UNIFIED	195318
ORA	Santa Ana	1221	1	46	SANTA ANA UNIFIED	195318
ORA	Santa Ana	1221	1	46	SANTA ANA UNIFIED	195318
ORA	Santa Ana	1221	1	46	SANTA ANA UNIFIED	195318
ORA	Santa Ana	1237	1	47	ORANGE UNIFIED	319560
ORA	Tustin Foothills	1258	1	47	TUSTIN UNIFIED	319560
ORA	Tustin Foothills	1259	1	47	TUSTIN UNIFIED	319560
ORA	Tustin Foothills	1240	1	47	ORANGE UNIFIED	319560
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ORA	Orange	1154	1	47	ORANGE UNIFIED	319560
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ORA	Orange	1205	2	47	ORANGE UNIFIED	319560
ORA	Santa Ana	1205	1	47	ORANGE UNIFIED	319560
ORA	Orange	1205	1	47	ORANGE UNIFIED	319560
ORA	Orange	1114	1	47	ORANGE UNIFIED	319560
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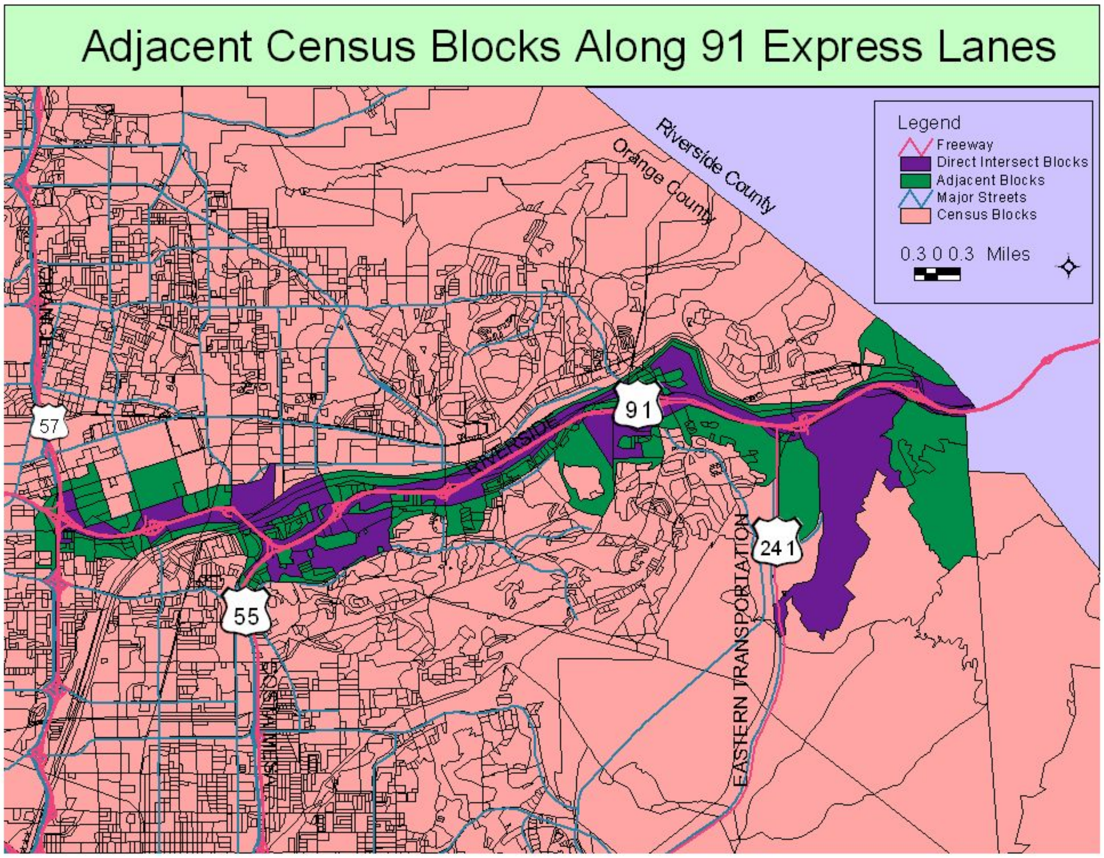
ORA	Orange	1114	1	47	ORANGE UNIFIED	319560
ORA	Orange	1114	1	47	ORANGE UNIFIED	319560
ORA	Orange	1114	1	47	ORANGE UNIFIED	319560
ORA	Orange	1114	1	47	ORANGE UNIFIED	319560
ORA	Orange	1114	3	47	ORANGE UNIFIED	319560
ORA	Orange	1114	4	47	ORANGE UNIFIED	319560
ORA	Orange	1132	1	47	ORANGE UNIFIED	319560
ORA	Orange	1167	3	47	ORANGE UNIFIED	319560
ORA	Orange	1145	1	47	ORANGE UNIFIED	319560
ORA	Orange	1145	1	47	ORANGE UNIFIED	319560
ORA	Anaheim	1151	1	47		319560
ORA	Anaheim	1151	1	47		319560
ORA	Anaheim	1110	1	47		319560
ORA	Anaheim	1110	2	47		319560

ORA	Anaheim	1139	1	47		319560
ORA	Anaheim	1139	3	47		319560
ORA	Anaheim	1139	1	47		319560
ORA	Anaheim	1139	1	47		319560
ORA	Anaheim	1110	1	47	PLACENTIA-YORBA LINDA UNIFIED	319560
ORA	Anaheim	1101	1	45		288415
ORA	Anaheim	1128	1	46		195318
ORA	Anaheim	1121	1	46		195318
ORA	Anaheim	1121	1	46		195318
ORA	Anaheim	1106	2	46		195318
ORA	Anaheim	1121	1	46		195318
ORA	Anaheim	1162	1	46		195318
ORA	Anaheim	1162	1	46		195318
ORA	Garden Grove	1187	1	46	GARDEN GROVE UNIFIED	195318
ORA	Garden Grove	1188	1	46	GARDEN GROVE UNIFIED	195318
ORA	Anaheim	1203	1	46		195318
ORA	Garden Grove	1202	2	46	GARDEN GROVE UNIFIED	195318
ORA	Garden Grove	1246	1	46	GARDEN GROVE UNIFIED	195318
ORA	Fountain Valley	1300	1	45		288415
ORA	Huntington Beach	1284	1	45		288415
ORA	Huntington Beach	1286	1	45		288415
ORA	Huntington Beach	1304	1	45		288415
ORA	Huntington Beach	1451	1	45		288415
ORA	Garden Grove	1213	1	45	GARDEN GROVE UNIFIED	288415
ORA	Cypress	1174	1	39		240458
ORA		1036	1	39		240458
SBD	Chino Hills	853	2	41	CHINO VALLEY UNIFIED	207997
SBD	Chino Hills	815	1	41	CHINO VALLEY UNIFIED	207997
SBD	Chino Hills	815	1	41	CHINO VALLEY UNIFIED	207997
SBD	Chino Hills	1443	3	41	CHINO VALLEY UNIFIED	207997
SBD	Ontario	659	2	41		207997
RIV	Corona	1076	1	43	CORONA-NORCO UNIFIED	158433
RIV		1057	1	43		158433

Data Sources

This study used census blocks as the base unit of geographic analysis. The census blocks in the adjacent areas of the 10-mile SR91 Express Lane are shown as follows:

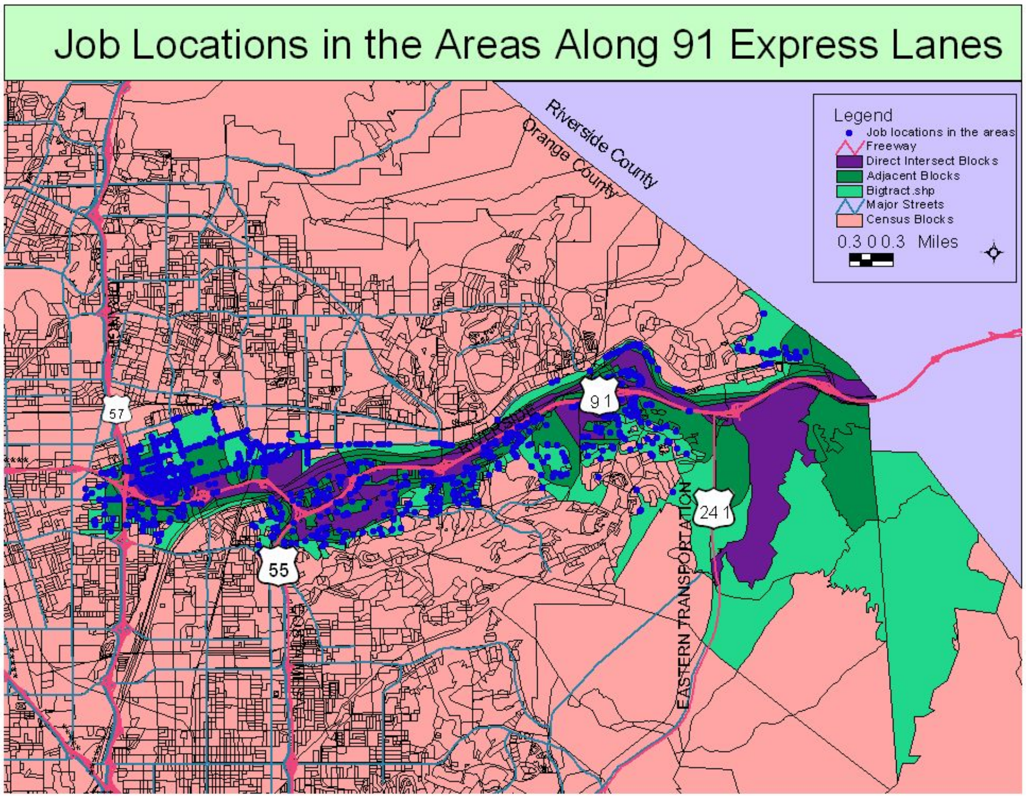
Figure B.1



Employment Data

SCAG 1997 employment data provided the most recent employment by sector at spatial point locations, which are shown as follows:

Figure B.2



The jobs by location were aggregated to census blocks using a developed Arcview Script. The aggregated jobs by census block are shown in Figure B.3.

