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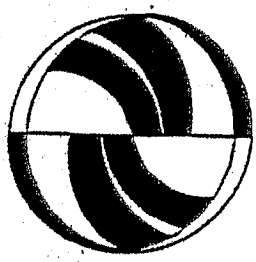
Publication Date
1991



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Genevieve Giuliano
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Regional Science and Urban Economics 21 (1991) 163–182. North-Holland

Subcenters in the Los Angeles region*

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Received October 1990, final version received January 1991

We investigate employment subcenters in the Los Angeles region using 1980 Census journey-to-work data. A simple subcenter definition is used, based solely on gross employment density and total employment. We find a surprising dominance of downtown Los Angeles and three large subcenters with which it forms a nearly contiguous corridor. Two-thirds of the region's employment, however, is outside any of the 32 centers we identify. Most centers have high population densities in and near them, and their workers' commutes are just 2.4 miles longer than other workers' commutes. A cluster analysis of employment by industry reveals several distinct types of centers, and a wide dispersion of sizes and locations within each type.

1. Introduction

This paper presents an empirical analysis of employment and population patterns of subcenters in the Los Angeles region. The research has three objectives: (1) to develop a method for systematically identifying employment subcenters; (2) to apply it to data from the Los Angeles region; and (3) to analyze the functions and distribution of centers and their associated commuting flows.

Contemporary metropolitan areas bear little resemblance to the monocen-

*Financial support has been provided by the U.S. Department of Transportation and the California Department of Transportation, through the University of California Transportation Center. We received valuable assistance in data assembly from Firooz Hamedani of the California Department of Transportation, Ding Bang Lee of the Southern California Association of Governments, and Debra Whitmore; statistical advice from Robert Newcomb; and research assistance from Myung Jin Jun, Hyun Lee, Jane Morrison, Shunfeng Song, and Feng Zhang. We are grateful for comments on earlier drafts from Rodney Erickson, Peter Gordon, William Oakland, William Wheaton, Michael Wiseman, and participants at seminars at the Lincoln Institute of Land Policy, Tel Aviv University, University of California at Davis, University of California at Irvine, and University of Southern California. All responsibility for opinions, errors, and omissions lies with the authors.

tric model of urban structure that has dominated urban economics and regional science for nearly three decades. Rather, they are characterized by decentralized patterns of employment, some dispersed along with population and some concentrated in activity centers. A growing body of theoretical literature describes how such subcenters develop and what impacts they have on land values, population distribution, and travel patterns [e.g. Hartwick and Hartwick (1974), White (1976), Odland (1978), Fujita and Ogawa (1982), Kim (1983), Wieand (1987), Sasaki (1990)]. These theories postulate economic forces to account for changing urban structure.

Empirical analysis of employment subcenters can illuminate these economic forces, which, briefly stated, create a conflict between agglomeration economies and congestion. When the congestion effects of central agglomeration become sufficiently high, some activities will decentralize, i.e., relocate outside the central core. If agglomerative forces are weak, these activities may decentralize to dispersed locations throughout the region; but if those forces are strong, activities will tend to concentrate in secondary clusters or nodes, called subcenters. Empirical study can determine the degree to which this employment is concentrated in subcenters, and thereby reveal the strength of agglomeration economies. It can also determine the economic functions of subcenters within the regional space economy.

The first empirical step is to establish a consistent definition. Prior studies have defined subcenters and documented their presence in various ways. Some arbitrarily define subcenter locations and then estimate density functions, either of population or employment, around these points [Bender and Hwang (1985), Mahmassani, Hadi-Baaj and Chung-Tong (1988)]. Others use centers as defined by a regional planning agency or local business association [Greene (1980), Griffith (1981a, b), Heikkila et al. (1989), Richardson et al., (1990)]. Still others define subcenters as municipalities of a certain minimum size [Erickson (1986)], or as historical growth poles such as often found near major transportation facilities [Baerwald (1982), Erickson and Gentry (1985)]. Some use industry case studies [Scott (1988)] or visual examination of commute flows (Bourne (1989)]. Getis (1983) uses a purely statistical approach based on point-pattern analysis, but this does not identify the actual subcenter locations.

Only a few researchers discuss empirical criteria for identifying subcenters from large regional data sets. Dunphy (1982), using a block-level land-use inventory of the Washington, D.C. area, describes a rather complex process involving visual analysis of density maps, cutoffs based on minimum total employment and maximum area, elimination of medium-sized clusters if too specialized, and boundary adjustments based upon employment densities. Gordon, Richardson and Wong (1986), using 1980 Los Angeles data, identify peaks in employment or population density, but do not delimit subcenter boundaries.

