Validation of the RELU-TRAN L.A. Model

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1. Introduction

Background

The RELU-TRAN L.A. model is a spatially detailed computer general equilibrium model of the Greater Los Angeles Region and Imperial County, designed to treat the effects of a variety of changes and policies in the region. The Regional Economy and Land Use (RELU) model is a general equilibrium model of the local economy which includes components reflecting the key choices of consumers, producers, landlords and developers and their interactions in the labor, housing, outputs for industries and land markets. Consumers and firms are competitive in all markets, taking prices as given. Government is in the background through policy inputs such as property taxes that can be levied in each property type. All the markets (land, housing, products and labor) are connected by the regional mass transit and road networks. The TRAN algorithm of stochastic equilibrium supplies travel times and monetary costs to travel between home and work locations which are then used in the RELU model.

By focusing on the principal agents in urban markets and the choices they make about location and development, the RELU-TRAN L.A. model deals directly with behavior that planners and policymakers can readily understand and analyze. This behavioral approach based on microeconomic theory provides a structure more transparent than “black-box” models that do not clearly identify economic agents’ actions being modeled. The original RELU-TRAN model´s detailed structure, equation system and solution algorithm are described in Anas and Liu (2007).

The RELU-TRAN L.A. model is calibrated to the base year of 2000 and the approach in deciding on the model’s parameters was a mixture of fixing some parameters at reasonable values and calibrating others in such a way that the model’s elasticity relationships concerning location demand, housing demand and supply and the labor market are within reasonable ranges of estimates by various econometric studies in the literature.

However, to ensure that the RELU-TRAN L.A. model can actually be used as a robust platform for the development and testing of various transportation policies and development regulations on the Los

Angeles region, it is important to confirm that the base model accurately and realistically represent observed conditions on the six-county area.

In order to test the ability of the model to predict future behavior, validation requires comparing the model predictions with information other than that used in estimating the model. This step is typically an iterative process linked to model calibration. It involves checking the model results against observed data from independent sources and estimates in the literature and adjusting parameters until model results fall within an acceptable range of error. If the only way that a model will replicate observed data is through the use of unusual parameters and procedures or localized "quick-fixes", then it is unlikely that the model can reliably forecast future conditions.

Objective

The purpose of this report is to summarize the main findings of a preliminary validation of the RELU-TRAN L.A. model. This preliminary validation exercise consists in (i) assessing the accuracy of the calibration of the model in order to identify problems rather than to suggest how these problems might have occurred or might be solved and (ii) to assure that the calibrated RELU-TRAN base model accurately and realistically represent observed conditions on the six-county area in the year 2000. In particular, the calibrated model was evaluated by examining the predicted values for the year 2000 against real world values for the same year for the following endogenous variables: wages, commercial and residential rents, land and asset values, land use by building type and building stocks and flows. For completeness we have also examined construction and demolition costs, floor-to-area ratios/densities, commuting times from place of residence to work place and the distribution of workers, population and employed population both at the county and model-zone levels.

It should be noted that the production side of RELU L.A. and the TRAN part have not been examined in detail in this preliminary validation exercise. As such, this report does not identify problems on the production side of the model or provides any discussion on the model´s predicted production values for the year 2000. The report also does not discuss the model estimates on the generalized transportation costs obtained from TRAN L.A.

Report Organization

The rest of the report is structured as follows. Section 2 provides a brief overview how the Greater Los Angeles Region and Imperial County are represented in the RELU-TRAN L.A. model. Section 3 provides a summary of the data sources used in the calibration as well as a brief overview of the data obtained from the estimates based on the la-plan project´s econometric results. Section 4 discusses the main findings of this preliminary validation exercise and finally, section 5 offers conclusions and provides directions for future calibration experiments and refinements as well as some recommendations.

2. Representing the Greater Los Angeles Region and Imperial County

The Greater Los Angeles Area is a term used for both the urbanized region and Combined Statistical Area (a group of interacting metropolitan areas) sprawling over five counties in the southern part of California: Los Angeles, Ventura, San Bernardino, Riverside and Orange counties. According to the Census, the Los Angeles Metropolitan Area consists of Los Angeles and Orange counties. They are the two most populated counties in California with Los Angeles (9.5 million residents in 2000, according to the Census) being the most populated county in the United States. The Inland Empire is a metropolitan area located east of the Los Angeles Metropolitan Area and consists of Riverside County and San Bernardino County.

While Imperial County is not part of the Greater Los Angeles Area, it is included in the Southern California Association of Governments (SCAG) region (see figure 1). SCAG is the metropolitan planning organization of six of the ten counties in Southern California, serving Los Angeles County, Orange County, Riverside County, San Bernardino County, Ventura County and Imperial County.

Figure 1: SCAG Region and Surroundings

Source: http://www.scag.ca.gov/eMap/images/scag_region04.jpg

Model Zones

In the RELU-TRAN L.A. model, the Greater Los Angeles Area plus Imperial County are represented by a system of 97 model zones and by an aggregation of the major and local road networks.

Model zones in the RELU-TRAN L.A. resulted from the application of the moment of inertia (MI) approach to a compactness-driven, multi-constraint regionalization problem. The goal was to aggregate the 4109 transportation analysis zones (TAZs) in Los Angeles, Riverside, San Bernardino, Orange, Ventura and Imperial counties into approximately 100 regions, the maximum number considered computationally feasible for the subsequent work in microeconomic simulation of the study area.

The model zones were created to maximize the overall compactness of the generated zones while assuring that each zone was spatially continuous, their boundaries did not cross physiographic features and county boundaries and the intra-zonal traffic within a generated zone was smaller than a certain percentage of all traffic generated by that zone. Currently, only 97 model zones are used in the RELU-TRAN model. Full details of the zoning process can be found in Wenwen et al. (2013) and Church and Wenwen (2010).

Table 1 presents the distribution of the model zones by county in the RELU-TRAN L.A. model.

Table 1: RELU-TRAN L.A. Model Zones

Model Zones	County
Zones 1 through 46	Los Angeles
Zones 47 through 49	Ventura
Zones 50 through 66	Orange
Zones 67 through 80	San Bernardino
Zones 81 through 95	Riverside
Zones 96 through 97	Imperial

Figure 2 illustrates the 97 zones and Figure 3 illustrates the aggregated road network. Both maps were generated using the Graphical User Interface (GUI) available in the project website (la-plan.org). GUI is an online geographic information system (GIS) that supports data organization, data sharing and data visualization. However, because it is not a sophisticated GIS, this interface does not provide complex editing or analysis functions, such as cartography tools or spatial analysis tools. For further details see Goodchild et al. (2012).

Figure 2: RELU-TRAN L.A. Model Zones for SCAG Region

Figure 3: Road Network in the RELU-TRAN L.A

3. Data and Calibration

The RELU-TRAN L.A. model is calibrated to the base year of 2000 and the approach in deciding on the model's parameters was a mixture of fixing some parameters at reasonable values (for example demolition costs) and calibrating others in such a way that the model's elasticity relationships concerning location demand, housing demand and supply and the labor market are within reasonable ranges of estimates by various econometric studies in the literature.

Travel times and work trips from residences to workplaces by income and by mode of travel (car, bus and non-motorized) came from the year 2000 Census Transportation Planning Package (CTPP)-Part 3. From the CTPP, jobs by zone of workplace and estimates of wages by place of work were also determined. Non-work trip frequencies from residences were determined from SCAG data.

Residential housing stock is from the year 2000 Census, and non-residential values and building stocks from SCAG and Dataquick's tax assessment files.

Construction costs came from the R.S. Means database. Their data on construction costs include material costs, labor costs, and equipment costs. No land costs are included in their data. The RS Means Building Construction Cost 64th and 67th editions provide estimates of the per square foot construction cost for several types of commercial structures in the Greater Los Angeles Area. The types of construction include apartment buildings, department stores, factories, office buildings and retail stores. The RS Means Residential Construction Cost Data, 25th Annual Edition provides estimates of the per square foot construction costs for different types of residential structures. The building types are differentiated by square footage, number of stories, and quality of building materials. Four quality types are considered: economy, average, custom, and luxury.

The industries and inter-industry trade-flow relationships were obtained by following the IMPLAN's economic modeling system as were also expenditure shares by intermediate input categories (see Anas and Indra (2012)).

Car costs are from the American Automobile Association (AAA, 2005) and the Bureau of Transportation Statistics (RITA).