Population Data

The population data came from Geolytics's Census 2000 blocks CD. Total population at the block level was extracted from the Geolytics CD and plugged into our census block-based data set. The population data are shown in Figure B.4:

Figure B.3

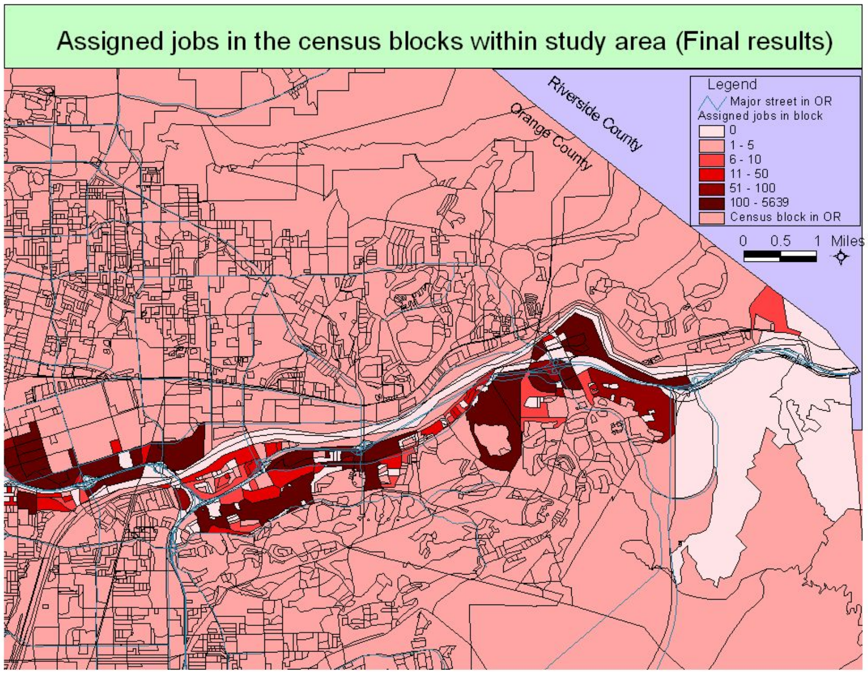
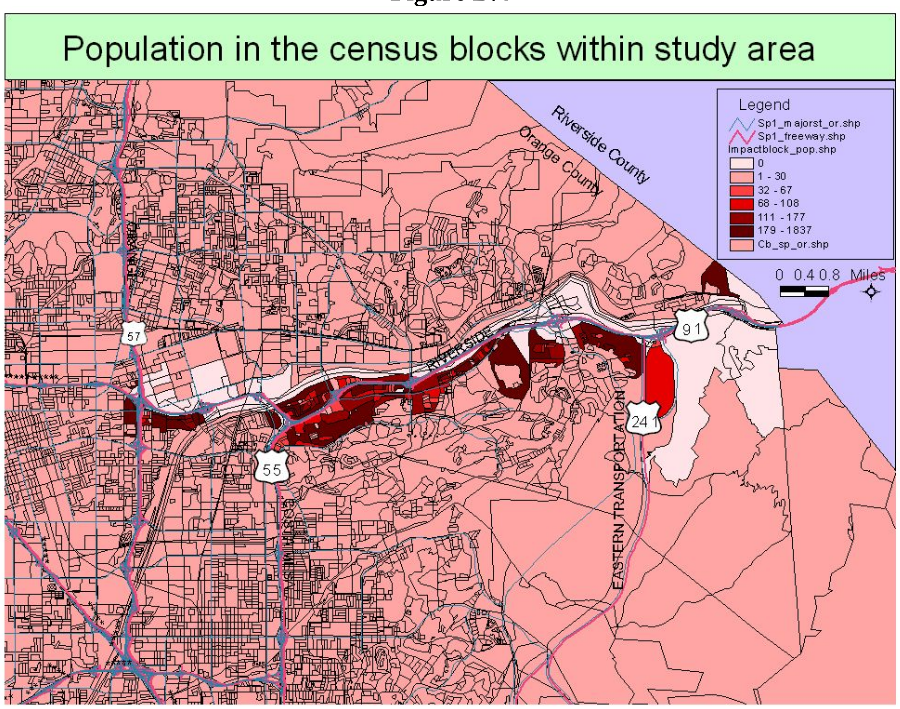


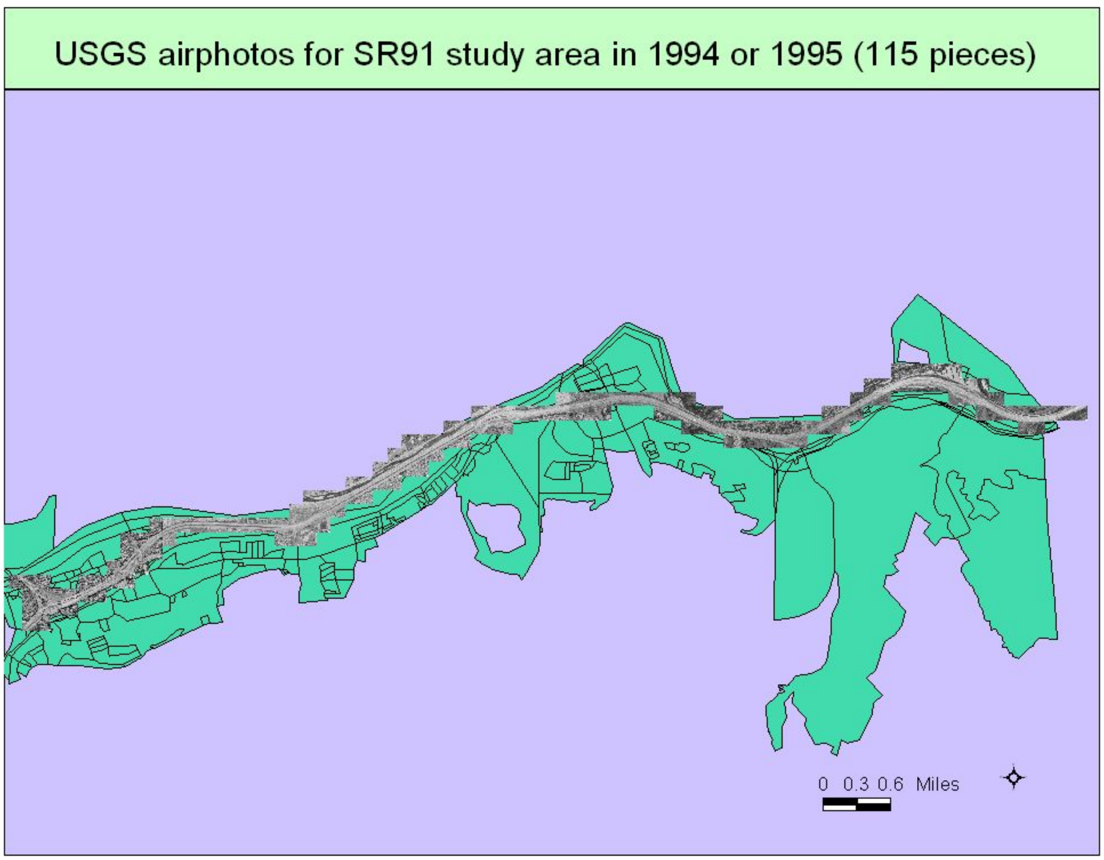
Figure B.4



USGS Air-photos

USGS air photos were collected for the study area along the SR91 highway alignment. The air photos were taken by USGS on June 1, 1994 and Oct. 3, 1995. The air photos are piece-by-piece images in JPEG format with 1-meter resolution, which is downloadable from the Microsoft Terra Server Imagery (http://terraserver.homeadvisor.msn.com/image.asp?S=10&T=1&X=2115&Y=18727&Z=11&W=0). There are 115 pieces of air photos covering the study areas (Figure B.5). A program was developed to translate the world projection files for all the downloaded air-photos.

Figure B.5



The following figures show different land-use types at the west, middle and eastern parts of the SR91 toll road.