McDonald (1987) defines a subcenter as a zone whose measure of employment concentration is higher than all adjacent zones. For that measure, he suggests either gross employment density or employment–population ratio, for either total or manufacturing employment. This definition does not address the size of subcenters that cover two or more zones. McDonald identifies four subcenters from 1970 Chicago area data, aggregated to 44 zones. McDonald and McMillen (1989) use the same criteria to compare the subcenter patterns between 1956 and 1970.

Cervero (1989) reviews a number of ways that 'suburban employment centers' or 'activity centers' have been defined, noting such criteria as amount of floor space of development of various kinds (total, office, or retail), amount or density of employment, net inflow of morning commuters, and heterogeneity of land uses. Wishing to concentrate on commuting flows, he opts for minimum total employment (2,000) and minimum office floor space (one million square feet). Boundaries are defined by property lines or local planning agencies. Cervero's data come from a variety of sources requiring intensive research into each locality.

Given the variety of methods, it is perhaps not surprising that previous studies have obtained vastly different results, even for the same metropolitan area. The results of McDonald (1987) on Chicago differ substantially from the previous studies he reviews. For Washington, D.C., Dunphy (1982) gets 26 subcenters while according to Cervero (1989, p. 16), a real estate firm identified 13. The three prior studies using Los Angeles area data identify subcenters ranging in number from 6 to 54 [Gordon, Richardson and Wong (1986), Gordon, Richardson and Giuliano (1988), Heikkila et al. (1989)]. Furthermore, studies have found no consistent relationship between employment and population subcenters [Gordon, Richardson and Wong (1986)], despite the close relationship implied by standard theory.

We believe that better consistency and comparability can be obtained by applying an objective definition to standard data at a fine level of geographical detail. In this paper, we do so using 1980 Census journey-to-work data for the Los Angeles region, thereby providing a systematic method of employment-center identification which can be applied to other regions. The resulting data set, consisting of 32 centers with their characteristics, provides a rich description of employment centers in the region. In the remainder of the paper we present these descriptive data, discuss some intriguing features of the centers, and exploit the data for preliminary analysis of the spatial distribution, commuting patterns, and types of industrial specialization characterizing these centers.

2. Data and study area

The Los Angeles region provides an ideal area for studying subcenter

emergence and growth. The conventional view of the region is one of endless urban sprawl, with employment and population dispersed throughout. Indeed, its development history is one of decentralization, originally along an extensive interurban rail network [Brodsky (1981)] and later along the freeway system [Wachs (1984)].

Metropolitan growth was largely confined to Los Angeles County up to World War II. Since then, decentralization has been rapid and extensive. By 1965, residential suburbs extended well into Orange County to the south and the San Fernando Valley to the north. By 1980 these areas had their own extensive employment base, and suburban development had reached still further, taking in large tracts in Riverside and San Bernardino Counties to the east. Ventura County, located on the region's western edge, remained primarily residential.

Our study region consists of the 1146 'transportation analysis zones' (AZs) as defined by the Southern California Association of Governments (SCAG), after deleting 139 very low-density outlying zones. It encompasses 3,536 square miles and covers the urban portions of Los Angeles, Orange, Ventura, Riverside, and San Bernardino Counties. With 10.7 million people and 4.65 million jobs in 1980, the region is part of the United States' second largest consolidated statistical metropolitan area. It includes the nation's second largest city, Los Angeles, and more than 150 other municipalities.

The Census journey-to-work data provide information on population characteristics, employment, and travel flows at a reasonably fine level of spatial detail. In order to facilitate the computation of commuting times and distances, as well as future year-to-year comparisons, we use the version of the data created for the Urban Transportation Planning Package (UTPP), which are transformed from the census-tract geography to the SCAG analysis-zone geography. Like census tracts, AZs are aggregates of census blocks; but the AZ boundaries are determined by functional characteristics, and need not include a fixed population.

3. Definition and traits of employment centers

3.1. Definition and identification of subcenters

We agree with McDonald (1987) that employment, not population, is the key to understanding the formation of urban centers; and that a center is best identified by finding a zone for which gross employment density exceeds that of its neighbors. We seek a definition that incorporates adjacent high-density zones, and which restricts attention to centers large enough to exert a potentially significant influence.

We therefore define a center as a continuous set of zones, each with density above some cutoff $\bar{D}$, that together have at least $\bar{E}$ total employment

and for which all the immediately adjacent zones outside the subcenter have density below $\bar{D}$. (To be classified as adjacent, the zones must have at least 0.25 miles of common boundary.) With this definition, all high-density zones in the region are classified as part of some center unless they are both small (less than $\bar{E}$ employment) and isolated (not part of a cluster of high-density zones with $\bar{E}$ employment in total). The *peak* of the center is defined as the highest-density zone or group of contiguous zones within the subcenter that together have at least $\bar{E}$ employees.