The value for vacant land was estimated using the SCAG database (see Zhang and Arnott (2011)). Residential housing prices and rents for floor space in single and multiple family housing were estimated using both Census data and SCAG parcel data (see Zhang and Arnott (2012)). Rents and value of offices were inferred by an imputation procedure that used the Costar Office data (see Ban and Arnott (2011)). Both developed and developable vacant lands in each model zone were estimated using the SCAG dataset (see Guo and Arnott (2012)). The structural density of buildings by type for each model zone was then constructed as a zone-average floor area per acre using the estimated values of developed land in each model zone and building stocks (see Gu and Arnott (2011)).

4. Discussion

Spatial Distribution of Consumers

The total number of consumers is given exogenously in the RELU-TRAN L.A. model and in this sense the model represents a "closed" region. The model then allocates this given aggregate population of consumers among the 97 model zones. In the base model there are 11,771,195 consumers.

The 2000 census, however, indicates the combined Greater Los Angeles Region and Imperial County population to have been 16,516,006 persons. *The discrepancy between these two absolute values should be addressed*, even though the equilibrium relative distribution of the population across the six county area matches the relative values observed based on the 2000 census data.

Table 2: Population by County

Comparison of U.S. Census and RELU-TRAN L.A. Base Case, year 2000

Counties	Census Data	% of Total Population	RELU-TRAN L.A. Base Case	% of Total Population
Los Angeles	9,519,338	58%	6,821,389	58%
Ventura	753,197	5%	539,165	5%
Orange	2,846,289	17%	2,068,777	17%
San Bernardino	1,709,434	10%	1,160,084	10%
Ventura	1,545,387	9%	1,082,544	9%
Imperial	142,361	1%	99,235	1%

Source: Calculated from Census2000 and from the RELU L.A. population by model zone output (excel file RELU_LA_JOBS_POP)

Spatial Distribution of Employed Population and Workers

Table 3: Workers by County

Comparison of CTPP and RELU-TRAN L.A. Base Case, year 2000

County	Total Workers CTPP (1)	Total Workers Base Model (2)	(2)/(1)
Los Angeles	3,921,708	3,836,112	0.98
Ventura	290,577	284,258	0.98
Orange	1,302,009	1,289,865	0.99
San Bernardino	555,205	533,815	0.96
Riverside	484,860	474,198	0.98
Imperial	25,928	25,754	0.99
Total	6,580,287	6,444,002	0.98

Sources: calculated from RELU L.A. jobs by model zone output (excel file RELU_LA_JOBS_POP) and from the data matrix used to target the work-trip pattern by mode of commuting and skill type in RELU L.A., which was based on the 2000 CTPP data for the SCAG region (excel file: trip).

Table 3 shows how well the calibrated model fits the target of jobs by zone constructed from the CTPP data. In the RELU-TRAN L.A. model there are a total of 6,444,002 people who work in the six-county study area. This amount also represents the number of jobs available in the model. A worker could be, in principle, either a resident or a non-resident of the six-county area.

Based on workers' residence locations, there are also a total of 6,478,779 employed residents in the RELU-TRAN L.A model. We define total employed residents as the total number of residents in the region who are currently employed. The destinations of these workers' commute can be anywhere within the six-county area.

The *RELU-TRAN L.A. model assumes that total employed residents are equal to total workers. There is however a small discrepancy (0.15%) in the base predicted outcomes of these two variables. It is possible that the small difference observed is due to imputation.*

Table 3A: Employed Population and Workers by County

RELU-TRAN L.A. Base Case, year 2000

Counties	Employed Population (1)	Workers (2)	Employed Population (%)	Workers (%)	Workers/Employed Population (2)/(1)
Los Angeles	3,664,632	3,836,112	57	59.5	1.05
Ventura	329,996	284,258	5	4.4	0.86
Orange	1,257,403	1,289,865	19	20	1.03
San Bernardino	622,804	533,815	10	8.3	0.86
Riverside	563,169	474,198	9	7.4	0.84
Imperial	40,775	25,754	1	0.4	0.63

Source: Workers: calculated from RELU L.A. jobs by model zone output (excel file RELU_LA_JOBS_POP); Employed Population: calculated from RELU L.A. employed population by skill type output (excel file: woknum)

Based on table 3A, about 76% of workers lived in Los Angeles County (57%) and Orange County (19%). For workers who had their workplaces inside the Greater Los Angeles Region, about 59.5% had their workplaces in Los Angeles County and 20% had their workplaces in Orange County, corresponding to a total of 5,125, 977 workers. Even though the Los Angeles MSA, which comprises Los Angeles County and Orange County, does not have the same clear-cut core/periphery pattern that most smaller metro areas evidence, the largest single employment cluster in the RELU-TRAN L.A. model is Downtown Los Angeles (MZ 1), although it accounts for only about 8% of the jobs in the metro area (see table 3B). This value is of the same order of magnitude of the value reported by Marlay and Gardner (2010). Marlay and Gardner (2010) use tract-to-tract commuting data from Census 2000 to identify high-employment nodes within metropolitan areas. According to the authors, downtown Los Angeles accounts for 6% of the jobs in the Los Angeles-Long Beach-Santa Ana Metropolitan Statistical Area and represents the largest employment cluster of the metropolitan area.

An analysis at the MZ level also reveals that the Los Angeles Metropolitan Area has a very decentralized distribution of employment, with high-job-density employment clusters and low-density-employment clusters scattered throughout the metro area (see table 3B). This is also consistent with existing empirical studies that provide support for job decentralization in the Los Angeles Metro Area. For example, Giuliano and Small (1991) investigate employment subcenters in the Greater Los Angeles Region using 1980 Census journey-to-work data. The authors identified 32 employment subcenters in the region with 29 located in Los Angeles County and Orange County. More recently, Marlay and Gardner (2010), using 2000 Census journey-to-work data, identified 25 employment clusters in the Los Angeles-Long Beach- Santa Ana MSA, which comprises Los Angeles County and Orange County.

Table 3B: Workers in the Los Angeles Metropolitan Area by Model Zone: RELU-TRAN L.A. Base Case, year 2000

County	Model Zone	Model Zone Name	Workers	Workers (%)
Los Angeles	1	Downtown Los Angeles	410,875	8.02
Los Angeles	2	Westside	83,226	1.62
Los Angeles	3	Glendale	108,436	2.12
Los Angeles	4	East Los Angeles	80,696	1.57
Los Angeles	5	Maywood	63,332	1.24
Los Angeles	6	Florence	40,964	0.80
Los Angeles	7	Baldwin Hills	117,126	2.28
Los Angeles	8	Beverly Hills	189,439	3.70
Los Angeles	9	El Segundo	175,007	3.41
Los Angeles	10	Santa Monica	139,038	2.71
Los Angeles	11	Marina del Rey	35,831	0.70
Los Angeles	12	Westwood	62,992	1.23
Los Angeles	13	East Santa Monica Mountains	76,628	1.49
Los Angeles	14	Reseda - Van Nuys	105,611	2.06
Los Angeles	15	East Van Nuys	91,412	1.78
Los Angeles	16	Burbank	127,277	2.48
Los Angeles	17	Pasadena	95,825	1.87
Los Angeles	18	East Pasadena	49,020	0.96
Los Angeles	19	Rosemead	87,053	1.70
Los Angeles	20	Pico Rivera	85,843	1.67
Los Angeles	21	South Gate	51,547	1.01
Los Angeles	22	West Compton	76,618	1.49
Los Angeles	23	Torrance	102,140	1.99
Los Angeles	24	Palos Verdes	51,568	1.01
Los Angeles	25	Carson	75,873	1.48
Los Angeles	26	Long Beach	38,079	0.74
Los Angeles	27	Signal Hill	120,681	2.35
Los Angeles	28	Compton	80,147	1.56
Los Angeles	29	Hawaiian Gardens	39,030	0.76