Figure B.6

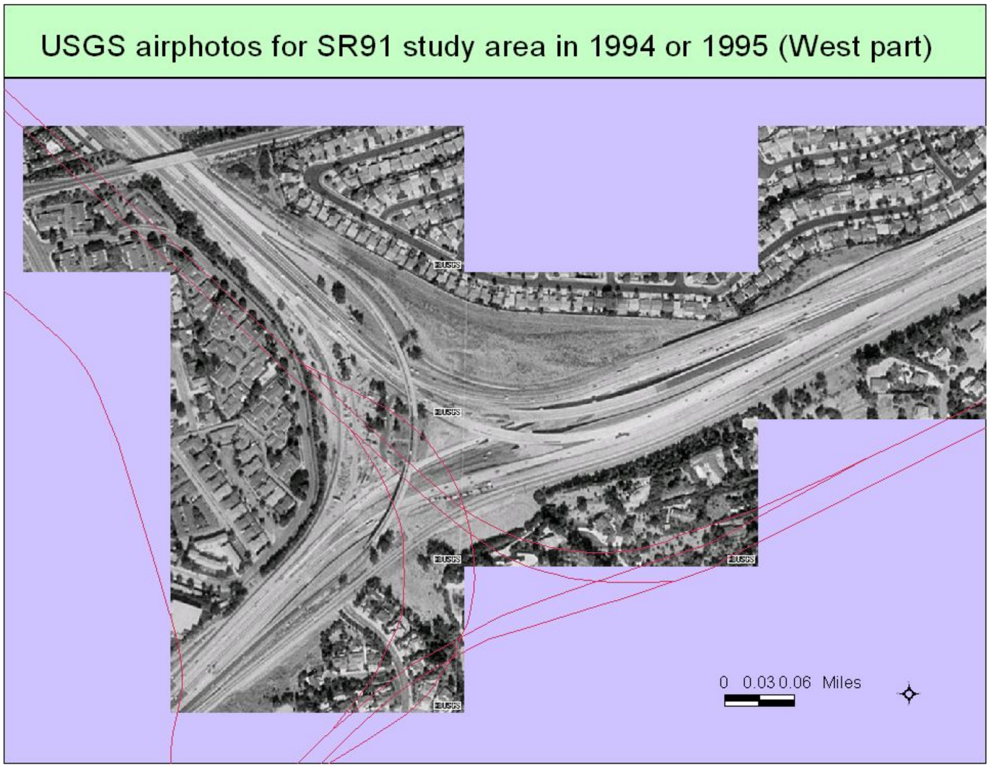


Figure B.7

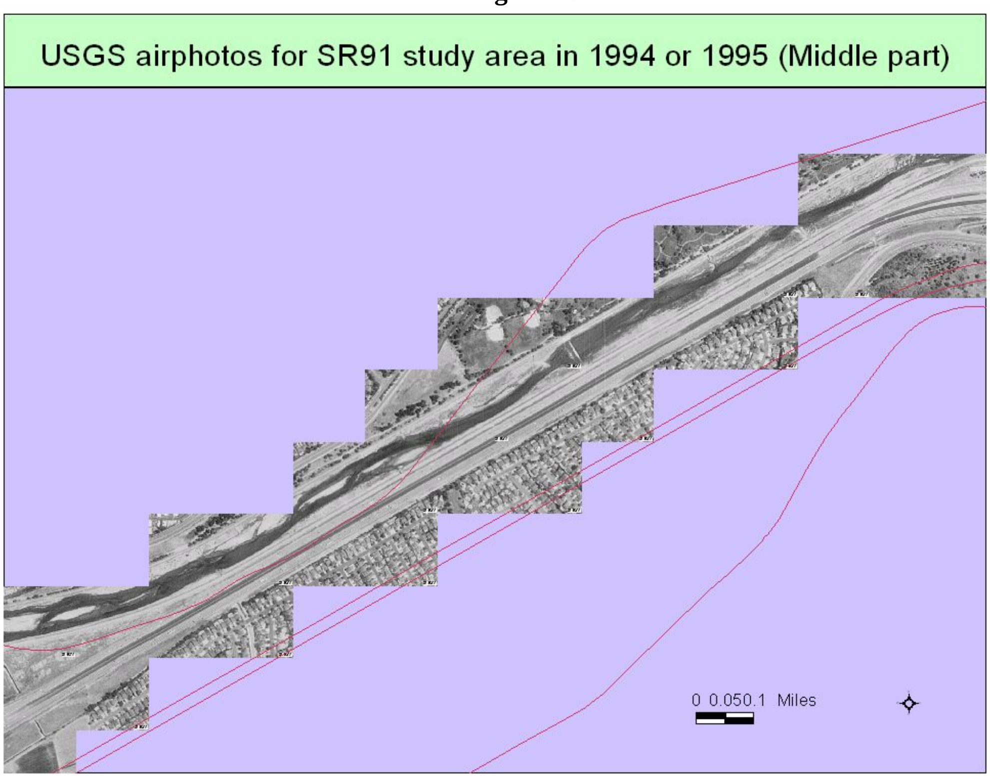
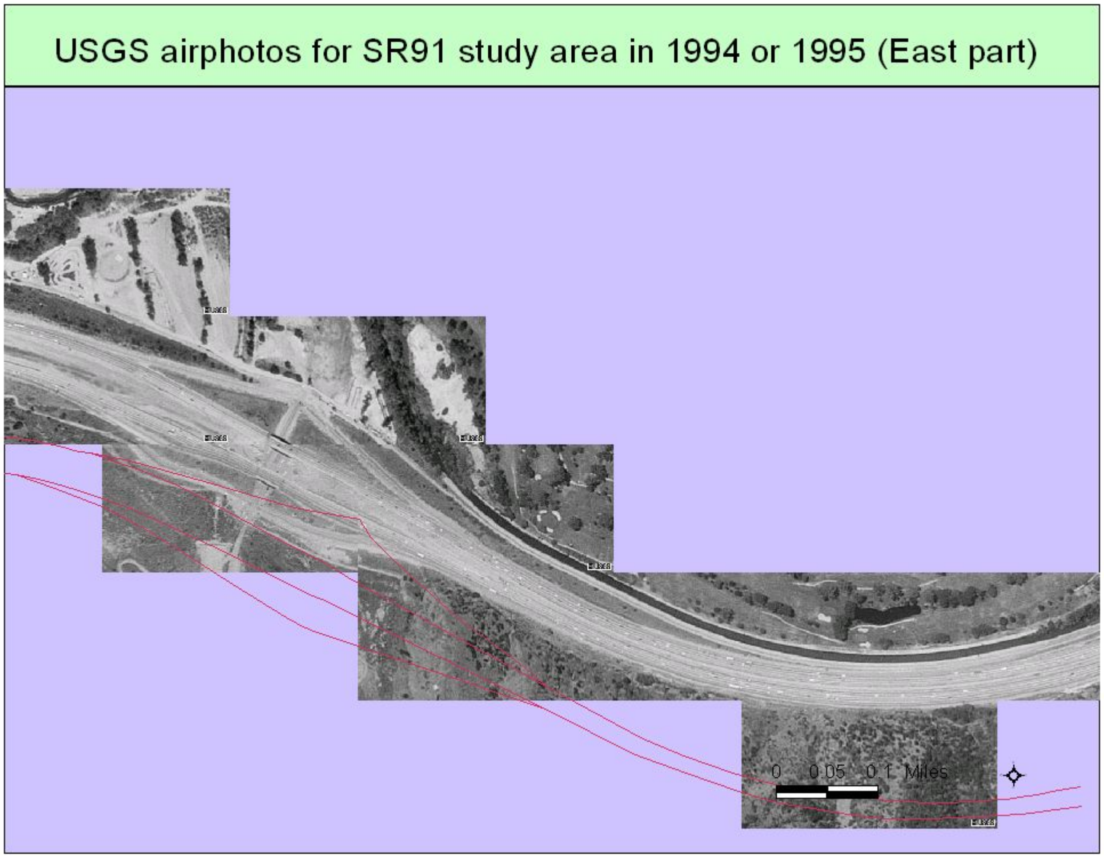


Figure B.8



The air photos are useful to observe land use types and locations along the freeway alignment. However, these show the situation several years ago. They are not reliable for counting housing units and business establishments impacted by the freeway expansion. Fieldwork was necessary to collect up-to-date information.

Field Work

We designed a fieldwork plan for the 10-mile SR91 alignment based on the air photos. The 10-mile toll road was separated into several parts to facilitate fieldwork: From SR 55 to Lakeview Avenue (Figure B.9), From Lakeview Avenue to Imperial highway (Figure B.10), from Imperial highway to Weir Canyon Road (Figure B.11), from Weir Canyon Road to Gypsum Canyon Road (Figure B12), from Gypsum Canyon Road to the county bline (Figure B13). The census blocks along the freeway visited in the fieldwork are shown in Figure B.14.