Our choice of cutoff values is governed by the desire to match the theoretical concept, to be able to analyze commuting to subcenters, and to end with a manageable number suitable for statistical analysis. This implies that an employment center should be relatively compact and contain a sizeable employment base. These criteria are met with a density cutoff of 10 employees per acre, and a minimum total employment of 10,000. Higher density cutoffs would exclude from subcenters many predominantly employment-oriented zones that are contiguous with the higher-density peaks, and would exclude altogether some sizeable outlying peaks in employment densities.

We decided against a criterion using the employment density relative to a surrounding subregion. Although such a criterion would identify some distinct but quite small employment concentrations in outlying areas, it would exclude some much larger concentrations in the central counties. We also decided against a criterion using employment–population ratio because economies of agglomeration depend on the distances between firms, whether or not there is interspersed population.

Using these criteria, the three outer counties – Riverside, San Bernardino, and Ventura – contain only one subcenter. Their chief employment centers (one in each country) were small and isolated in 1980, but constituted definite peaks in employment density. For these counties, we lower our employment cutoff $\bar{E}$ to 7,000 and classify the resulting three centers as *outer centers* rather than subcenters. In addition, we designate the employment concentration around downtown Los Angeles that is identified by our criteria as the *main center*, rather than a subcenter. When we refer to the 32 *centers*, then, we mean all those identified by our criteria, whereas the 28 *subcenters* exclude Downtown Los Angeles, Riverside, Oxnard, and San Bernardino.

3.2. Subcenter characteristics

The 32 centers are listed in table 1, each named by the primary cities or neighborhoods in which it is located. Their locations are shown in fig. 1. Table 2 provides summary statistics.

The four largest centers form an arc from Santa Monica through

Table 1

Centers by rank order.

Rank	Location[a]	Employment (1000's)	Employment density (no./acre)	Area (1000s) acres)	Employment–population ratio	Distance from CBD (miles)
1	Downtown LA	469.0	36.0	13.0[c]	1.47	0.1
2	LA West	176.2	25.5	6.9[c]	1.37	15.8
3	Santa Monica	65.1	16.9	3.8[c]	1.11	16.7
4	Hollywood	64.2	21.4	3.0[c]	0.73	7.3
5	LA Airport	59.1	16.7	3.5[b]	4.32	18.8
6	Orange Co. Arpt. (OR)	47.7	16.1	3.0	1589.87	40.7
7	Glendale	43.0	15.5	2.8[c]	1.07	12.3
8	Commerce	41.9	17.0	2.5[b]	4.05	9.8
9	Vernon/Hunting. Park	39.2	33.2	1.2[b]	2.42	4.9
10	San Pedro	37.6	15.7	2.4[b]	2.74	23.3
11	Santa Ana (OR)	37.5	17.3	2.2[b]	1.51	32.9
12	Inglewood	36.5	14.6	2.5[c]	1.24	14.7
13	Pasadena	35.9	25.3	1.4[b]	1.73	12.1
14	Long Beach Airport	33.2	15.5	2.1	3684.78	23.3
15	Marina Del Rey	31.7	11.4	2.8[c]	1.28	14.0
16	Long Beach	29.7	18.0	1.6[c]	0.84	25.3
17	Van Nuys Airport	27.8	12.6	2.2[b]	2.04	22.1
18	Burbank Airport	26.2	28.4	0.9	10.86	16.5
19	Hawthorne	17.9	12.4	1.4	0.74	13.5
20	Canoga Pk./Warner Ctr.	17.2	11.2	1.5	1.21	27.4
21	Lawndale	16.9	17.1	1.0	1.36	20.5
22	LA East	16.3	37.3	0.4	2.30	6.8
23	Fullerton/Anaheim (OR)	16.1	11.4	1.4	4.97	27.3
24	Downey	14.6	17.3	0.8	2.38	14.8
25	Riverside (RIV)	14.2	21.4	0.7	3.76	56.9
26	Santa Ana South (OR)	14.1	12.2	1.2	1.76	37.4
27	Sherman Oaks	13.3	11.9	1.1[b]	1.04	18.6
28	Burbank SW	12.7	18.0	0.7	1.92	14.1
29	Orange/Gar. Grove (OR)	10.5	11.3	0.9	1.06	30.2
30	Gar. Grv./Stanton (OR)	10.1	12.9	0.8	5.60	26.6
31	Oxnard (VEN)	8.3	10.3	0.8	0.98	63.0
32	San Bernardino (SB)	7.3	22.9	0.3	7.89	63.6
Total centers (32)		1,490.9	21.0	71.0	1.55	N/A
Total subcenters (28)		922.2	17.7	56.2	1.58	N/A

[a]County in parentheses if not Los Angeles County. OR = Orange; RIV = Riverside; SB = San Bernardino; VEN = Ventura.

[b]This center consists of two transportation analysis zones.