Los Angeles	30	Cerritos	26,495	0.52
Los Angeles	31	Norwalk	144,862	2.83
Los Angeles	32	Industry	87,647	1.71
Los Angeles	33	Diamond Bar	50,775	0.99
Los Angeles	34	North El Monte	54,318	1.06
Los Angeles	35	West Covina	34,180	0.67
Los Angeles	36	Glendora	39,028	0.76
Los Angeles	37	La Verne - Azusa	86,262	1.68
Los Angeles	38	Altadena	30,254	0.59
Los Angeles	39	North Hills - Sylmar	62,286	1.22
Los Angeles	40	Chatsworth	79,096	1.54
Los Angeles	41	Calabasas	96,759	1.89
Los Angeles	42	Malibu - Point Dume	14,499	0.28
Los Angeles	43	Agoura Hills	25,832	0.50
Los Angeles	44	Lake Los Angeles	2,397	0.05
Los Angeles	45	Lancaster - Palmdale	74,866	1.46
Los Angeles	46	Santa Clarita	65,242	1.27
Orange	50	Seal Beach - Los Alamitos	37,432	0.73
Orange	51	Cypress	24,443	0.48
Orange	52	South Buena Park	15,269	0.30
Orange	53	Buena Park - La Habra	105,886	2.07
Orange	54	Placentia	86,437	1.69
Orange	55	Yorba Linda	21,782	0.42
Orange	56	Huntington Beach	72,453	1.41
Orange	57	Garden Grove	69,447	1.35
Orange	58	Anaheim	142,083	2.77
Orange	59	North Tustin	46,935	0.92
Orange	60	Costa Mesa	38,963	0.76
Orange	61	Santa Ana	313,499	6.12
Orange	62	Tustin	50,946	0.99
Orange	63	Newport Coast	64,908	1.27
Orange	64	Irvine	74,735	1.46
Orange	65	East Orange County	75,246	1.47
Total			**5,125,977**	**100**

Source: RELU L.A. jobs by model zone output (excel file: RELU_LA_JOBS_POP)

The jobs/housing ratio expresses quantitatively the relationship between where people work (the job side) and where they live (the housing side). The typical measures of jobs/housing ratios include jobs-households, jobs-housing units, and jobs-employed residents. Table 3A also presents the workers-employed residents ratio for the six counties that come out of the base model. The ratios are calculated as the average of the workers-employed residents' ratios for each model zone within the county. Based on the values of table 3A, this ratio varies across the six-county area and ranges from 0.63 to 1.05. The ratio for the Greater Los Angeles Region as a whole is 0.994. What these values seem to suggest is that jobs-rich areas are located primarily along the coast, in Los Angeles and Orange Counties. The Inland Empire and Ventura County are essentially housing-rich areas. This is actually in accordance with previous studies on the jobs-housing balance on Southern California (SCAG, 2001).

Two remarks are nevertheless in order. The first is that the ratio workers-employed residents' indicator varies substantially across space within each county. For example, table 4 shows that for Los Angeles County the ratio ranges from 0.27 (Lake Los Angeles, MZ 44) to 3.26 (Westwood, MZ 12). The ratio for Downtown Los Angeles (MZ 1) is 2.77.

Table 4: Workers/Employed Residents Ratios Range by County

RELU-TRAN L.A. Base Case, year 2000

County	Maximum	Minimum
Los Angeles	3.26 Westwood, MZ 12	0.27 Lake Los Angeles, MZ 44
Ventura	0.96 Oxnard-Camarillo, MZ 49	0.86 Ventura North County, MZ 47
Orange	3.01 Irvine, MZ 64	0.44 North Tustin, MZ 59
San Bernardino	2 Rancho Cucamonga, MZ 69	0.51 Crestline, MZ 75
Riverside	2.29 Riverside, MZ 86	0.39 Lake Elsimore, MZ 85
Imperial	0.66 El Centro, MZ 97	0.59 Imperial Valley, MZ 86

Source: Workers: calculated from RELU L.A. jobs by model zone output (excel file RELU_LA_JOBS_POP);
Employed Population: calculated from RELU L.A. employed population by skill type output (excel file: woknum)

The second remark worth mentioning is that when analyzing commuting patterns, counties in which the number of workers and the number of employed residents is close to parity (such as in Los Angeles and Orange Counties) have substantial in- and out- commuting. Commuting refers to a worker's travel from home to work. Place of work refers to the geographic location of the worker's job.

Table 5 displays the percentage of employed residents by county who work in counties that are different from the county in which they live. It shows that the most housing-rich counties, San Bernardino and Riverside, have the lowest percentage of employed residents who both live and work in the county: Riverside (73.52%) and San Bernardino (69.85%). In addition, 925,331 workers (that is, 14% of workers) travel between counties to work. Los Angeles County attracts significantly more workers from other counties to work there than other counties, followed by Orange County.

We define resident workers in table 5 as the number of workers who reside locally. When computing workers/resident workers ratios based on the 2000 CTPP data, there is clearly a regional imbalance between jobs and housing in the Greater Los Angeles Region.

Table 5: 2000 CTPP Residence Based Work Person Trip Distribution

From/To	Los Angeles	Ventura	Orange	San Bernardino	Riverside	Imperial	Total
Los Angeles	3,519,427	31,702	157,057	40,716	9,268	102	3,758,272
	93.64%	0.84%	4.18%	1.08%	0.25%	0.00%	100.00%
Ventura	68,027	257,332	807	316	167	0	326,649
	20.83%	78.78%	0.25%	0.10%	0.05%	0.00%	100.00%
Orange	186,516	720	1,064,363	9,440	11,354	92	1,272,485
	14.66%	0.06%	83.64%	0.74%	0.89%	0.01%	100.00%
San Bernardino	110,859	601	28,701	444,686	51,678	74	636,599
	17.41%	0.09%	4.51%	69.85%	8.12%	0.01%	100.00%
Riverside	36,812	222	51,054	59,990	411,719	204	560,001
	6.57%	0.04%	9.12%	10.71%	73.52%	0.04%	100.00%
Imperial	67	0	27	57	674	25,456	26,281
	0.25%	0.00%	0.10%	0.22%	2.56%	96.86%	100.00%
Total	3,921,708	290,577	1,302,009	555,205	484,860	25,928	6,580,287
	59.60%	4.42%	19.79%	8.44%	7.37%	0.39%	100.00%
Workers/Resident Workers	1.11	1.13	1.22	1.25	1.18	1.02	

Source: calculated from the data matrix used to target the work-trip pattern by mode of commuting and skill type in RELU L.A., which was based on the 2000 CTPP data for the SCAG region (excel file: trip).

Workforce Composition

After determining where employment tends to cluster within the Greater Los Angeles Region and Imperial County, we have examined the composition of the workers who hold the jobs that make up the clusters in the RELU-TRAN L.A. model. Because jobs tend to cluster, it is logical to assume that similar jobs will cluster together, which in turn would mean that employment clusters would tend to host a relatively homogenous population of employees. In the RELU-TRAN L.A. model there are four skill types of workers, where skill-type 1 refers to the lowest skill level and skill-type 4 is the highest. The four skill types correspond roughly to income quartiles. The IMPLAN sectors reported on the table 6D-3 are based on the original sectoring scheme of IMPLAN which included 528 sectors.

Table 6A-1: 2000 CTPP Workforce Skill Composition by County

County	Type 1 (1)	% (1)/(5)	Type 2 (2)	% (2)/(5)	Type 3 (3)	% (3)/(5)	Type 4 (4)	% (4)/(5)	Total Workers
Los Angeles	2,730,418	60	619,378	57	290,287	57	281,625	60	3,921,708
Ventura	192,737	4	48,940	5	24,931	5	23,969	5	290,577
Orange	818,237	18	238,075	22	115,801	23	129,896	28	1,302,009
San Bernardino	400,780	9	97,682	9	39,931	8	16,812	4	555,205
Riverside	362,041	8	73,151	7	31,927	6	17,741	4	484,860
Imperial	18,348	0.4	4,555	0	2,239	0	786	0	25,928

Total (5)	4,522,561	100	1,081,781	100	505,116	100	470,829	100	

Source: calculated from the data matrix used to target the work-trip pattern by mode of commuting and skill type in RELU L.A., which was based on the 2000 CTPP data for the SCAG region (excel file: trip).

Table 6B: 2000 CTPP Workforce Composition by County

County	Skill Type 1		Skill Type 2		Skill Type 3		Skill Type 4		Total
	R	NR	R	NR	R	NR	R	NR	
Los Angeles	2,470,785	259,633	544,536	74,842	252,026	38,261	252,080	29,545	3,921,708
	63%	7%	14%	2%	6%	1%	6%	1%	100%
Ventura	169,348	23,389	43,532	5,408	22,655	2,276	21,797	2,172	290,577
	58%	8%	15%	2%	8%	1%	8%	1%	100%
Orange	655,354	162,883	193,147	44,928	97,267	18,534	118,595	11,301	1,302,009
	50.33%	12.51%	14.83%	3.45%	7.47%	1.42%	9.11%	0.87%	100%
San Bernardino	317,914	82,866	79,392	18,290	33,182	6,749	14,198	2,614	555,205
	57.26%	14.93%	14.30%	3.29%	5.98%	1.22%	2.56%	0.47%	100%
Riverside	306,215	55,826	61,435	11,716	27,934	3,993	16,135	1,606	484,860
	63%	12%	13%	2%	6%	1%	3%	0%	100%
Imperial	17,965	383	4,489	66	2,216	23	786	0	25,928
	69%	1%	17%	0%	9%	0%	3%	0%	100%
Total	2,470,785	259,633	544,536	74,842	252,026	38,261	252,080	29,545	

Source: calculated from the data matrix used to target the work-trip pattern by mode of commuting and skill type in RELU L.A., which was based on the 2000 CTPP data for the SCAG region (excel file: trip).Note: R stands for resident in the county and NR stands for non-resident in the county.