Figure B.9

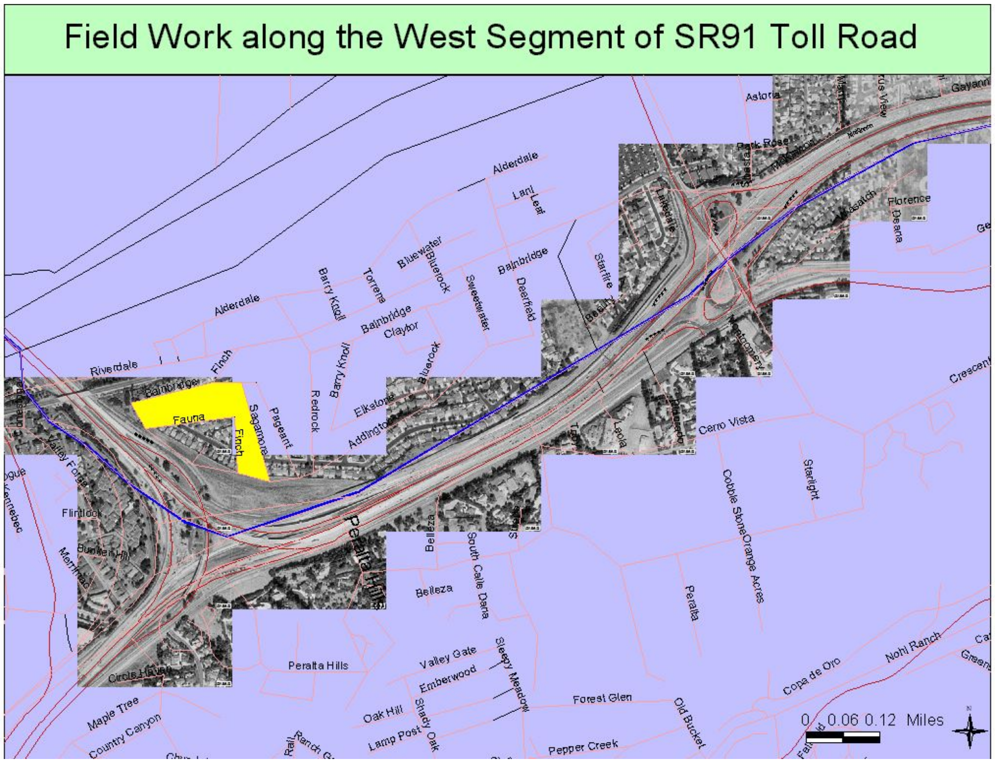


Figure B.10

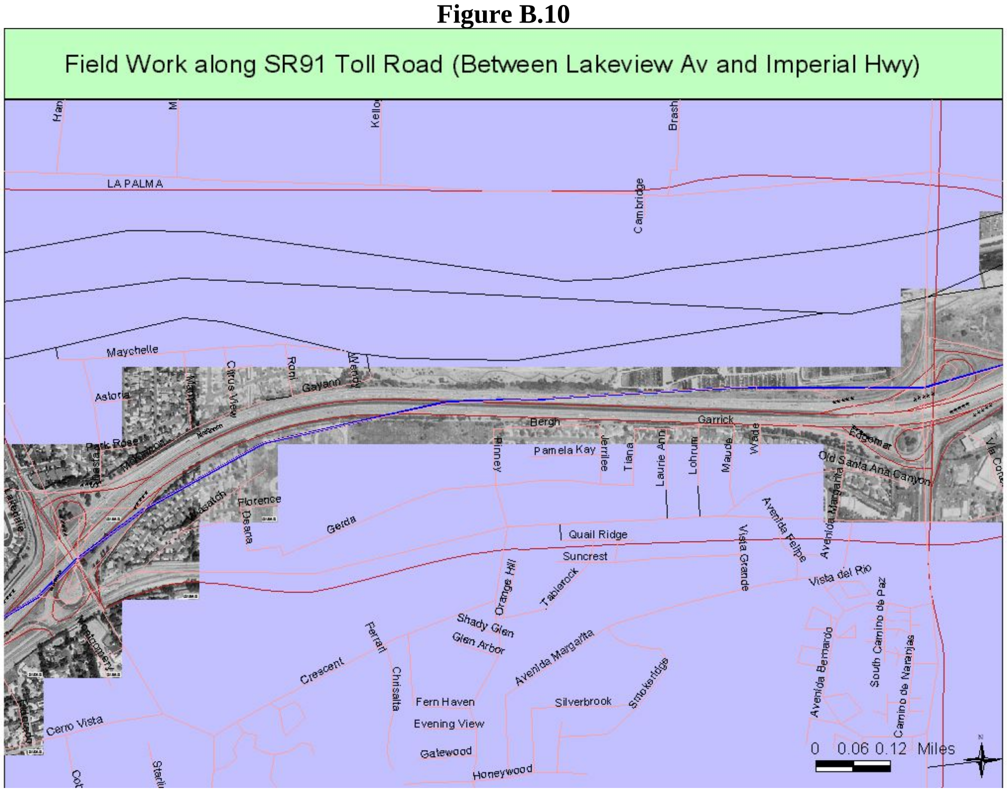


Figure B.11

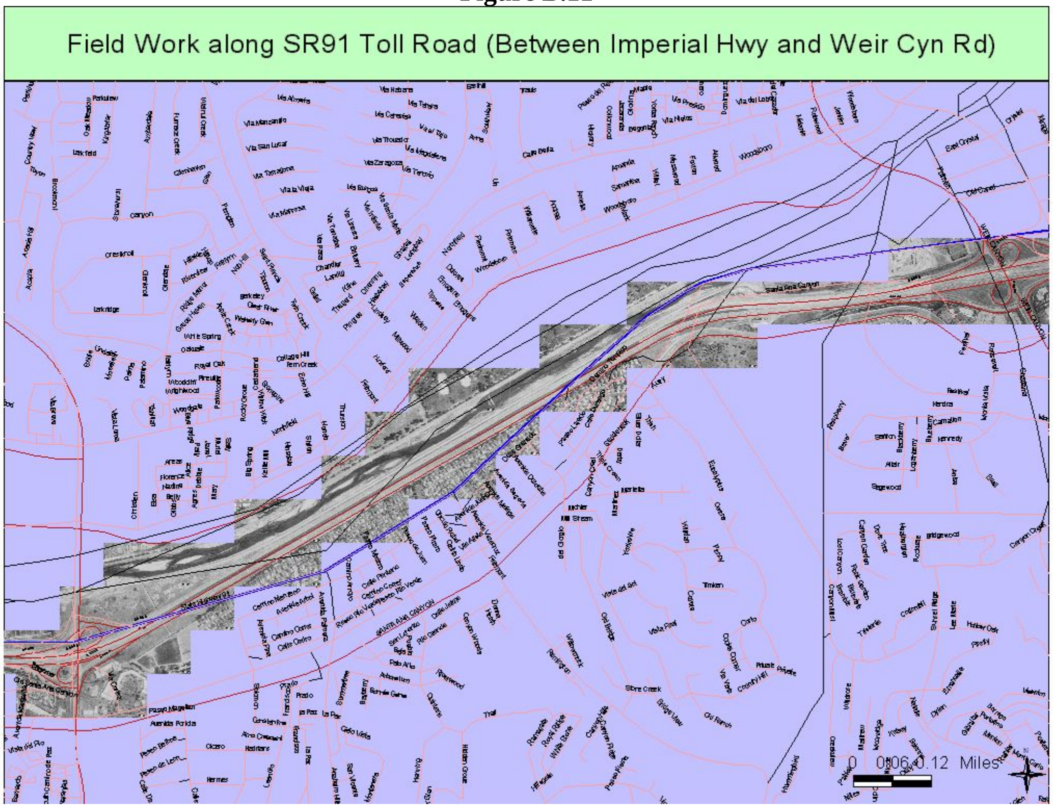


Figure B.12

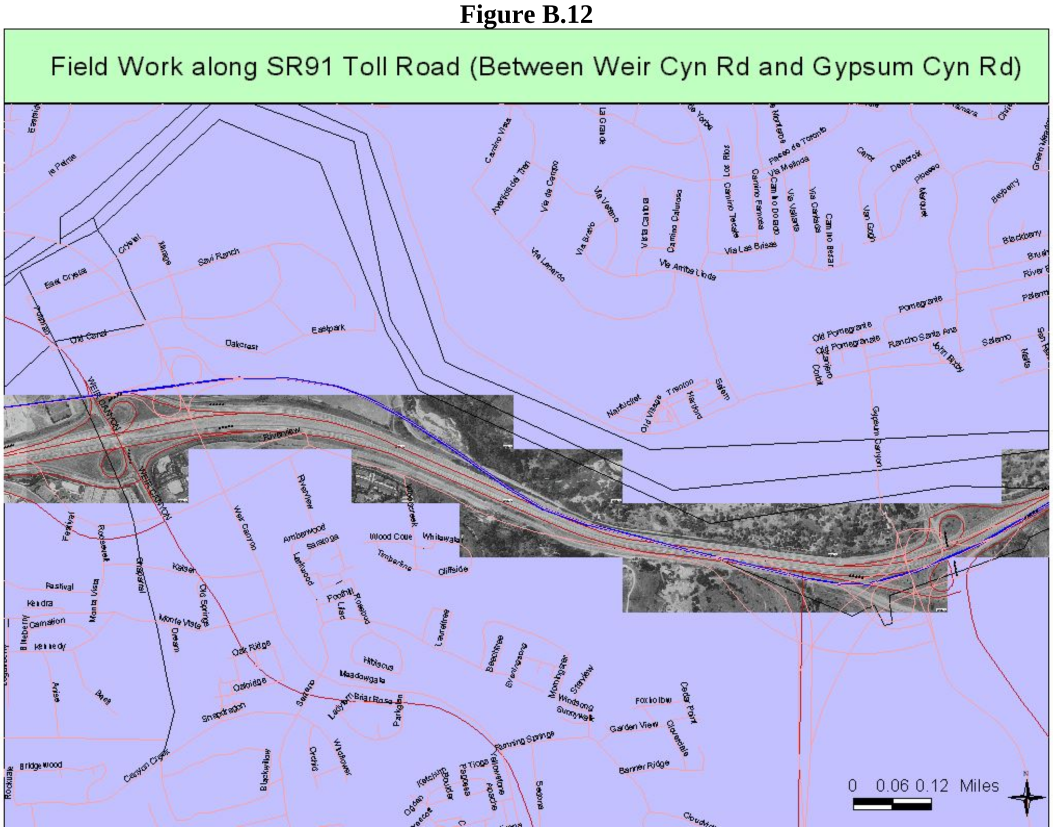


Figure B.13

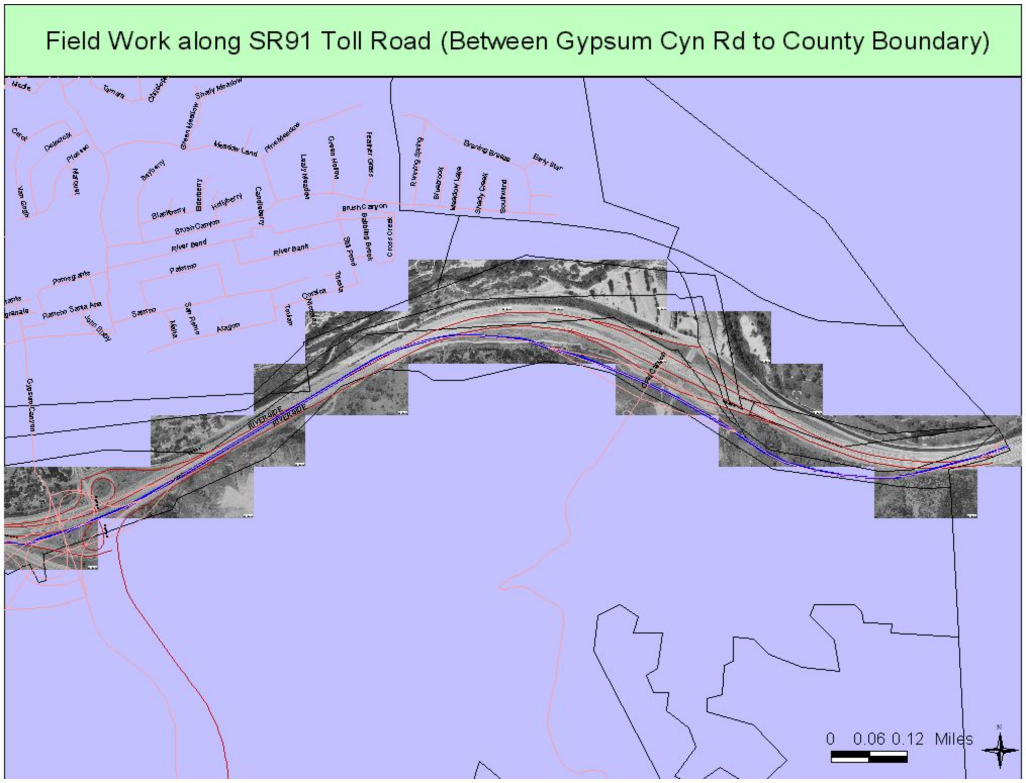
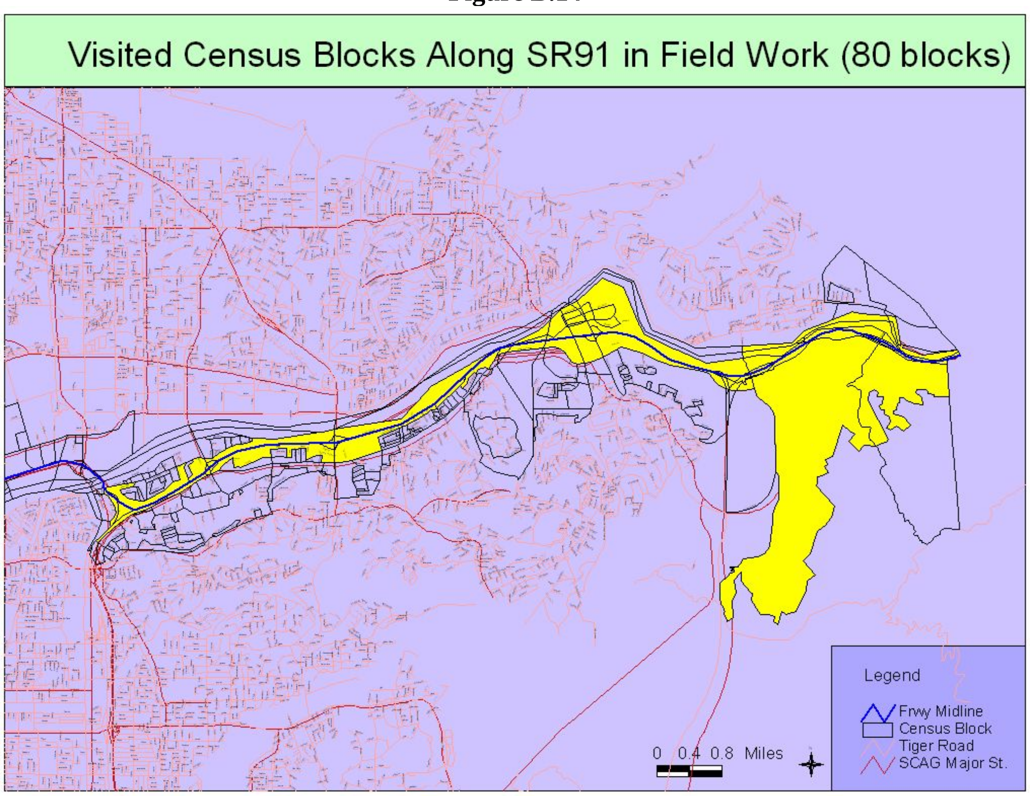


Figure B.14



The data collected from the fieldwork are shown in Table B.3.

Table B.3: Impacted Housing Units and Businesses Estimated from Fieldwork

STFID	POP_2000	JOB_1997	SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	SIC7	SIC8	SIC9	LANDUSE	IMP_HOUSE	IMP_JOB	IMP_POP	VISIT_0130	COMMENTS
060590218262997	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590218262998	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219031000	131	1	1	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219031012	457	273	8	4	0	5	114	94	25	23	0	Mix	73	0	219	1	Res+School+Park
060590219031015	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219031016	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219031017	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219031018	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219033000	121	39	32	0	0	2	0	0	2	3	0	Vac	0	0	0	1	
060590219033001	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219033003	374	8	2	0	0	0	3	0	3	0	0	Mix	65	0	195	1	Res+Road+School
060590219033004	0	0	0	0	0	0	0	0	0	0	0	Mix	0	0	0	1	Road+Vac
060590219052000	127	4	0	0	0	0	2	2	0	0	0	Res	38		114	1	
060590219052018	112	720	18	3	6	12	469	47	85	60	0	Mix	32	0	96	1	Res+Vac
060590219052019	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219053000	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053001	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053002	0	35	0	0	0	0	0	0	35	0	0	Mix				1	Com+Vac
060590219053003	0	324	0	0	0	0	312	0	12	0	0	Mix				1	Com+Vac
060590219053005	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053006	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053007	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053008	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219053009	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590219053010	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219053011	0	58	0	0	0	0	58	0	0	0	0	Mix	0	0	0	1	Com+Vac
060590219053012	0	382	12	0	23	1	58	191	23	68	0	Mix	0	0	0	1	Com+Vac
060590219053013	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219053014	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219053015	191	11	0	0	0	0	8	0	0	3	0	Mix	24	0	75	1	Res+Com
060590219053016	0	5	0	0	0	0	0	5	0	0	0	Vac	0	0	0	1	
060590219053017	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219053020	124	7	0	0	0	0	0	0	7	0	0	Res	34	0	106	1	
060590219152000	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219152002	0	0	0	0	0	0	0	0	0	0	0	Mix	0	0	0	1	Road+Vac
060590219241000	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241001	2	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241002	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241003	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241004	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241005	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241006	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241007	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241008	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241009	0	2094	236	123	767	15	501	119	220	113	0	Mix	0	0	0	1	Com+Vac
060590219241010	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219241011	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219241012	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219241013	0	0	0	0	0	0	0	0	0	0	0	Mix				1	Com+Vac
060590219241014	0	250	0	0	250	0	0	0	0	0	0	Mix				1	Com+Vac
060590219241015	0	352	7	12	48	0	214	0	71	0	0	Mix				1	Com+Vac
060590219241016	0	170	0	0	0	0	170	0	0	0	0	Mix				1	Com+Vac
060590219241017	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590219241018	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241019	0	0	0	0	0	0	0	0	0	0	0	Mix	0	0	0	1	Com+Vac
060590219241040	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241041	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241042	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241043	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241044	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241045	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241046	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241047	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241048	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241049	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590219241050	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	