[c]This center consists of three or more transportation analysis zones.

downtown Los Angeles, which we call the Wilshire Corridor. They are so close together that at a lower density cutoff, these four plus one smaller subcenter (Los Angeles East, no. 22) would form one giant center, 19 miles long. We call these five centers together the *core*.

The most striking observation from tables 1 and 2 is the dominance of the

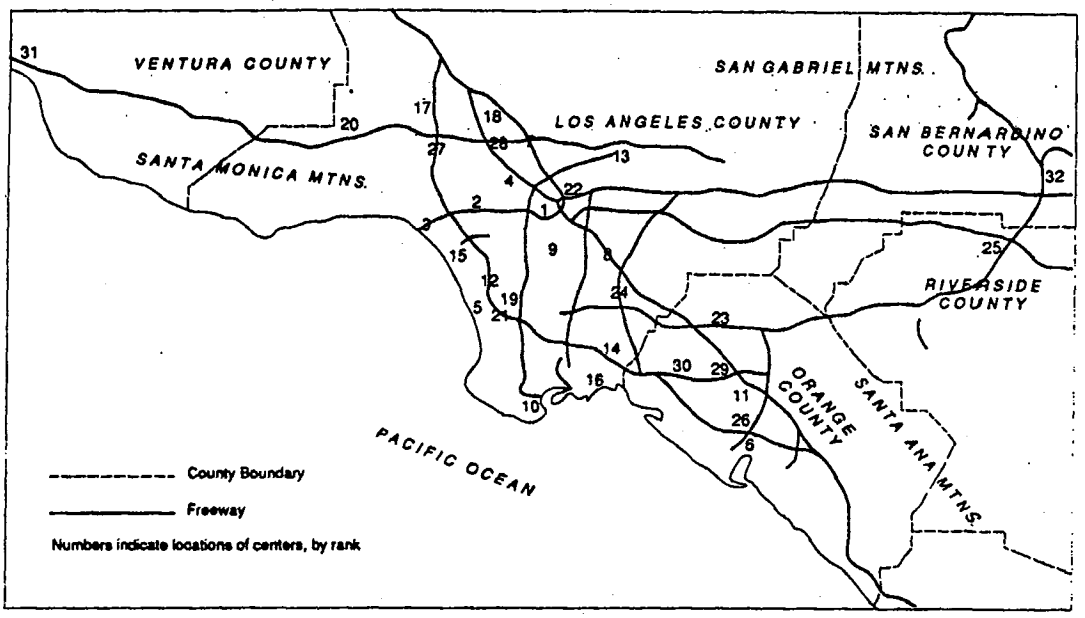

Fig. 1. Locations of employment centers.

Table 2

Aggregate employment, population, and area within and without centers.

	Employment (1000s)	Population (1000s)	Area (1000s acres)	Empl. density (no./acre)	Pop. density (no./acre)	Empl.–pop. ratio
Within centers						
Main Center	469.0	319.0	13.0	36.0	24.5	1.47
Other Core Centers	321.9	282.2	14.2	22.7	19.9	1.14
Other LA Co. Centers	534.3	296.8	32.6	16.4	9.1	1.80
LA County Total	1,325.1	897.9	59.8	22.2	15.0	1.48
Orange County	136.0	48.7	9.4	14.4	5.2	2.80
Outer Counties	29.8	13.1	1.8	16.7	7.4	2.27
Total in centers	1,490.9	959.7	71.0	21.0	13.5	1.55
Not within centers						
LA County	2,036.3	6,334.5	765.5	2.7	8.3	0.32
Orange County	739.9	1,878.3	377.1	2.0	5.0	0.39
Outer Counties	384.7	1,531.4	1,050.1	0.4	1.5	0.25
Total not in centers	3,160.9	9,744.2	2,192.3	1.4	4.4	0.32
All zones						
LA County	3,361.4	7,232.3	825.0	4.1	8.8	0.46
Orange County	875.9	1,927.0	386.5	2.3	5.0	0.45
Outer Counties	414.5	1,544.6	1,051.8	0.4	1.5	0.27
Region total	4,651.8	10,703.9	2,263.3	2.1	4.7	0.43

core, and especially of Downtown Los Angeles. The region's overall employment pattern conforms surprisingly well to the notion of a dense center surrounded by areas of gradually declining density. Downtown Los Angeles, with just over one-half percent of the region's land area, contains 10 percent of its jobs and fully 31 percent of all jobs within centers. The five core centers together contain more than half of all jobs located in centers. The core's average density, 29 employees per acre, is exceeded by only one other center (Vernon/Huntington Park, no. 9), which is also near downtown. There is not even a single zone outside of Los Angeles County with density that high.