Table 6C: 2000 CTPP Workforce Composition in Downtown Los Angeles and Beverly Hills

Downtown Los Angeles MZ 1	Type 1	Type 2	Type 3	Type4	Total	%
Car	220,467	50,251	27,004	27,488	325,210	78
Bus	51,724	5,057	1,981	1,478	60,240	14
Rail	7,355	2,277	1,358	1,073	12,063	3
Other	17,971	1,401	588	553	20,513	5
Total	297,517	58,986	30,931	30,592	418,026	
%	71	14	8	7		100
Beverly Hill MZ 8						
Car	93,398	28,570	13,796	26,292	162,056	84
Bus	12,015	1,649	453	525	14,642	8
Rail	348	81	27	51	507	0
Other	8,249	2,877	1,426	3,291	15,843	8
Total	114,010	33,177	15,702	30,159	193,048	
%	59	17	8	16		100

Source: calculated from the data matrix used to target the work-trip pattern by mode of commuting and skill type in RELU L.A., which was based on the 2000 CTPP data for the SCAG region (excel file: trip).

The majority of the workforce commutes by car from their residences to Downtown Los Angeles and Beverly Hills, the two biggest employment clusters in the Los Angeles Metropolitan Area. This is not surprising and concurs with the sprawling car-dependence characteristics of the MSA. Los Angeles´s sprawl may originate in the region´s decentralized structure. Its major commercial, financial and cultural institutions are geographically dispersed rather than being concentrated in a single downtown or central areas. Moreover, those jobs are not very accessible by public transportation.

Table 6D-1: Employed Population by Skill Type in Downtown Los Angeles and Beverly Hills RELU-TRAN L.A. Base Case, year 2000

Model Zone	Type 1 (1)	% (1)/(5)	Type 2 (2)	% (2)/(5)	Type 3 (3)	% (3)/(5)	Type 4 (4)	% (4)/(5)	Total (5)
Downtown Los Angeles	125,316	84	15,288	10	5,087	3	2,853	2	148,543
Beverly Hills	47,861	40	29,667	25	18,365	15	23,070	19	118,963

Source: Calculated from RELU L.A. workers by skill type by model zone output (excel file: woknum)

The workforce composition by skill type in Downtown Los Angeles and Beverly Hills is also in sync with the types of industries located in the two model zones (see table 6D-2). Downtown Los Angeles has a broad mix of industries, somewhat weighted toward services, which is characteristic of a "traditional downtown". On the other hand, Beverly Hills is a more service-oriented zone with a moderate retail base (Giuliano and Small (1991)). It should be mentioned that the film industry (IMPLAN Sector 483- Motion Pictures) is aggregated with the service sector.

Table 6D-2: Value of Output Produced by Industry in Downtown Los Angeles and Beverly Hills: RELU-TRAN L.A. Base Case, year 2000

Industry	Downtown Los Angeles MZ 1		Beverly Hills MZ 8	
Agriculture	$289,170	0.002%	$53,485	0.001%
Finance/Insurance/Real Estate	$2,537,608,883	16%	$1,195,812,215	17%
Manufacturing	$2,718,717,870	17%	$235,629,115	3%
Public Administration	$298,082,459	2%	$19,481,797	0.3%
Retail	$2,148,514,479	14%	$1,533,186,605	22%
Services	$4,936,057,911	32%	$3,700,267,108	53%
Transportation, Warehousing	$863,425,375	6%	$105,005,098	1%
Utilities	$703,810,036	5%	$85,455,789	1%
Wholesale Trade	$1,378,794,403	9%	$152,857,236	2%
Total	$15,585,300,585	100%	$7,027,748,447	100%

Source: Calculated from RELU L.A. value of production by industry output (excel file: indfinprodzr)

Table 6D-3: RELU Industry and corresponding IMPLAN Sectors

RELU Industry	IMPLAN Sectors
Agriculture	1-47,57
Finance/Insurance/Real Estate	456-460, 462
Manufacturing	58-432
Public Administration	512,515,519,520,522,523
Retail	448-455
Services	463-509,525
Transportation, Warehousing	433-442,510,513
Utilities (electric, gas, sanitary services)	443-446,511,514
Wholesale Trade	447

Source: Anas and Indra (2012)

Table 6D-4: Employed Population by Skill Type by County

RELU-TRAN L.A. Base Case, year 2000

County	Type 1 (1)	% (1)/(5)	Type 2 (2)	% (2)/(5)	Type 3 (3)	% (3)/(5)	Type 4 (4)	% (4)/(5)	Total (5)
Los Angeles	2,029,520	55	816,778	22	461,931	13	356,403	10	3,664,632
Ventura	159,593	48	76,968	24	50,710	15	42,725	13	329,996
Orange	593,921	47	296,095	24	192,452	15	174,935	14	1,257,403
San Bernardino	343,411	55	155,131	24	84,379	14	39,883	7	622,804
Riverside	313,186	56	132,690	24	76,822	14	40,471	6	563,169
Imperial	26,001	64	8,789	22	4,229	10	1,756	4	40,775
Total									6,478,779

Source: Calculated from RELU L.A. workers by skill type by model zone output (excel file: woknum)

Table 6B provides the number of workers by skill type who live in the county based on the CTPP data, while table 6D-4 shows employed population by skill type in each county in the base model. *When examining both data one notices that the base model skill-type 1 employed population for Los Angeles, Ventura and Orange counties are lower than skill-type 1 resident workers according to the 2000CTPP. Therefore, further investigation should be in order.*

Commuting Times

In the RELU-TRAN L.A. model, commuting times, that is, travel time by car, from residences to workplaces were calibrated with data from the 2000 Census Transportation Planning Package (CTPP)-Part 3 (see excel file: commutetime).

A preliminary examination of the database showed that some of the reported commuting times between model zones seem unrealistic. In addition, there were several entrances with zero values. A comparison between CTPP travel times and commuting times generated by Google Maps was then conducted as part of this RELU-TRAN L.A. model validation process. The validation analysis focused just on pairs within the Los Angeles County and work trips by car.

Because Google Maps provides car travel under ideal conditions and CTPP gives reported car travel times, one may expect that the difference is due primarily to congestion. However, there are a couple of cases where clearly this does not seem to be the case. For example, the reported one-way travel time by car from East Van Nuys to Altadena is 19.14 minutes. However, these two model zones are 23 miles apart. According to Google Maps the estimated one-way travel time by car between the same two model zones using highway CA 134 E is 32 minutes under regular traffic conditions.

A major drawback of the CTPP-Part 3 data is that it does not include information on commute distance, speed or car travel times by time of the day. So one may also use goggle's travel time under current conditions to assess how car travel times in the same route would change depending on the time of the day. This would be an indirect way to infer the impact of congestion on car travel times.

Another example is the reported travel time between Marina del Rey (model zone 11) and Glendora (model zone 36). The reported one-way car travel time is zero minutes for a distance of 47.1 miles. One possible explanation for this reported value is that employed consumers do not commute between these two model zones by car, as it seems to be the case in this example. Therefore, one should check if all the reported zeros for the year 2000 correspond to cases in which employed population does not commute by car between the respective (origin-destination) pair. If this turns out to be the case, then these zero values should not affect the equilibrium distribution of the employed population since the calibration of the model is set to replicate the observed residence-work trips in CTPP-Part 3 for the year 2000. However, the same commuting patterns should emerge from the model optimization if the estimated travel time by car between these model zones was included in the model. *More work is therefore needed on the commuting times used to calibrate the RELU-TRAN L.A. model.*

For the Los Angeles County there are 4,462 possible pairs (residence, workplace). We randomly selected 137 pairs and analyzed separately all the entrances in the CTPP database matrix in Los Angeles County with a value equal to zero. A preliminary analysis of the sample revealed that out of the 137 randomly selected pairs, 34% are within reasonable commuting values, 45% are within unreasonable values (where 64% are too high) and 21% are clearly wrong.