060590219241051	2	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241052	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241053	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241066	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241067	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241068	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241069	33	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241070	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590219241996	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241997	0	0	0	0	0	0	0	0	0	0	0	Vac				1	
060590219241998	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590219241999	0	0	0	0	0	0	0	0	0	0	0	Vac	0	0	0	1	
060590762024000	0	0	0	0	0	0	0	0	0	0	0	Mix	0	0	0	1	Road+Vac
060590762024001	0	0	0	0	0	0	0	0	0	0	0	Mix	0	0	0	1	Res+Vac

Based on the results from the fieldwork, the land use type and impacted housing units in each census block are shown in Figure B.15 and B.16. The impacted population in each census block (Figure B.17) is estimated using the persons-per-household ratio (3.29) calculated from Census 2000 Quick Facts (http://quickfacts.census.gov). There are no businesses impacted by the freeway expansion.

Figure B.15

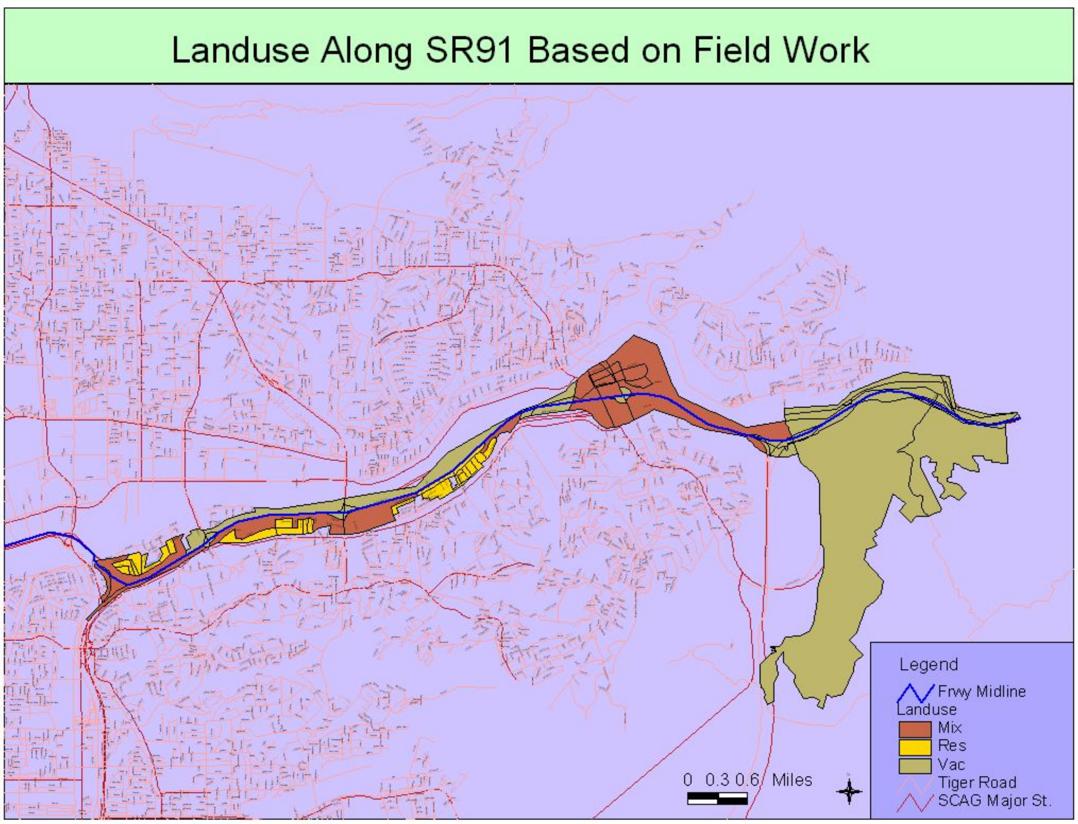


Figure B.16

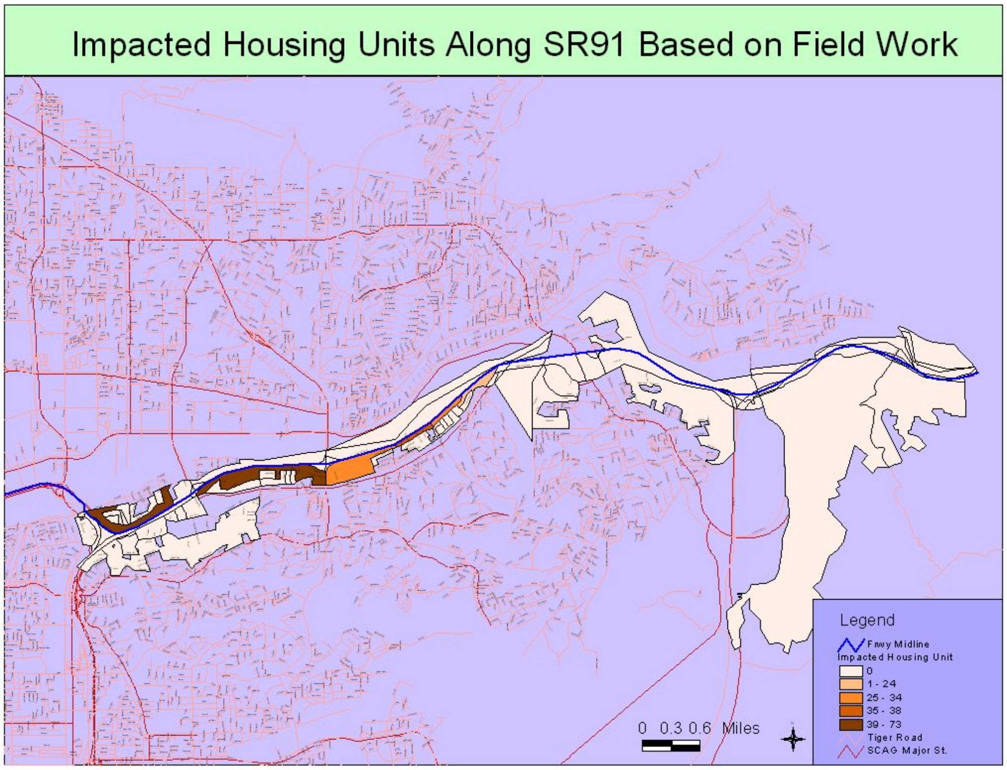
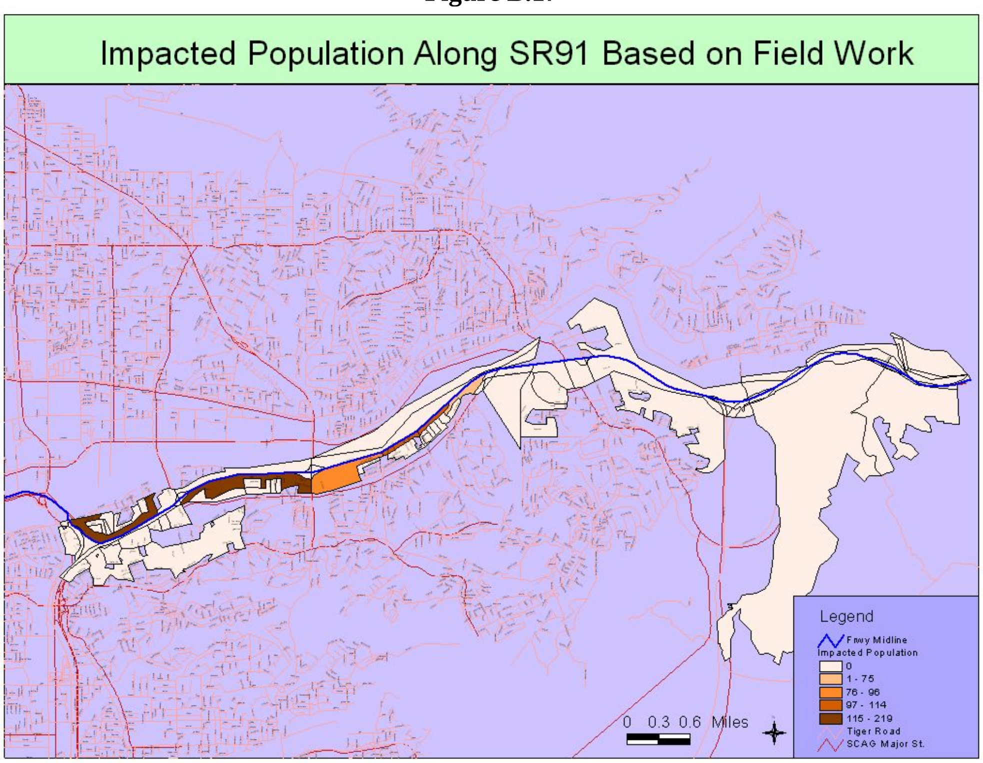


Figure B.17



Household Relocation

Theoretical Bases

According to various empirical findings (Quigley and Weinberg 1977; Clark and Burt 1980; Clark et al. 2002), intra-regional residential move distances are distributed exponentially. Typically,

the probability density function (Pdf) is:
$f_X(x) = \lambda e^{-\lambda x}$, x ≥ 0,

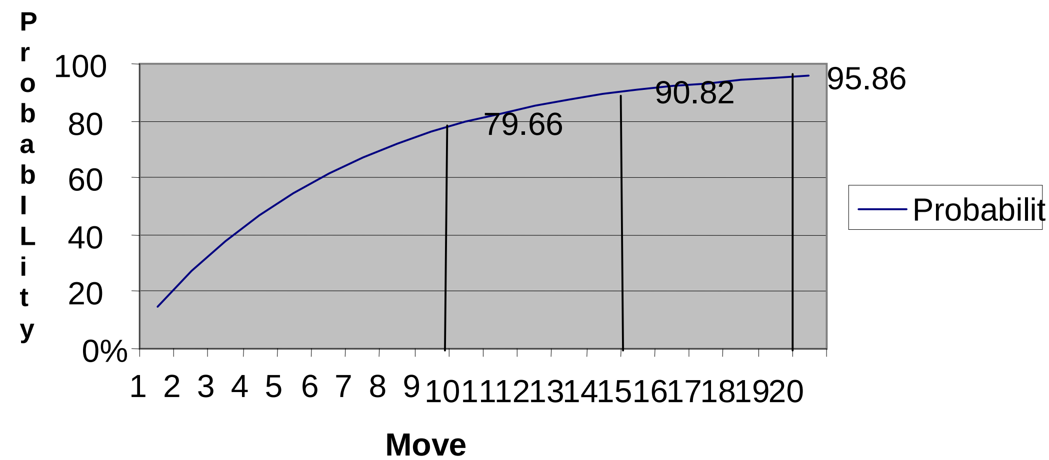
the probability distribution function (PDF) is:
$F_X(x) = 1 - e^{-\lambda x}$, x ≥ 0,

where x is the residential move distance (miles),

According to a study by Clark et al. (2001) on the association between residential changes and commuting behavior in the greater Seattle area, the mean move distance is 6.28 miles, that is, $1/\lambda = 6.28$. Therefore, the PDF is:
$F_X(x) = 1 - e^{-x/6.28}$

which is shown as Figure B.18.