Downtown Los Angeles, by this definition, is much larger in extent that the seven zones that constitute the traditionally defined central business district (CBD). The CBD contains only 152,000 employees, just 3.3 percent of the region's employment. This small proportion is often cited to show how decentralized Los Angeles is, but it ignores the enormous concentration of high-density employment around the CBD, nearly half a million workers within an area approximating a circle of 2.5 miles radius.

The dominance of Downtown Los Angeles is further illustrated by the fact that distance from its highest density zone is strongly correlated with employment density, both within and outside of centers. For example, the Spearman rank correlation between employment density of our subcenters and distance from the Los Angeles CBD is 0.50, significant at a one percent significance level. Of the variance in zonal employment density for all 893 zones in Los Angeles and Orange Counties, 69 percent is explained by distance from the CBD, based on a nonlinear-least-squares estimate of a simple exponential density function (its gradient is -1.13 per mile with standard error 0.03); the CBD has far more explanatory power and greater statistical significance than any other center, either alone or in combination.[1] These findings are consistent with the observation by Brigham (1965) of a strong land-value gradient with distance from the Los Angeles CBD, and contrasts with the failure by Frieden (1961) and Heikkila et al. (1989) to find such a gradient. (Brigham attributes Frieden's result to failure to control for amenities.)

After the four large core centers, the next largest (no. 5) is a complex abutting Los Angeles International Airport on the south. (Because the airport itself is so large in area, it falls below the density cutoff, hence its 16,900 employees are excluded from this center.) Sixth ranked is an area known locally as South Coast Metro, centered at the Orange County Airport and including parts of three cities. The other Orange County subcenters are ranked 11, 23, 26, 29, and 30, while the Riverside outer center is ranked 25.

[1]Based on estimating polycentric density functions, as forms suggested by Griffith (1981a) and Gordon, Richardson and Wong (1986).

Only one of the Orange County centers – Santa Ana (no. 11), the county seat and its oldest city – is at the center of a municipality.

Five of the centers, each with more than 26,000 employees, are at regional airports. Another (San Pedro) is the region's main ocean port. As we shall see, all six of these centers are industrial in nature, several specialized in aircraft and electronics. This may be driven as much by historical accident as economic logic: an aircraft manufacturer's private airstrip would later become an airport, while the aircraft business itself spawned defense contracts and electronics manufacture that might or might not require access to air transportation. Scott (1988, pp. 105–116, 160–202) traces the locational predilections of these and related industries in the region over a period of several decades.

To see whether any of our centers consists mainly of just one large employer, we obtained a list of large employment sites in 1988. From this it appears that two centers may have had more than half their 1980 employment in a single firm: Hawthorne (no. 19) and Lawndale (no. 21), each just a few miles from Los Angeles Airport and containing a large defense plant. One could question, then, whether these two are legitimate centers with agglomeration forces. On the other hand, the relatively large size of the outlying zones could obscure a small high-density center from our observation.

It is evident that the clustering of employment into centers is important to the Los Angeles region. Nearly one-third of the region's employment occurs in centers occupying only 3 percent of its land area. This clustering exists even outside the core centers, although to a much smaller degree: of all employment outside the core, 18 percent is in centers. Still, the majority of employment is not in centers at all. Dispersed development emanating from a large corridor-shaped core, more than subcentering, describes the location of the majority of the region's jobs.

A more surprising finding is that centers have a high concentration of population – 9 percent of the region's total. Employment–population ratios are surprisingly low, even in the main center, and are in fact lower in the Los Angeles County centers than in other centers. The average employment–population ratio for all centers is 1.55, less than four times the average for the entire region. Clearly there is a great deal of intermixing of population and employment, even within well defined employment concentrations. Even the peaks of most centers have high population density and an employment–population ratio only moderately higher than the entire center. For example, the downtown center's peak has an employment–population ratio of 2.4, compared to 1.4 for the entire downtown center. The main exceptions to this are the peaks consisting of airports, which have almost no population. The employment–population ratio for all peaks combined is 2.6.

Table 3 shows the distributions of total employment, employment density,

Table 3

Distributions of employment, employment density, and employment-population ratio among centers.

	Number of centers in each area and range				
	Core	Other LA Co.	Orange County	Outer counties	Total
All centers	5	18	6	3	32
Employment (1000's)					
80+	2	0	0	0	2
40–80	2	3	1	0	6
20–40	0	9	1	0	10
10–20	1	6	4	1	12
0–10	0	0	0	2	2
Employment density (no./acre)					
30+	2	1	0	0	3
20–30	2	2	0	2	6
15–20	1	9	2	0	12
12–15	0	3	2	0	5
10–12	0	3	2	1	6
Peak employment density (no./acre)					
40+	2	1	0	0	3
20–40	3	4	0	2	9
15–20	0	8	2	0	10
12–15	0	3	2	0	5
10–12	0	2	2	1	5
Employment–population ratio					
8+	0	2	1	0	3
4–8	0	2	1	1	4
2–4	1	4	1	1	7
1–2	3	8	3	0	14
0–1	1	2	0	1	4

peak employment density, and employment–population ratio across our sample of centers, by location. This makes it clear that the largest, densest centers tend to be close to the core, whereas there is no such pattern for the employment–population ratio. However, there is only a slight tendency for larger subcenters to be near downtown as measured by network distance: the Spearman rank correlation between size and proximity to the downtown peak is 0.28, which is insignificantly different from zero at a 5 percent level of significance.