The Google Maps application provides the shortest road route, the average driving time in ideal conditions (in good weather with no other cars on the road) (T_i) and what it believes to be driving time based on current conditions (T_c). Obviously, the current travel time reported changes depending on the time of the day that one performs the request and the difference between T_i and T_c can be quite large.

The results presented next are based on the T_i travel times in the shortest route reported by Google Maps. In order to assess the bias, we have also computed the root-mean-square deviation (RMSD) and the coefficient of variation of the RMSD (CV(RMSD)).

The RMSD was calculated as follows:

$$RMSD = \sqrt{\frac{\sum_{i=1}^{N}(x_i^{google} - x_i^{CTPP})^2}{N}}$$

where x_i^{google} is the car travel time reported in Google Maps under perfect conditions and x_i^{CTPP} is the reported car travel time in the 2000 CTTP dataset (excel file). N is the size of the sample. A very large value for this indicator means that the values are dissimilar and a zero means they are identical in conformation.

The CV(RMSD) was calculated as follows:

$$CV(RMSD) = \frac{RMSD}{\bar{x}^{google}}$$

where $\bar{x}^{google}$ is the mean of the reported values in Google Maps. This indicator shows the extent of variability in relation to the mean of the observed values in Google. If the mean of the measurements is too far away from the prediction (with the distance measured in standard deviation) then we consider the measurements as contradicting the prediction.

Tables 7A and 7B present the results of the analyses performed and which can be summarized as follows.

1.Cases within reasonable values

On average, one-way travel times reported in the CTPP are 5% higher than those reported by Google Maps. The Average Distance between residence-work on these pairs is 32 miles. As expected the RMSD value is not high.

2.Cases for which CTPP values seem too high

On average, one-way travel times reported in the CTPP are 30% higher than those reported by Google Maps. The Average Distance between residence-work on these pairs is 21 miles. Since the values of the CTPP pairs fall outside the ranges of the values that would be reasonably expected, the values of both RMSD and CV(RMSD) are high. However, these cases may reflect traffic congestion conditions. *Further investigation should be in order.*

3. Cases for which CTPP values seem too low

On average, one-way travel times in CTPP are 30% smaller than those reported by Google Maps under ideal conditions. The average distance between residence-work on these pairs is 38 miles. Like in the previous case the RMSD and CV(RMSD) are both high. *Thus, these cases should also be revisited since CTPP values clearly do not reflect traffic congestion conditions.*

4. Cases which are clearly wrong

On average, these values are 300% lower than those values reported by Google Maps. It should be noted that these cases fall into types of pairs: distance between residence and work place is either too high (above 50 miles) or too low (below 12 miles). The average distance in this sub-sample is 43.75 miles. *These cases should also be revisited*.

5. The Zero cases

Based on the Google Maps values, the average distance in these pairs is 75 miles and the average one-way travel time is 81 minutes. This suggests that the reported zeros in the CTPP dataset probably mean that the people who answered the questionnaire did not commute between those pairs. Out of the 17 reported zeros, 11 cases involve the model zone Lake Los Angeles. From these 11 cases, 9 involve residential zones too far from the work-zone Lake Los Angeles (see table 7B). Lake Los Angeles is located in the northern part of Los Angeles County, 17 miles east of Palmdale's Civic Center. An examination of work trips between these model zones reveals that in fact there are no work trips between these origin-destination pairs.

Table 7A: RMSD and CV(RMSD) Values

	Average Distance between O/D (in miles)	Average One-way Travel Time between O/D in Google Maps (in minutes)	Average One-way Travel Time between O/D in CTPP (in minutes)	Google Travel Time/ CTPP Travel Time	RMSD	CV(RMSD)
Entire Sample (137 pairs)	32.28	39.2	38.4	1.02	22.75	0.578
Sample reasonable values (46 pairs)	32.25	40.08	41.9	0.956	4.61	0.115
Sample unreasonable values (62 pairs)	26.9	33.85	37.34	0.906	11.89	0.35
Sample for which CTPP values seem too high (40 pairs)	21.13	27.47	38.44	0.714	11.69	0.425
Sample for which CTPP values seem too low (22 pairs)	37.51	45.45	35.32	1.286	12.23	0.269
Sample of clearly wrong values	43.75	49.68	35.09	1.42	45.93	0.924

Source: calculated from the data matrix used to calibrate travel times by car between residences and workplaces, which was based on CTPP data (excel file commutetime).

Table 7B: Pairs within Los Angeles County with CTPP travel time zero

Los Angeles County Residence-Work Pair	CTPP2000-Part3	Distance (in miles)	One-way Travel Time (google) (in minutes)
Florence-Lake Los Angeles	0	85.8	92
Marina del Rey- Glendora	0	47.1	54
Westood-Lake Los Angeles	0	73.7	79
East Pasadena-Lake Los Angeles	0	84.8	87
Rosemead-Lake Los Angeles	0	87.7	91
Cerritos-Lake Los Angeles	0	98.7	101
Cerritos-Malibu Point Dume	0	54.3	68
Cerritos-Altadena	0	36.8	43
West Covina -Lake Los Angeles	0	79.9	82
Glendora- Lake Los Angeles	0	73.6	78
Malibu/Point Dume-Altadena	0	54.9	67
Malibu/Point Dume-Lake Los Angeles	0	97.5	108
Malibu/Point Dume- Lancaster/Palmdale	0	88.3	93
Agoura Hills-Florence	0	42.9	51
Agoura Hills- Lake Los Angeles	0	84.2	89
Lake Los Angeles - Long beach	0	101	103
Lake Los Angeles -Agoura Hills	0	82.7	86

Florence-Lake Los Angeles	0	85.8	92
Marina del Rey- Glendora	0	47.1	54
Westood-Lake Los Angeles	0	73.7	79
East Pasadena-Lake Los Angeles	0	84.8	87
Rosemead-Lake Los Angeles	0	87.7	91
Cerritos-Lake Los Angeles	0	98.7	101
Cerritos-Malibu Point Dume	0	54.3	68
Cerritos-Altadena	0	36.8	43
West Covina -Lake Los Angeles	0	79.9	82
Glendora- Lake Los Angeles	0	73.6	78
Malibu/Point Dume-Altadena	0	54.9	67
Malibu/Point Dume-Lake Los Angeles	0	97.5	108
Malibu/Point Dume- Lancaster/Palmdale	0	88.3	93
Agoura Hills-Florence	0	42.9	51
Agoura Hills- Lake Los Angeles	0	84.2	89
Lake Los Angeles - Long beach	0	101	103
Lake Los Angeles -Agoura Hills	0	82.7	86

Source: calculated from the data matrix used to calibrate travel times by car between residences and workplaces, which was based on CTPP data (excel file commutetime).

Developed Land & Developable Vacant Land

Table 8A: Amount of Developed Land:

Comparison of Exogenous Sources and RELU-TRAN L.A. Base Case

County	Developed Land In RELU-TRAN L.A (in sqKm)	Developed Land (%)	Developed Land, NLCD 2001 (in sqkm)	Developed Land, NLCD 2001 (%)	Estimated Developed Land Guo and Arnott (2012) (in sqkm)
Los Angeles	6,205	54	3,508	38	6,790.63
Ventura	458	4	612	7	625.78
Orange	806	7	1,246	14	1,171.20
San Bernardino	1,268	11	1,747	19	9,455.01
Riverside	2,395	21	1,683	18	2,400.29
Imperial	274	2	329	4	2,140.53
Total	1,1407	100	9,129.3912	100	22,583.44

Sources: RELU L.A. developed land calculated based on the calibrated exogenous FAR values (excel file: far) and RELU L.A. existing floor space for each type of property output (excel file: stock).

The amount of developed land for each county reported on the second column in Table 8A was calculated as the sum of developed land in the county under residential (single and multi-family housing), commercial, industrial and public use. The amount of developed land for property type K was determined as the ratio of total square feet of existing floor space for property type K to floor-area-ratio (FAR) of property type K. In the RELU-TRAN L.A. model FAR values are exogenous while total square feet of existing floor space for a particular property type is endogenous.

According to the RELU-TRAN L.A. model, 54% of the entire developed land in the six-county study area is located in Los Angeles County, followed by Riverside County and San Bernardino County.