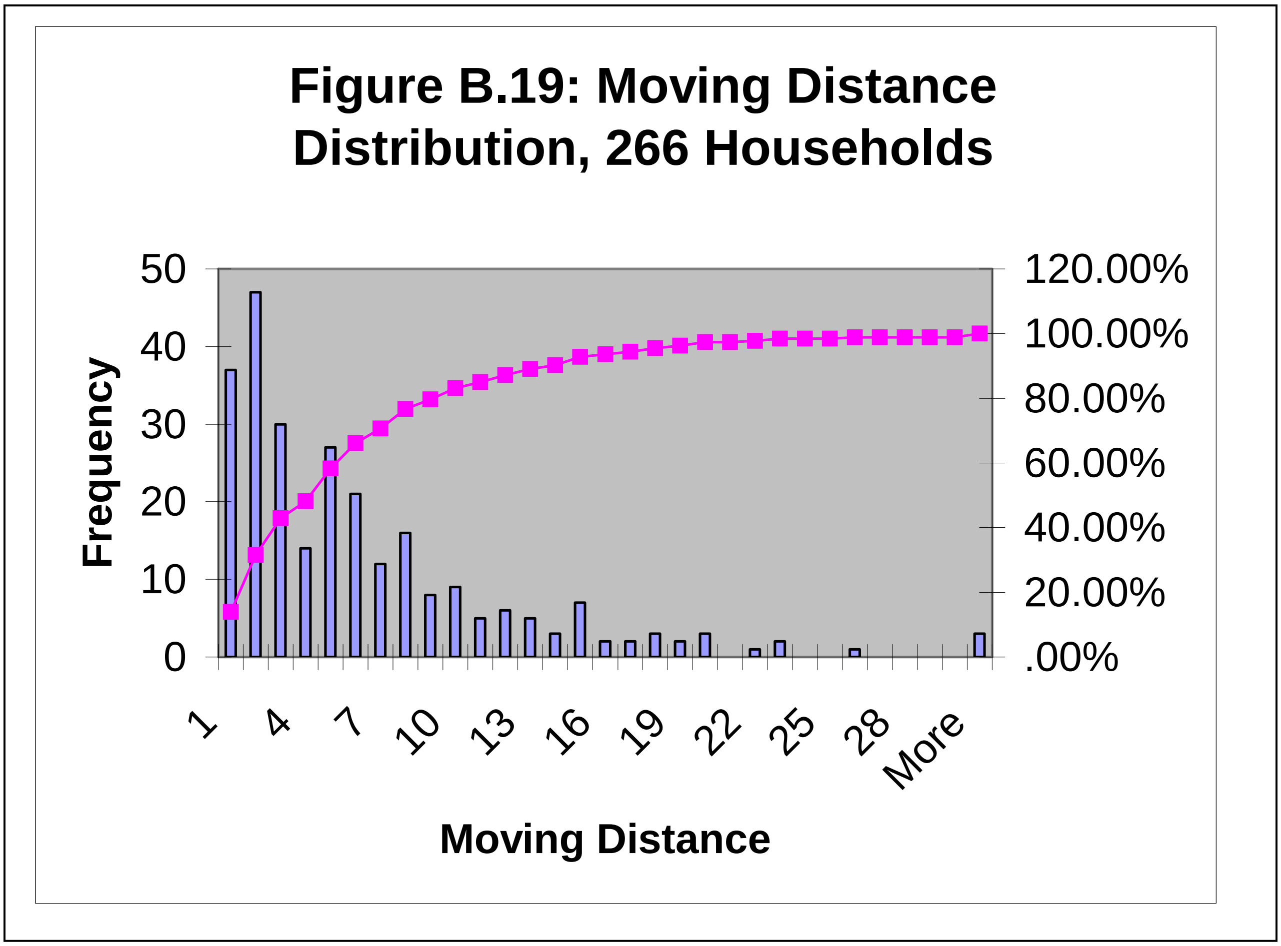
Figure B.18: Probability of Move Distances



Household Relocation Procedures

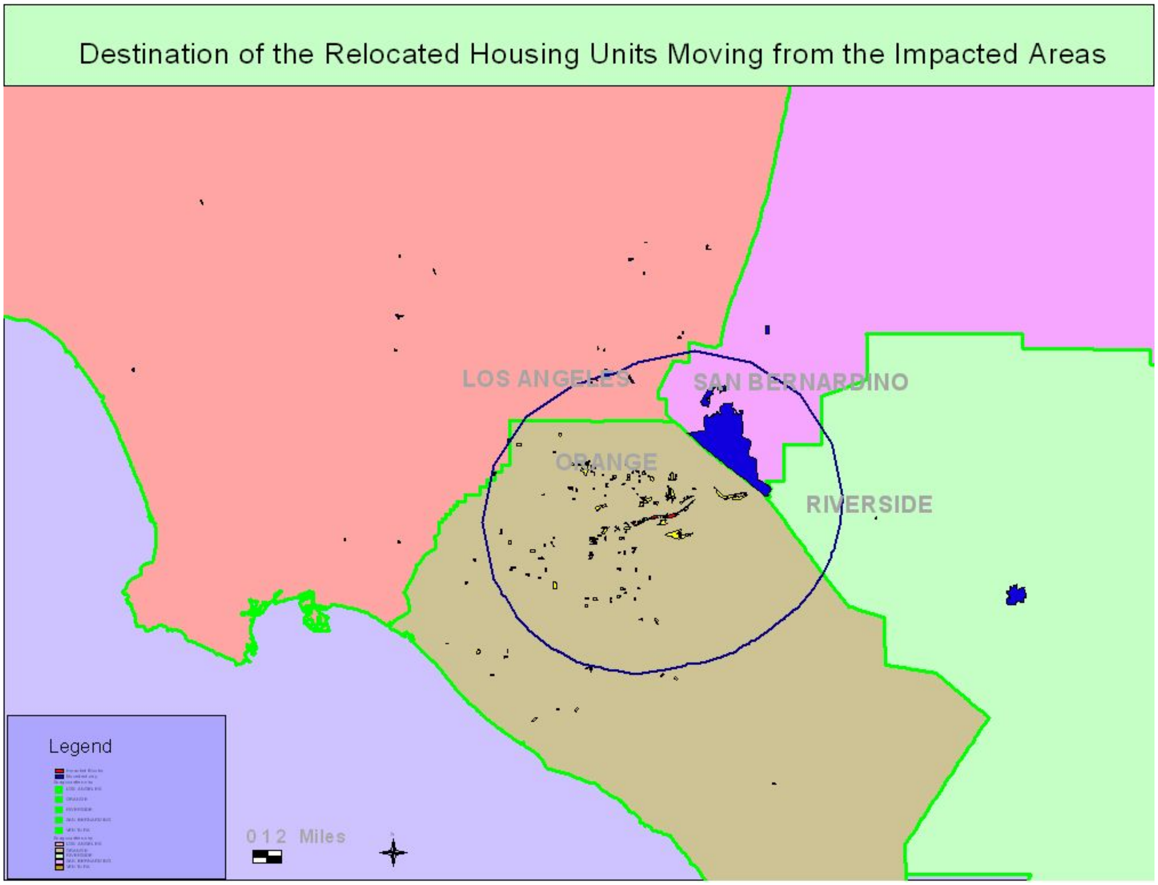
To implement the household relocation estimation procedure, two programs were developed. One was used to generate household moving distances. The other was used to find a plausible move-in place, given the distance, for each move-out household.

Randomly generate move distance for all 266 households using the probability distribution function (PDF) function with the mean move distance 6.28 miles. The following figure shows the distribution of random generated numbers (total 266) for move distance:



The second program used to relocate households was developed on a GIS platform because of the need to use spatial information extracted from census-block polygon maps. Because Census 2000 only released median housing unit prices at block group level, Census 1990 data were used to obtain the housing unit price at the block level for both origin and destination locations. These were later migrated from Census 1990 block-level files (SF4) to Census 2000 block-level maps. The distribution of relocated households is shown in Figure B.20:

Figure B.20



The distribution of the 266 relocated housing units in the SCAG region is shown in Table B.4.

Table B.4: Distribution of the 266 Relocated Housing Units in SCAG Region

County	Housing Units Moving in	Percentage
Orange	230	86.47%
Los Angeles	25	9.40%
San Bernardino	9	3.38%
Riverside	2	0.75%
Total	266	100%

Out of all the 266 relocated housing units in SCAG region, 230 (86.47%) housing units will remain in Orange County. The distribution of these housing units in the 2000 places (cities) is shown in Figure B.21 and Table B.5:

Figure B.21

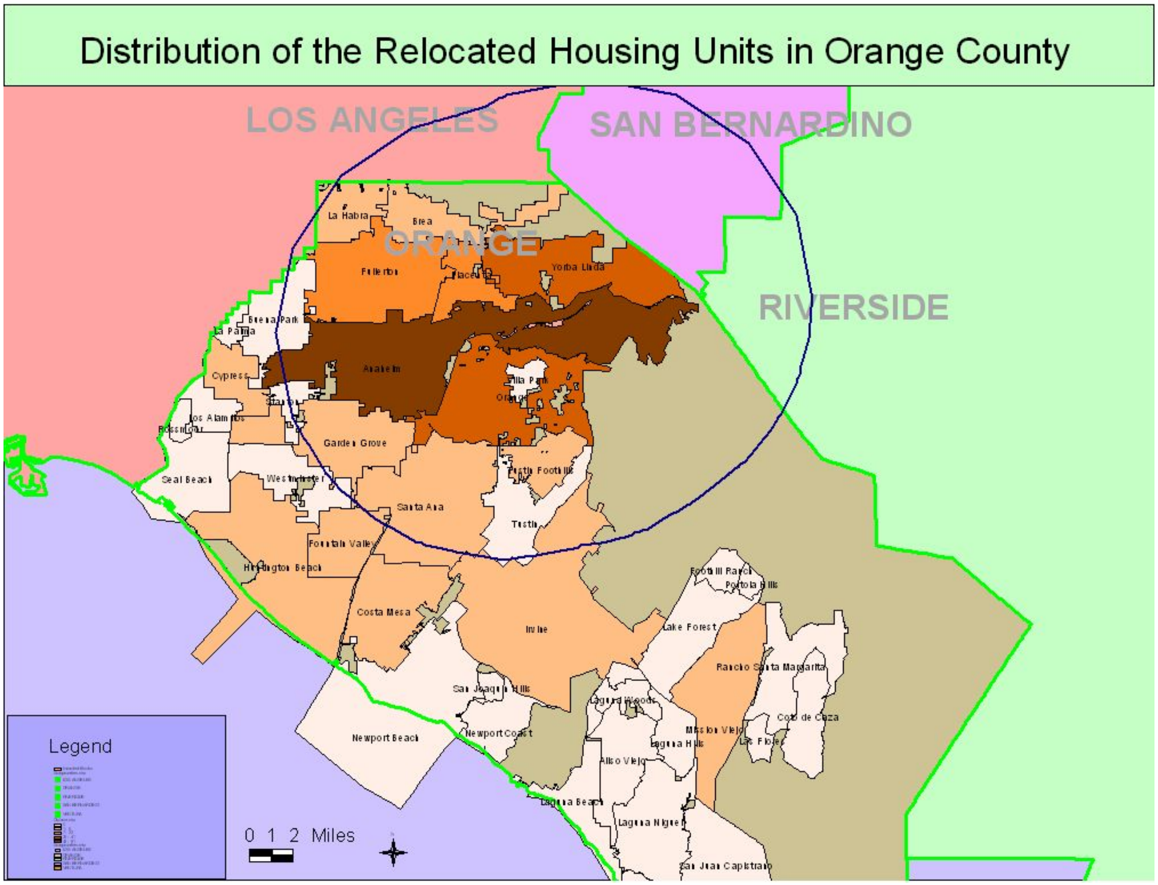


Table B.5: Distribution of Relocated Housing Units in the Cities of Orange County