The subcenters have a size distribution which seems reasonably consistent with the idea of a hierarchy of functions, not unlike that characterizing metropolitan areas within a nation or subcontinental region. We can characterize this distribution by fitting the following Pareto distribution to

our collection of 28 subcenters plus one main center, using ordinary least squares:

$$\ln(\text{rank}) = 5.827 - 0.963 \ln(\text{employment}).$$
$$(0.173)\ (0.049)$$

Standard errors are given in parentheses. This equation explains 94 percent of the variance in ln(rank). The coefficient of ln(employment) is insignificantly different from one at a 5 percent significance level, suggesting that the well-known rank–size rule (which asserts that rank times size is constant throughout the distribution) holds to a remarkably close approximation.

3.3. *Commute flows*

Our data permit us to compute the distribution of residence zones for people working in any given location. We also have the network distances and peak-period travel times between each pair of zones, from the UTPP traffic assignment model. Combining these, we can compute average travel distance and average travel time for all workers in any location. This enables us to examine several hypotheses about the effects of centers on commuting, including: (a) that clustered employment requires longer commutes than dispersed employment; (b) that larger centers require longer commutes; and (c) that the main center (downtown Los Angeles) requires a longer commute than subcenters. (Because our data are derived from Census surveys of area residents, we will miss the small number of commutes from outside the region.)

Table 4 presents the results. Regarding the first hypothesis, commutes to jobs within centers are longer than commutes to jobs outside of centers. This is true for all categories shown except the outer counties. This result is consistent with the usual belief that most centers, being large concentrations of jobs relative to the immediately surrounding population, must draw workers from a correspondingly large geographical area. This explanation is further supported by the fact that the main center has a longer average commute, 13.9 miles, than all other categories of centers. There are, however, four centers with longer commutes than the main center: San Pedro, no. 10 (20.9 miles), Burbank Airport, no. 18 (15.1 miles), Los Angeles Airport, no. 5 (14.7 miles) and Van Nuys Airport, no. 17 (14.4 miles). All four are within Los Angeles county and outside the core area.

Except for downtown, the 'core centers' forming the Wilshire corridor have a commute two miles shorter than the rest of LA County centers, and only slightly longer than the average commute to LA County jobs outside of centers. Employment–population ratios in these core centers are substantially lower than in downtown Los Angeles and lower than the average for all

Table 4

Mean commuting distance and time by job location.

	Distance (miles)	Time (minutes)
Within centers		
Main center	13.9	29.5
Other core centers	11.2	24.8
Other LA Co. centers	13.2	27.2
LA County total	13.0	27.4
Orange County	11.3	23.8
Outer counties	8.3	17.2
Total in centers	12.7	26.8
Not within centers		
LA County	10.8	22.8
Orange County	9.9	21.0
Outer counties	8.8	18.2
Total not in centers	10.3	21.8
All zones		
LA County	11.7	24.6
Orange County	10.1	21.5
Outer counties	8.8	18.1
Region total	11.1	23.4

centers; this intermixing of population and jobs may account for the shorter average commute.

Table 4 also shows that commutes are somewhat longer to more densely developed areas. Average commuting distance to centers in Los Angeles County is almost two miles longer than to centers in more suburban Orange County, and five miles longer than to centers in the outer counties. Commutes to jobs outside the centers follow the same pattern, though with smaller differentials. These outer counties have the lowest employment–population ratios, suggesting that the plentiful supply of workers allows firms to draw workers from a smaller geographic area.

The pattern in travel times is essentially identical to that in distances, so is not discussed separately.

A reversed pattern of commute lengths is observed when we categorize by place of residence. As expected, people living in centers have shorter commutes than those living outside centers. People living in the three outer centers have the shortest average commute (5.3 miles), perhaps reflecting the small size and isolation of those centers. Average commute length is 7.6 miles for people living in the core excluding downtown Los Angeles, and 9.3 miles for Los Angeles County centers outside the core. It is higher still for people

living outside centers: 10.8 miles in Los Angeles County and 13.0 miles in the three outer counties, the latter reflecting scarcity of local job opportunities.

4. The functions of employment centers

What economic roles do these employment centers play? Theory suggests that they are based upon agglomeration economies. Some of these economies apply only within an industry, creating a tendency for some centers to specialize. Others apply to an entire complex of industries, creating centers with mixed activities much like those typical of big-city downtowns. Furthermore, the spatial distribution of centers should depend upon how they interact with each other, how they use land as a factor input, and the extent to which they produce services for subregional populations.