The values from the base case were compared with the values from the National Land Cover Dataset 2001 (NLCD2001). The NLCD 2001 is a 16-class land cover classification scheme that has been applied consistently across all 50 United States and Puerto Rico at a spatial resolution of 30 meters. NLCD2001 is based primarily on the unsupervised classification of Landsat Enhanced Thematic Mapper+ (ETM+) circa 2001 satellite data. The NLCD2001 provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover.

With the exception of Los Angeles, the amount of developed land in each county is lower than the amount reported in the NLCD2001 database. In the case of Los Angeles, developed land is almost twice the amount reported in NLCD2001.

FAR values in the RELU-TRAN L.A. model were calibrated with data from SCAG. Because of the possibility of severe coding errors in the floor area data from SCAG, appropriate adjustments were made in order to avoid the underestimation of aggregate floor area at the model zone level. Nevertheless, *in general, the adjusted FAR values used in calibration are too low, especially for the commercial and industrial uses in Los Angeles County.*

For example, FAR values for commercial and industrial uses in Downtown Los Angeles (MZ 1) are calibrated as 0.54. If a 50% coverage is assumed, this would imply one-story buildings for these two types of properties in the Downtown Los Angeles model zone, which covers major high-rise districts such as downtown LA, Hollywood and Wilshire Center. On the other hand, if a 10% coverage is assumed, we would get at the most a five-story building. However, this would also imply the existence of unrealistic setback regulations in the zone.

Yet, in most downtown Los Angeles, developers are technically entitled to build projects with a FAR of 13:1. That means a building designed to cover the entire land parcel would be allowed to rise 13 floors. Buildings with a footprint that takes up only half the parcel would reach 26 floors. While 13 to 1 is considered relatively high, most of the Los Angeles city is zoned at 3 to 1 or less- a voter approved ballot initiative in 1986 halved allowed density citywide. That in turn slashed the Downtown limit to 6 to 1, which is still higher than the one used in calibration.

In addition, it should be noted that there is also a discrepancy between the RELU-TRAN L.A. base case for developed land and the amount estimated by Guo and Arnott (2012) and reported in the technical report 2012-8, available at la-plan.org.

The observed discrepancy in developed land between the RELU-TRAN L.A. base case and the amounts reported by LNCD might be explained by the calibration of the floor-area-ratios (FAR) in the base model since the calibrated FAR values are too low as explained above. However, calibrated FAR values cannot explain the observed *discrepancy between the amounts reported in the technical report by Guo and Arnott (2010) and the amounts provided by the NLCD2001. Therefore, further investigation should be in order.*

Table 8B lists the amount of developable vacant land in each county in the RELU-TRAN L.A. model. Developable vacant land is defined as vacant land that is suitable for development at some point in the future. In general, the values for developable vacant land from the RELU-TRAN L.A. model seem also too low, especially when compared with the estimates provided by Landis (2000) and Fulton et al. (2003) and the estimates for developable vacant land (3000 & 3100) provided by Guo and Arnott (2012). The only exception is Los Angeles County.

Table 8B: Developable Vacant Land:

Comparison of Exogenous Sources and RELU-TRAN L.A. Base Case

County	**Developable Vacant Land in RELU-TRAN L.A. (in acres)**	**Potentially Developable Land Area as of 1996 (in acres) Landis (2000)**	**Potentially Developable Land Area as of 2000 (in acres) Fulton et al. (2003)**	**Estimated Total developable vacant land (in acres) 3000 &3100 Guo and Arnott (2012)**	**Estimated Total developable vacant land (in acres) Guo and Arnott (2012)**
Los Angeles	113,388	165,609	n/a	185,629.72	218,387.91
Ventura	4,902	88,987	94,986 with 20,860 inside the UGBs	68,601.15	137,202.30
Orange	7,229	57,603	n/a	40,142.66	46,140.99
San Bernardino	97,196	214,443	n/a	259,712.34	298,519.94

Riverside	81,915	293,164	n/a	376,649.47	432,930.43
Imperial	410,330	n/a	n/a	228,144.00	526,326.72

Source: RELU L.A. developable vacant land output (excel file: vacland)

In a study for the California Department of Housing and Community Development, Landis (2000) assembled data for land availability for housing development throughout California. The study defines raw land as comprising parcels located at the fringe of existing urban areas (designated as "Greenfields" sites) and distinguishes it from "infill" sites, which are located within developed urban areas. The data on raw land was gathered from digital maps from several sources such as the U.S. Geological Survey, the California Farmland Mapping and Monitoring Project, the State of California Teale Data Center, the National Wetlands Inventory, FEMA, the U.S. Census Bureau, the CA Department of Fish and Game's Natural Heritage Program, and the GAP Analysis Project. The data was formed into grids of one-hectare cells before separating it by county. Due to lack of data for urban areas, the analysis does not cover the urban areas and hence lacks the infill component in the eventual calculations. California's 60% land area is accounted for and the calculations cover 35 counties.

Land was also classified according to seven main categories: (1) already developed sites, (2) undeveloped sites, (3) potentially developable sites, (4) developable and accessible sites, (5) developable and accessible sites excluding wetlands and unique farmlands, (6) developable and accessible sites excluding wetlands, prime and unique farmlands, Q3 floodzones and areas identified as significant natural areas; developable and accessible sites excluding wetlands, prime and unique farmlands, Q3 floodzones and sites classified as highly suitable for eight or more threatened and endangered amphibian, bird, mammal or reptile species and (7) developable and accessible sites excluding wetlands, prime and unique farmlands, Q3 floodzones and sites 1 mile or more beyond existing urban development.

Land on the last category included undeveloped and privately owned sites that were not underwater and had an average slope of 15 percent or less within 6.2 miles of a major roadway or within 6.2 miles of existing urban development. The category excluded developable sites which were located more than one-mile form existing urban development in the process simulating the effect of comprehensive 1-mile urban growth boundaries (UGB) and their effect on the supply of raw land. The values reported in table 8B refer to the values provided in this last category.

In a more recent study Saiz (2010) uses satellite-generated data on terrain elevation and presence of water bodies to precisely estimate the amount of developable land in U.S. metropolitan areas. The author reports that of all MSAs with population over 500,000 in the 2000 Census, Ventura is the most constrained, with 80% of the area within a 50-km radius rendered undevelopable by the Pacific Ocean and mountains. The author also reports the percentages of undevelopable area for the Los Angeles-Long Beach (52.47%) and Riverside-San Bernardino (37.90%) metropolitan areas, but does not provide the actual amounts of raw land available in each county in the year 2000.

Fulton et al (2003) on the other hand provide information on their estimated amounts of developed and undeveloped land for Ventura County in the year 2000. The land use layers used in the study for developed area and farmland were derived from the California Department of Conservation's Farmland Mapping and Monitoring Program (FMMP) land conversion statistics for Ventura County. The water and wetlands layer was derived from multiple data sources, and the steep slope layer was derived by calculating slope from a 30M USGS DEM and selecting those areas greater than 25% slope. The open space layer was contributed by Ventura County.

The study reports that in the year 2000, Ventura County's urban footprint consisted of approximately 96,000 acres (or 389.773 Km^2). Of the remaining land, most is either steeply sloped land (slopes > 25%), cultivated farmland or permanently protected as open space of the total. A small amount is wetlands. Only 95,000 acres, or 17% of the total, is undeveloped and unconstrained by these other factors. This amount in turn accords with the percentage of undevelopable vacant land provided for Ventura County in Saiz (2010).[1]

Fulton et al. (2003) also report that the county's growth boundaries contained approximately 147,000 acres, or 26% of the land in the county. Most of this land (82,000 acres, or 56% of the total) was developed. Approximately 65,000 acres, or 44% of the land inside the boundary, remained undeveloped. About 14,000 acres of land, or 9% of the land inside the boundary, was protected open space, leaving 51,000 acres that is undeveloped and privately owned. Of that, most was either steeply sloped (18,000 acres, or 12% of the land inside the boundaries), protected (almost 14,000 acres, or about 9%), or farmland (10,800 acres, or about 7%). Again, a small amount was wetlands. Thus, only 20,860 acres, or about 14% of the land inside the boundaries, was undeveloped and unconstrained by these other factors.

Finally, there is also a discrepancy between the RELU-TRAN L.A. values and the values reported for developable vacant land on the technical report 2012-8 by Guo and Arnott, available at la-plan.org. The estimated values in the technical report were derived from SCAG parcel database and based on the current land use classification.

[1] It is reported that 461,793 acres are undeveloped land. 80% of this amount gives 369,434 acres of undevelopable land which implies an amount of potentially developable amount of 92,358 acres.