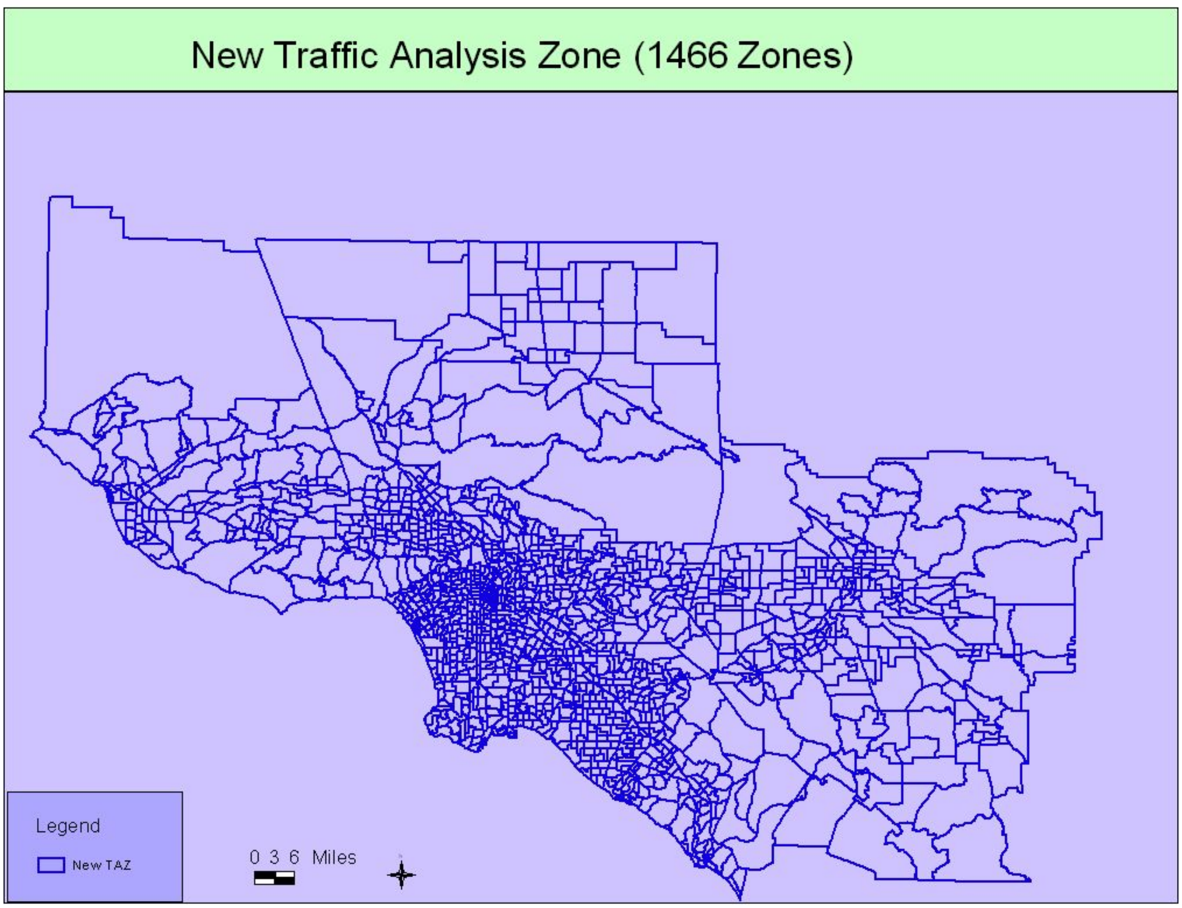
ID	COUNTY	PLACE	NAME	MOVEINTOT	% of TOTAL
2	06059	02000	Anaheim	81	30.45%
42	06059	86832	Yorba Linda	41	15.41%
27	06059	53980	Orange	35	13.16%
28	06059	57526	Placentia	22	8.27%
11	06059	28000	Fullerton	13	4.89%
12	06059	29000	Garden Grove	6	2.26%
35	06059	69000	Santa Ana	6	2.26%
5	06059	16532	Costa Mesa	4	1.50%
13	06059	36000	Huntington Beach	4	1.50%
39	06059	80868	Tustin Foothills	4	1.50%
14	06059	36770	Irvine	3	1.13%
3	06059	08100	Brea	1	0.38%
7	06059	17750	Cypress	1	0.38%
10	06059	25380	Fountain Valley	1	0.38%
19	06059	39290	La Habra	1	0.38%
24	06059	48256	Mission Viejo	1	0.38%

Design of USC Traffic Analysis Zone (USC TAZ)

To facilitate the SCPM model, a new traffic analysis zone system was developed on the basis of the SCAG 1990 TAZ and SCAG 1996 TAZ system. We refer to it as USC TAZ.

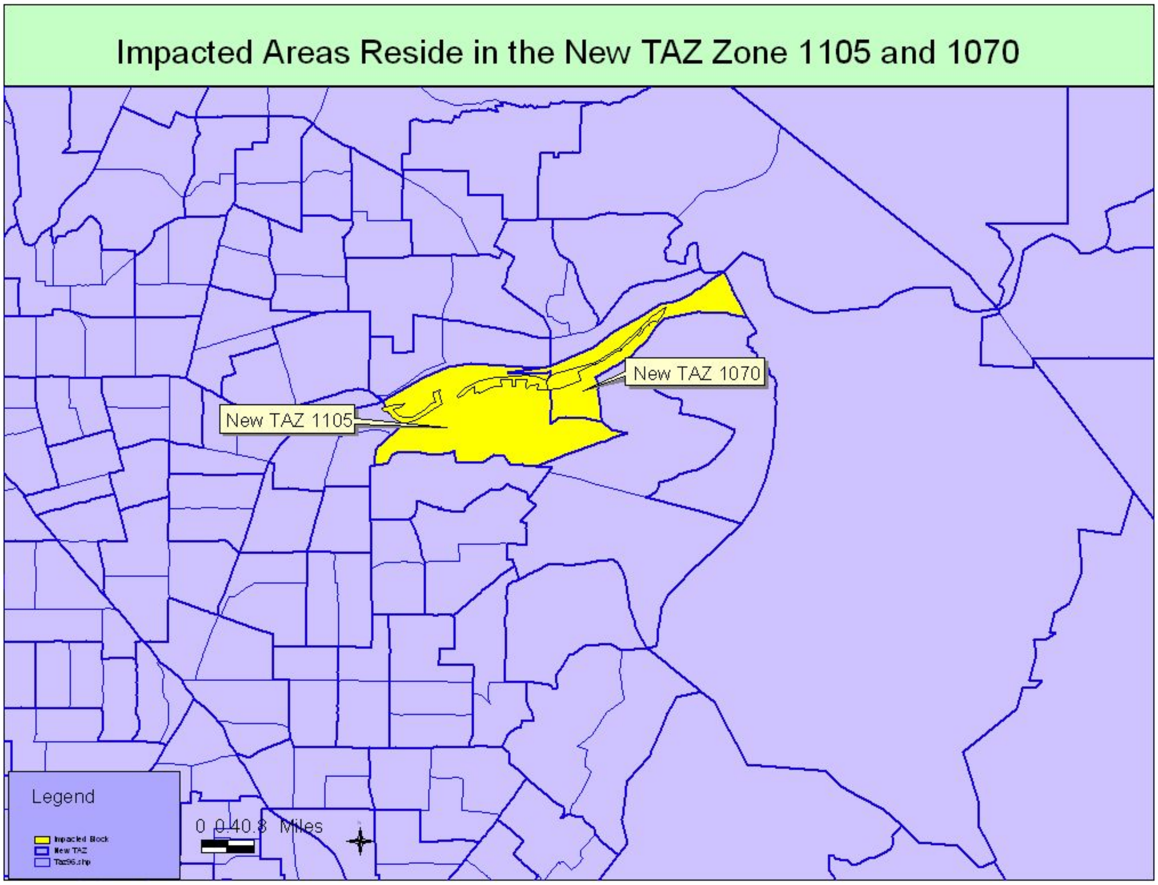
The procedure is to select and merge zones in SCAG 1996 TAZ (3192 zones) system that have their center in the same zone of SCAG 1990 TAZ (1527 Zones). This reduced the total number of TAZs to 1464. The USC TAZ system follows the boundaries of the TAZ 1996 zones (Figure B.22).