To examine such questions, we use data on the industries constituting each center's employment base. Our data contain industries defined at the one-digit (and in a few cases two-digit) levels of the Standard Industrial Classification (SIC) codes used by the United States Department of Commerce. We delete agriculture and mining as being of minute significance, and construction as being caused by the growth process rather than explaining it. Based on their high correlation, we also combine business, personal, and professional services into 'other services'. The resulting eight industrial sectors account for approximately 95 percent of all employment in centers.

The largest sector is manufacturing, with 28 percent of aggregate employment in all our centers. Manufacturing, transportation, communication, utilities, and wholesale trade together form a group of production-oriented sectors accounting for an employment share of 41 percent; the other sectors, all service-oriented, account for 55 percent. Zones located outside of centers have a somewhat smaller share in production-oriented sectors (35 percent) and larger share in service-oriented (58 percent). Centers have a higher proportion of their employment in finance, insurance, and real estate than do non-centers (9.6 versus 6.3 percent) and a higher proportion in public administration (4.9 versus 3.1 percent), but a lower proportion in retail trade (11.3 versus 18.3 percent).

In what follows, we describe a cluster analysis using our 32 centers as observations and these eight industry shares (expressed as percentages) as variables. Each observation is described as a point in eight-dimensional space; the clustering algorithms search for observations that are close to each other in this space, forming a group or 'cluster'. Closeness is measured by Euclidean distance in the space; that is, the 'distance' or 'dissimilarity' between two employment centers is the square root of the sum of eight squared differences between their industry shares. Because the share has a

natural unit (all are between zero and 100), we do not normalize the variables by their standard deviations.

4.1. Cluster analysis

There are two basic types of clustering methods: 'hierarchical' and 'iterative partitioning' [Aldenderfer and Blashfield (1984), Punji and Stewart (1983)]. The hierarchical methods link successive pairs of observations based on their similarity. One linkage is accomplished at each pass of the data, and it cannot be later broken. Clusters are formed or combined as cases are linked to one another; the longer the algorithm proceeds, the fewer the clusters, and the greater the within-cluster dispersion. Deciding when to stop determines the number of clusters, but there is no formal statistical test. The iterative-partitioning methods start with a predetermined number of clusters, and continue to define and redefine clusters so as to minimize within-cluster dissimilarity relative to between-cluster dissimilarity. With neither type is there a reliable statistical test to determine whether cases are clustered naturally or whether they simply fall randomly in a multidimensional continuum.

We follow the method recommended by Punji and Stewart (1983): use hierarchical clustering to determine the approximate number of clusters, then use iterative partitioning to determine the appropriate cluster groups. The hierarchical method we use is Ward's method with squared Euclidean distance as the dissimilarity measure; the iterative-partitioning method is Anderberg's with simple Euclidean distance. In the discussion that follows, 'dissimilarity' refers to simple Euclidean distance.

4.2. Cluster analysis results

With the hierarchical analysis, we found that the within-cluster dissimilarity increases very little as the number of clusters is reduced to five; it then rises rather smoothly as the number of clusters declines to two, and rises a lot between two and one. We therefore applied the iterative partitioning method using two, three, four, and five clusters. Inspection of the results revealed that some subcenters are outliers. Two centers, Hollywood (no. 4) and Burbank Southwest (no. 18), have unusually large shares of entertainment employment. Three centers – LA West (no. 2), LA East (no. 22), and Orange/Garden Grove (no. 29) – have unusually large shares of 'other services' and low shares of production-oriented employment. When these were forces into other clusters, the dispersion within those particular clusters increased dramatically. The remaining subcenters fall into three relatively homogeneous groups.

Table 5

Results of iterative partitioning with five clusters.

Cluster 1: Specialized manufacturing	
14	Long Beach Airport[a]
18	Burbank Airport
19	Hawthorne
21	Lawndale
23	Fullerton
24	Downey
26	Santa Ana South
Cluster 2: Mixed industrial	
5	Los Angeles Airport[a]
6	Orange County Airport
8	Commerce
9	Vernon/Huntington Park
10	San Pedro
12	Inglewood
15	Marina del Rey
17	Van Nuys Airport
30	Garden Grove/Stanton
Cluster 3: Mixed service	
1	Downtown Los Angeles
3	Santa Monica
7	Glendale
11	Santa Ana
13	Pasadena
16	Long Beach
20	Canoga Park/Warner Center
25	Riverside
27	Sherman Oaks
31	Oxnard
32	San Bernardino[a]
Cluster 4: Specialized entertainment	
4	Hollywood[a]
28	Burbank Southwest[a]
Cluster 5: Specialized service	
2	Los Angeles West
22	Los Angeles East[a]
29	Anaheim/Orange/Garden Grove

[a]Denotes member closest to cluster centroid on similarity measure.