Further investigation should thus be conducted to determine why the amounts of developed and developable land used in the RELU-TRAN L.A. model are so different from the ones reported in the technical report 2012-8 by Guo and Arnott and from the values reported from the above external sources.

Land Prices

The price of a parcel of land measures not only demand for the land as an input into the production of residential or commercial buildings, but also demand for non-land attributes such as access to jobs, schools or consumption opportunities. In addition, because land is very durable, its price at any time has a forward-looking component associated with expected future changes in both the supply of these attributes and their value to users. Vacant land is also a unique commodity because, in addition to the attributes described, it offers its owner a low-cost option to build the optimal structure at the optimal time.

Table 9: Land Prices:

RELU-TRAN L.A. Base Case, year 2000

County	Average Land Price ($/sqft)
Los Angeles	52.86
Ventura	6.76
Orange	55.68
San Bernardino	19.84
Riverside	20.75
Imperial	2.76

Source: RELU L.A. land prices output
(excel file: value)

According to the RELU-TRAN L.A. model, the average price of vacant land in the SCAG Region is $26.44/square foot of land. However, average land prices are quite heterogeneous across the region. The most expensive areas are located in Los Angeles County and Orange County. The mean land price per square foot of land in these counties is respectively, $52.86/sqft and $55.68/sqft, reflecting the relative scarcity and desirability of vacant land in these areas. The mean land prices for San Bernardino and Riverside Counties are quite similar and around $20/sqft. Mean land prices for Ventura County and Imperial County are respectively, $6.76/sqft and $2.76/sqft. *The price of vacant land for Ventura County emerging from the base case is currently too low and deserves further investigation.*

It is interesting to note that base case prices per square foot of vacant land reveal that land closer to a particular CBD commands a higher price. This distance effect is consistent with the conventional economic view that the value of proximity to a central business district is capitalized into the price of a parcel of land. For example, the base model shows that the price per square foot of land in Downtown Los

Angeles (MZ 1) is \$108.56/sqft. A parcel located 10 miles from Downtown Los Angeles, say in Glendale (MZ 3) commands a price of \$37.15/sqft. A parcel in Burbank (MZ 16), which is 11.7 miles from downtown commands a price of \$26.14/sqft and if located 17 miles away from downtown, for example in Altadena (MZ 38), the price drops further to \$17.24/sqft. The land price for a parcel of land in Santa Clarita (MZ 46), which is 33 miles from downtown Los Angeles, is as low as \$5.67/sqft.

Wages and Rental Prices

The fundamental framework for analyzing compensating differentials and quality of life was developed by Rosen (1979) and Roback (1982). In these frameworks consumers/workers with similar preferences and firms with similar production technologies face different location specific amenity bundles across geographic areas. In spatial equilibrium, so that there is no incentive to move, differences in wages and/or housing prices develop to require payments for locating in amenity rich areas and provide compensation for locating in amenity poor areas.

Wages can differ because of skill differences but also because area amenities, fiscal conditions, and the price of goods and services vary across areas. In particular, prices may vary significantly for housing and other non-traded geographically-tied goods (e.g., climate, a mountain view, agglomeration economies). As emphasized by Roback (1982) area amenities act either to lower equilibrium wages or increase the price of land. Whether amenities raise land costs or lower wages depends on how amenities directly affect firms' costs of production. In Roback's model, a "productive" amenity (i.e., one that lowers a firm' costs) leads to higher land prices, but has an ambiguous effect on wages. Conversely, if amenities are unproductive, wages fall, but the amenity effect on rents is ambiguous. A combination of productive and unproductive amenities could both lower wages and increase the price of land.

A. Wages

Table 10 shows the mean hourly wage for each skill type for each county. The values were calculated assuming 250 working days a year and that employed residents work 8 hours a day. These assumptions are provided in excel files: d and H, respectively.

Table 10: Mean Hourly Wage ($/hour) by Skill Type:

RELU-TRAN L.A. Base Case, year 2000

Counties	**Hourly wage Skill Type 1**	**Hourly wage Skill Type 2**	**Hourly wage Skill Type 3**	**Hourly wage Skill Type 4**	**Average One-wayInter-county commuting time by car (in minutes)**
Los Angeles	7.7	19.3	30.3	60.4	37
Ventura	7.7	19.3	30.4	60.6	26
Orange	7.8	19.4	30.4	60.8	29
San Bernardino	7.7	19.2	30.3	59.6	30
Riverside	7.5	19.2	30.3	59.7	30
Imperial	7.6	19.2	30.3	59.8	21

Sources: RELU L.A. hourly wage output (excel file: wage) and commuting travel times calibrated based on CTPP2000-part3 data (excel file:commutetime)

Within the context of the RELU-TRAN L.A. model, the hourly wage for each skill level is quite similar across the six county area (see table 10). Note that average one-way commuting times (which are a disamenity) do not vary a lot across the six counties. The similarities of the observed inter-county commuting times may be explained by the observed inter-county decentralization of job opportunities. One nevertheless would still expect that areas with higher average commuting times would still pay higher average wages. However, anecdotal evidence shows that there are differences in urban amenities across these counties which may play an important role in the locational decisions of workers. This in turn may offset the impact of commuting times on wages, leading to the small discrepancies in average wages across the counties in the region of study. *Yet, one should check if the calibration of zone-specific locational amenities is consistent with this hypothesis.*

The values in table 10 for each skill type are nevertheless consistent with reported values by the Los Angeles-Riverside-Orange County, National Compensation Survey for April 2000 Bulletin. Data used in the bulletin was collected between September 1999 and October 2000.The average reference month in the bulletin is April 2000. Tabulations provide information on occupational wages and salaries for workers in a variety of occupations and at different work levels. The mean hourly wage for a blue collar is reported to range between $7.66/hour to $30.04/hour. The mean hourly wage for a white collar is reported to range between $8.15/hour to $63.64/hour. For example, the mean hourly wage for a white collar in the professional specially and technical group is $29.87/hour while for an executive, administrative or managerial white collar is $31.52/hour.

B. Annual rental price of each type of floor space

Table 11: Annual Rental price of Residential, Commercial, Industrial and Public Floor Space: RELU-TRAN L.A. Base Case, year 2000

	Rental Price (in $/sqft)					
County / *Type*	Los Angeles	Ventura	Orange	San Bernardino	Riverside	Imperial
Residential (single family)	16.8	14.7	16.3	10.2	11.7	6.7
Residential (multi-family)	8.8	11.1	12.6	12.5	13.7	4.8
Commercial	18.0	26.1	20.4	11.3	9.1	12.6
Industrial	19.4	20.6	20.4	11.8	12.3	10.7
Public	19.3	20.4	20.5	10.9	11.0	6.7

Source: RELU L.A. annual rental prices output (excel file: rent)

In contrast to wages, rental prices per floor space are quite heterogeneous across the six-county area. The highest residential-single family rental prices are in the Los Angeles Metropolitan Area (Los Angeles & Orange Counties), followed by Ventura County, the Inland Empire (Riverside & San Bernardino Counties) and finally, Imperial County. On the other hand, Ventura County has the highest commercial rental price per square foot in the RELU-TRAN L.A. model.

The equilibrium values for rental prices in the RELU-TRAN L.A. model are consistent with the economic theory that metropolitan areas with lower land availability tend to be more expensive in equilibrium. Lower land availability can be due to development regulations and/or to geographic features such as oceans, mountains or wetlands.

Geographically constrained metropolitan areas such as the Los Angeles MSA and Ventura also tend to have higher urban amenities in order to compensate for the higher housing prices.

In addition, the Wharton Residential Urban Land Regulation Index- created by Gyourko, Saiz and Summer (2008) to capture the stringency of residential growth controls- reveals that metropolitan areas in California are among those with the highest regulatory index values: Ventura, WRI=1.21; Los Angeles-Long Beach, WRI=0.49 and Riverside-San Bernardino, WRI=0.53. Saiz (2010) in turn shows that physical land scarcity is associated with stricter regulatory constraints to development, which may also explain why residential (Quigley and Raphael (2005), Glaeser et al. (2005)) and office/commercial floor space (Cheshire and Hilber (2008)) are more expensive in these metropolitan areas.

Construction Costs-to-Real Estate Asset Prices (excluding land)

In the RELU-TRAN L.A. model all real estate investors earn normal after-tax expected profits after competitive bidding on assets after receiving rents and accrued capital gains and incurring construction or demolition costs. There are four types of buildings (real estate asset): residential (single and multi-family housing), commercial, industrial and public.