Figure B.22



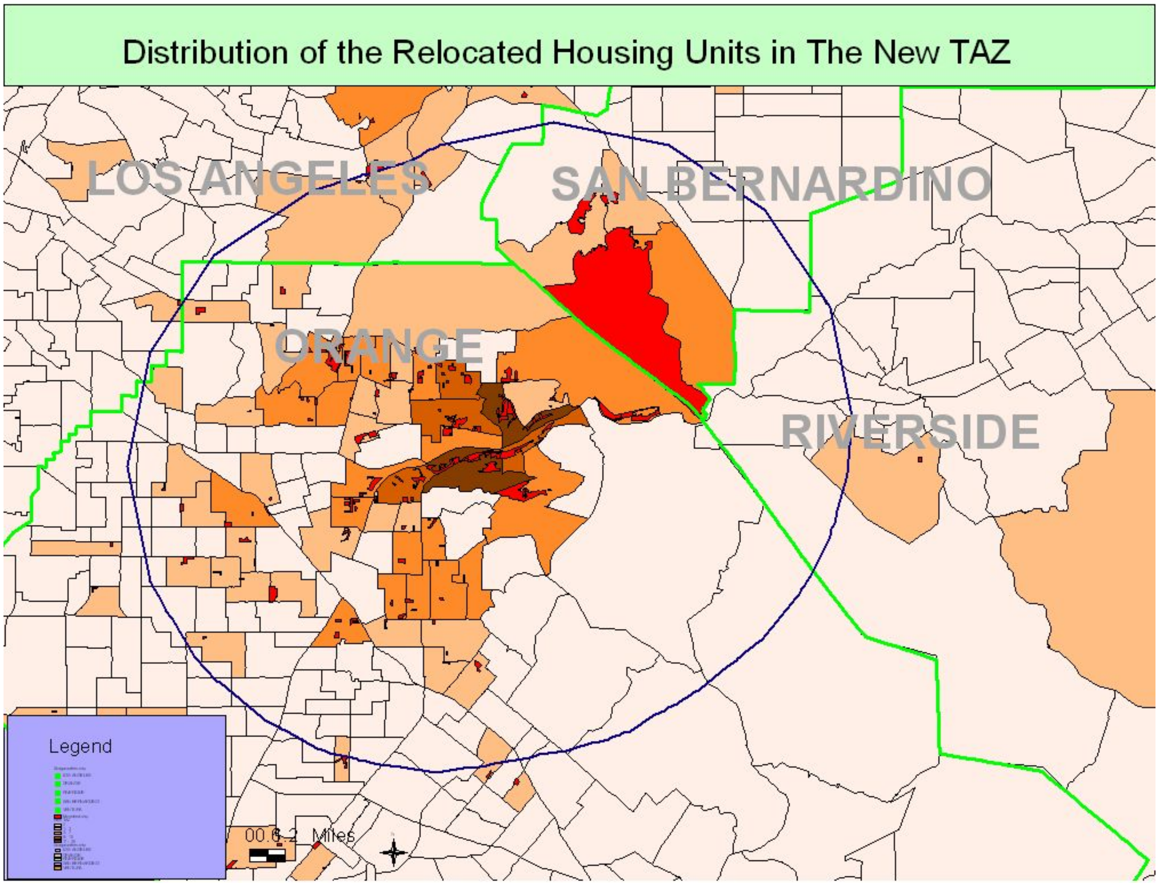
The impacted areas of SR91 expansion project in USC TAZ system are shown in the following figure:

Figure B.23



The distribution of the relocated housing units in the USC TAZ system is shown in Figure B.24.

Figure B.24



Appendix C: “Translators” for Highway Construction Impact Estimation

Table C.1

PCIO (94 sectors)			IMPLAN (94 sectors)		
ID	Industry	Factor	ID	Industry	Factor
21	Landscape and horticultural se	0.0076377	27	Landscape and horticultural services	0.0076377
26	Crude petrol. And natural gas	0.0000207	38	Natural gas & crude petroleum	0.0000207
27	Stone mining and quarrying	0.0102982	40	Dimension stone	0.0102982
28	Sand and gravel mining	0.0049495	41	Sand and gravel	0.0049495
33	Highway & street construction	0.3229258	51	New highways and streets	0.3229258
62	Ammunition, exc. Small arms	0.0000046	298	Ammunition, except for small arms, n.e.c	0.0000046
65	Small arms ammunition	0.0000127	297	Small arms ammunition	0.0000127
122	Cordage & twine	0.0000357	122	Cordage and twine	0.0000357
127	Knit outerwear mills	0.0000046	112	Knit outerwear mills	0.0000046
131	Apparel from purchased matls.	0.0000598	124	Apparel made from purchased materials	0.0000598
135	Canvas products	0.0000633	128	Canvas products	0.0000633
141	Sawmills & planing mills, genl	0.0002969	134	Sawmills and planing mills, general	0.0002969
144	Millwork	0.0003659	137	Millwork	0.0003659
146	Veneer & plywood	0.0014684	139	Veneer and plywood	0.0014684
147	Structural wood members, nec	0.0004879	140	Structural wood members, n.e.c	0.0004879
149	Wood preserving	0.0008136	145	Wood preserving	0.0008136
152	Wood products, nec	0.0003901	147	Wood products, n.e.c	0.0003901
170	Envelopes	0.0000104	171	Envelopes	0.0000104
177	Paperboard containers & boxes	0.0000230	164	Paperboard containers and boxes	0.0000230
190	Industrial chem., inorg & org	0.0000449	190	Cyclic crudes, interm. & indus. Organic chem.	0.0000449
196	Explosives	0.0011726	206	Explosives	0.0011726
199	Chemical preparations, nec	0.0000875	209	Chemical preparations, n.e.c	0.0000875
207	Surface active agents	0.0000023	198	Surface active agents	0.0000023
209	Paints & allied products	0.0080048	200	Paints and allied products	0.0080048
210	Petroleum refining	0.0784653	210	Petroleum refining	0.0784653
211	Lubricating oils & greases	0.0003050	213	Lubricating oils and greases	0.0003050
213	Paving mixtures & blocks	0.0617883	211	Paving mixtures and blocks	0.0617883
215	Tires & inner tubes	0.0000000	215	Tires and inner tubes	0.0000000
217	Fabricated rubber prod, nec	0.0000587	219	Fabricated rubber products, n.e.c	0.0000587
219	Rubber & plastic hose & belts	0.0000012	217	Rubber and plastics hose and belting	0.0000012
229	Glass & glass products, nec	0.0000046	230	Glass and glass products, exc containers	0.0000046
231	Cement, hydraulic	0.0072199	232	Cement, hydraulic	0.0072199
232	Brick & structural clay tile	0.0000748	233	Brick and structural clay tile	0.0000748
235	Structural clay prod, nec	0.0006813	236	Structural clay products, n.e.c	0.0006813
242	Concrete products, nec	0.0291743	243	Concrete products, n.e.c	0.0291743
243	Ready-mixed concrete	0.0429491	244	Ready-mixed concrete	0.0429491
244	Lime	0.0000023	245	Lime	0.0000023
246	Cut stone & stone products	0.0000311	247	Cut stone and stone products	0.0000311

251	Mineral wool	0.0005317	251	Mineral wool	0.0005317
254	Blast furnaces & steel mills	0.0031105	254	Blast furnaces and steel mills	0.0031105
256	Steel wire & related products	0.0015282	256	Steel wire and related products	0.0015282
PCIO (94 sectors)			IMPLAN (94 sectors)		
ID	Industry	Factor	ID	Industry	Factor
257	Cold finishing of steel shapes	0.0003682	257	Cold finishing of steel shapes	0.0003682
258	Steel pipe & tubes	0.0004902	258	Steel pipe and tubes	0.0004902
259	Iron & steel foundries	0.0023844	259	Iron and steel foundries	0.0023844
265	Primary nonferrous metals, nec	0.0000092	262	Primary nonferrous metals, n.e.c	0.0000092
266	Secondary nonferrous metals	0.0000104	263	Secondary nonferrous metals	0.0000104
268	Aluminum rolling & drawing	0.0002094	265	Aluminum rolling and drawing	0.0002094
270	Nf wire drawing & insulating	0.0023832	267	Nonferrous wire drawing and insulating	0.0023832
277	Metal sanitary ware	0.0000322	279	Metal sanitary ware	0.0000322
280	Fabricated structural metal	0.0318441	282	Fabricated structural metal	0.0318441
282	Fabr. Plate work (boiler shops)	0.0000150	284	Fabricated plate work (boiler shops)	0.0000150
283	Sheet metal work	0.0171660	285	Sheet metal work	0.0171660
284	Architectural metal work	0.0040392	286	Architectural metal work	0.0040392
286	Miscellaneous metal work	0.0076296	288	Miscellaneous metal work	0.0076296
287	Screw mach. Prod., bolts, nuts	0.0002704	289	Screw machine products and bolts, etc	0.0002704
294	Hardware, n.e.c.	0.0005604	278	Hardware, n.e.c.	0.0005604
297	Misc. Fabricated wire products	0.0038873	304	Miscellaneous fabricated wire products	0.0038873
298	Steel springs, except wire	0.0000046	302	Steel springs, except wire	0.0000046
315	Spec dies & mach tool access.	0.0000311	321	Special dies and tools and accessories	0.0000311
333	Carbs., pistons, rings, valves	0.0000150	350	Carburetors, pistons, rings, valves	0.0000150
334	Non-electrical machinery, nec	0.0001542	354	Industrial machines nec.	0.0001542
347	Switchgear & switchboard equip	0.0006306	356	Switchgear and switchboard apparatus	0.0006306
360	Lighting fixtures & equip.	0.0056158	369	Lighting fixtures and equipment	0.0056158
361	Wiring devices	0.0012233	368	Wiring devices	0.0012233
372	Engine electrical equipment	0.0000253	381	Engine electrical equipment	0.0000253
389	Transportation equip., nec	0.0000035	399	Transportation equipment, n.e.c.	0.0000035
394	Surgical appliances & supplies	0.0003878	408	Surgical appliances and supplies	0.0003878
399	Photographic equip. & supplies	0.0000460	413	Photographic equipment and supplies	0.0000460
411	Carbon paper & inked ribbons	0.0000046	425	Carbon paper and inked ribbons	0.0000046
417	Manufacturing, nec	0.0000242	432	Manufacturing industries, n.e.c.	0.0000242
418	Railroads & related services	0.0009620	433	Railroads and related services	0.0009620
419	Local transit, rail and h'way	0.0001438	434	Local, interurban passenger transit	0.0001438
420	Trucking & warehousing	0.0068977	435	Motor freight transport and warehousing	0.0068977
421	Water transportation	0.0007848	436	Water transportation	0.0007848
422	Air transportation	0.0007169	437	Air transportation	0.0007169
423	Pipelines,except natural gas	0.0001864	438	Pipe lines, except natural gas	0.0001864
425	Passenger transp. Arrangement	0.0000092	439	Arrangement of passenger transportation	0.0000092
426	Communications, exc radio & tv	0.0018481	441	Communications, except radio and tv	0.0018481
428	Electric utilities	0.0006755	443	Electric services	0.0006755
429	Gas utilities	0.0005017	444	Gas production and distribution	0.0005017
430	Water sup., waste disposal	0.0000449	445	Water supply and sewerage systems	0.0000449
431	Refuse, steam & irrigation svcs	0.0000012	446	Sanitary services and steam supply	0.0000012

PCIO (94 sectors)			IMPLAN (94 sectors)		
ID	Industry	Factor	ID	Industry	Factor
467	Engineer. & architect services	0.1727525	506	Engineering, architectural services	0.1727525
30	Misc. Minerals mining & serv.	0.0002451	46	Nonmetallic minerals (except fuels) service	0.0001226
			47	Misc. Nonmetallic minerals, n.e.c.	0.0001226
34	Other heavy const. Contractors	0.0227933	49	New industrial and commercial buildings	0.0267837
35	Plumb/heat/air cond. Contrctrs	0.0100831	50	New utility structures	0.0298512
37	Electrical const. Contractors	0.0168105	53	New mineral extraction facilities	0.0353993
38	Masonry, drywall & plastering	0.0268947	54	New government facilities	0.0248956
41	Concrete work	0.0067274			
43	Special trade contractors, nec	0.0336209			
172	Paper coated & laminated	0.0001715	165	Paper coated & laminated packaging	0.0000857
			166	Paper coated & laminated nec	0.0000857
365	Broadcast & commun. Equip., nec	0.0031128	373	Radio and tv communication equipment	0.0015564
			374	Communications equipment nec	0.0015564
432	Wholesaling: durable goods	0.0264343	447	Wholesale trade	0.0294436
433	Wholesaling: nondurable goods	0.0030093			

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