Table 12 presents the average value per square-foot of floor space for each type of building in the RELU-TRAN L.A. base case, average construction costs and the ratio of construction costs to asset value in the base case.

From the analysis of table 12, *the value per square-foot of floor-space for multi-family housing in Los Angeles County seems too low and deserves further investigation*. The *value per square-foot of floor space for single family housing in Imperial County should also be revisited* as the equilibrium land value per square-foot of land is quite small and there is also no empirical evidence that Imperial County has stringent land use regulations or strong geographic barriers. The *value per square-foot of floor-space for commercial and industrial uses in Riverside and San Bernardino Counties also seem too low and deserve further attention.*

Table 12: Asset Values, Construction Costs and Construction Costs/Asset Value Ratios

	Los Angeles	Ventura	Orange	San Bernardino	Riverside	Imperial
Asset Price ($/sqft)						
Residential Single-family	215.4	178.3	179.3	82.8	111.9	215.4
Residential Multi-family	98.3	119.8	123.8	325.4	201.5	98.3
Commercial	110.9	173.3	154.4	50.3	82.1	110.9
Industrial	82.0	220.0	135.6	17.0	34.3	82.0
Public	69.1	120.1	223.3	8.1	7.8	69.1
Construction Costs ($/sqft)						
Residential Single-family	75.828	75.615	75.331	72.704	74.905	75.828
Residential Multi-family	102.528	102.24	101.856	98.304	101.28	102.528
Commercial	99.1104	98.832	98.4608	95.0272	97.904	99.1104
Industrial	68.352	68.16	67.904	65.536	67.52	68.352
Public	99.1104	98.832	98.4608	95.0272	97.904	99.1104
Construction-Cost to Asset Value Ratio						
Residential Single-family	0.35	0.42	0.42	0.88	0.67	0.35
Residential Multi-family	1.04	0.85	0.82	0.30	0.50	1.04
Commercial	0.89	0.57	0.64	1.89	1.19	0.89
Industrial	0.83	0.31	0.50	3.85	1.97	0.83
Public	0.35	0.42	0.42	0.88	0.67	0.35

Sources: Asset values: RELU L.A. output (excel file: value); Construction Costs: based on the RELU L.A. calibrated values for construction costs which were based on the R.S. Means Construction Cost Data (excel file: conscost)

Currently, the base model suggests that in Los Angeles, Orange, Ventura and Imperial Counties, single family housing has its price determined roughly by the physical costs of construction, as most of this type of housing value is within 40%of physical construction costs. This result is actually not surprising since the Los Angeles Metropolitan Area has on average the most expensive land value per square-foot of residential-single family use in the RELU-TRAN L.A. model. In the case of Ventura County, as discussed earlier, the value per square foot of vacant land seems unrealistic and deserves further investigation. In the case of Imperial County, land values are also quite low but the single-family housing price per square foot of floor space seems too high given the demand (low urban consumption amenities) and supply-side characteristics of the county. On the other hand, in counties where land is less expensive (such as in Riverside and San Bernardino), the price per square-foot of floor space for single-family housing is closer to construction costs.

These results are consistent with the analysis of the relationship between home prices and construction costs conducted in Glaeser and Gyourko (2003). The authors use the American Housing Survey data on single-family housing prices and the R.S. Means construction costs to create the relationship between homes prices and construction costs for several cities (central and suburban areas) in the United States. The authors report that a number of places, primarily in California, have almost no homes that cost less than 1.4 times construction costs.[2] The authors provide indirect evidence that stringent zoning regulation may explain why housing is so expensive in western cities of the United States.

Demolition Costs

The California Demolition Contractors (CDC) website provides estimates for the demolition costs per square foot in Los Angeles. The website mentions that demolition costs can range from $4 per square foot to $15 per square foot. The website also discusses different variables that may increase demolition costs such as the presence of asbestos, toxic or dangerous contents and long distances to waste disposal sites which will increase transportation costs.

In the RELU-TRAN L.A. model, demolition costs are set to equal 10 percent of the estimated construction costs for each type of building type (excel file: demconratio). This assumption is arbitrary. Yet the 10 percent figure seems reasonable from anecdotal evidence, implying that demolition costs in the RELU-TRAN L.A. model are between $6.5 and $10.25 per square foot (depending on the model zone and

[2] The Southern California cities examined in Glaeser and Gyourko (2003) include Anaheim, Los Angeles, Oxnard, Riverside, Sacramento, San Diego and San Francisco.

building type), which are within the ranges provided by the CDC website. These values were calculated with data provided in the excel files: demconratio and conscost.

5. Recommendations and Further Work

The RELU-TRAN L.A. model is a spatially detailed computer general equilibrium model of the Greater Los Angeles Region and Imperial County that includes components reflecting the key choices of consumers, producers, landlords and developers and their interactions in the labor, housing, outputs for industries and land markets. In addition, all markets are connected by the regional mass transit and road networks. The RELU part of the model connects with the TRAN part via the mode-and-route composite trip times and monetary costs. The RELU-TRAN L.A. model is calibrated to the base year of 2000.

To ensure that the RELU-TRAN L.A. model can actually be used as a robust platform for the development and testing of various transportation policies and development regulations on the SCAG region, it is important to confirm that the base model accurately and realistically represent observed conditions on the six-county area.

The goal of this report was to summarize the main findings of a preliminary validation of the RELU-TRAN L.A. model. Overall the calibrated RELU-TRAN base model accurately and realistically represents observed conditions on the six-county area in the year 2000. However, further work could be done following on from the findings reported here. Some of the possibilities considered most appropriate are outlined below.

Recommendations

1. A technical report providing the main attributes including the size of each model zone would be helpful.

2. There should be also a technical report explaining how the calibration of the RELU-TRAN L.A. base model parameters was done as well as the data sources used in the calibration. In particular, it should be mentioned how the various data were obtained including which values were estimated, imputed and which are simply assumed.

3. It would be helpful that whenever estimates are made available for analysis or validation, information on how the data was obtained is also provided. In particular, it should be noted if the estimates are based on the project´s econometrics results, are actual data from the RELU-TRAN model or just assumed.

4. The TRAN part of the model should also be validated. In particular, there should be an examination of the average over modes commuting times and weighted average monetary commuting costs since these are used by consumers to make choices in RELU.

5. The production side of the RELU part should also be validated since it was not examined in detail in this preliminary exercise.

6. The approach in deciding on the RELU TRAN L.A. model's parameters was a mixture of fixing some parameters at reasonable values and calibrating others in such a way that the model's elasticity relationships concerning location demand, housing demand and supply and the labor market are supposedly within reasonable ranges of estimates by various econometric studies in the literature. Future work should discuss the model´s calibrated elasticity relationships and values of time calculated from the model´s predicted equilibrium for the year 2000. This is particular important to understand how building markets, including stocks, rents and values, respond under the calibrated elasticities.

7. Further investigation should be done to understand the existing discrepancy between the number of consumers in the base case and the number of persons reported by the 2000Census.

8. One assumption of the model is that building structural density is constant by building type and zone. If the building´s floor space could be directly chosen by the developer, the stock could be more elastic when the building value increases.

9. One serious caveat of the current base case is the estimated FAR values by property type which are currently too low for multi-family housing, commercial and industrial uses. These values should be revisited since they could be affecting the model´s vacant land stock and building stocks predicted equilibrium values for the year 2000. Currently, there is a discrepancy between the base case amount of developed land and the amount reported by LNCD. In addition, there is a discrepancy between the values reported in the technical report by Guo and Arnott (2010) and NLCD2001. Therefore, further investigation should be in order. Moreover, the RELU L.A. amounts of developable vacant land also seem too low, especially when compared with the estimates provided by Landis (2000) and Fulton et al. (2003) and the estimates provided for developable vacant land by Guo and Arnott (2012). The only exception is Los Angeles County. Thus, it is recommended further examination on the source of these differences.

10. The price of vacant land for Ventura County in the base case is currently too low and deserves further analysis.

11. The value per square-foot of floor-space for multi-family housing in Los Angeles County seems also too low. The value per square-foot of floor space for single family housing in Imperial County should also be revisited as the equilibrium land value per square-foot of land is quite small and there is no empirical evidence that Imperial County has stringent land use regulations or strong geographic barriers. The value per square-foot of floor-space for commercial and industrial uses in Riverside and San Bernardino Counties also seem too low and deserve further attention.

12. The base model skill-type 1 employed population for Los Angeles, Ventura and Orange counties are lower than the resident skill-type 1 workers based on the 2000CTPP. Therefore, further investigation should be in order.

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