These observations suggest that five clusters best describe the subcenters. The results of the five-cluster iterative partitioning are given in tables 5 and 6.

Cluster 1 consists of centers very highly specialized in manufacturing, which accounts for almost three-fourths of their employment. These centers have the smallest shares of retail and service-related employment. They include several areas located near airports and specializing in aerospace

Table 6

Composition and average characteristics of clusters.

	Cluster					
	1 Specialized manufact.	2 Mixed industrial	3 Mixed service	4 Specialized entertainment	5 Specialized service	All centers
No. of centers	7	9	11	2	3	32
Average dissimilarity						
Within cluster	7.8	15.5	20.8	10.7	16.7	
Cluster centroid to						
Cluster 1	0.0					42.9
Cluster 2	29.7	0.0				15.7
Cluster 3	66.4	38.7	0.0			23.9
Cluster 4	71.8	45.2	23.3	0.0		32.5
Cluster 5	85.8	60.7	29.9	32.9	0.0	45.7
Share of employment in major sectors (%)[a]						
Manufacturing	73.0	45.5	14.1	10.2	4.5	34.7
Transportation, commun. & util.	5.0	11.0	7.6	11.0	2.5	7.7
Wholesale trade	4.5	7.6	2.6	2.1	2.2	4.4
Retail trade	4.3	8.5	16.5	13.0	11.0	10.9
Finance, insur. & real estate	1.1	3.7	14.7	6.1	10.9	7.7
Entertainment	0.3	2.5	1.4	20.9	2.5	2.3
Public admin.	1.1	2.9	8.2	1.6	4.4	4.4
Other services	7.4	14.4	30.5	32.7	57.3	23.5
Distance from LA CBD (miles)						
Lowest	13.5	4.9	0.1	7.3	6.8	0.1
Average	21.9	19.4	29.9	10.7	17.6	22.8
Highest	37.4	40.7	63.6	14.1	30.2	63.6
Employment density (employees/acre)						
Lowest	11.4	11.4	10.3	18.0	11.3	10.3
Average	16.3	16.7	18.8	19.7	24.7	18.3
Highest	28.4	33.2	36.0	21.4	37.3	36.0

[a]Each share shown is the unweighted average of the shares for those n centers, where n is the number shown in the top row. It is not the aggregate employment share for those n centers. Hence the average shares shown in the last column differ from the aggregate shares quoted in the text.

manufacturing, and several older, diversified manufacturing centers in Los Angeles County and northern Orange County. These centers tend to be smaller ones, all but one being in the bottom half of the size distribution.

Cluster 2 centers contain a broad mix of industries, with somewhat more production-oriented industries and less service-oriented industries than the average center. This is what one might expect of areas starting out as low-density manufacturing districts close to transport nodes but attracting other functions as they grow; and in fact all but three are closely connected to an

airport, port, or marina. (Inglewood, center no. 12, borders Los Angeles International Airport and touches center no. 5 at a corner.) These centers tend to be larger than average.

Cluster 3 contains what we might term 'traditional downtowns': centers with a broad mix of employment, somewhat weighted toward services. The downtown areas of many of the region's oldest cities appear in this cluster. These cities functioned as independent centers before they were absorbed into the larger metropolitan area, and they apparently have retained these functions. This is also the largest cluster, with 11 members, and it contains the full range of sizes, from the very largest to the smallest. These centers are dispersed through the region, indicating that this type of center plays a role at all scales and locations.

Cluster 4 is uniquely southern Californian: it consists of the two major entertainment centers, Hollywood (no. 4) and Burbank Southwest (no. 28), the latter being the location of Burbank Studios. Its entertainment share is nine times the sample average. These centers are close to each other, 7 to 14 miles from downtown Los Angeles.

Cluster 5 consists of the three heavily service-oriented centers mentioned earlier: service industries account for over 90 percent of their employment. Each center in this cluster contains a major university medical center complex. For the two smaller centers, the medical center is dominant. Los Angeles West (no. 2), however, is a quite different case: a very large corridor-shaped center just west of downtown Los Angeles, including premier retail and office development as well as the largest campus of the University of California and a variety of museums and theaters. This center may be viewed as an extension of the more prestigious functions of downtown Los Angeles into the city's affluent close-in residential neighborhoods.

The bottom two panels of table 6 show how centers of different types of specialization are spatially organized. There is some tendency for the service centers to be closer to downtown and to exhibit higher employment densities. But except for the entertainment cluster, each cluster contains a wide array of locations and densities. The narrowest range is for the highly specialized manufacturing centers, which have moderate densities and lie in a band between 13 and 38 miles from downtown. The widest range is for the mixed-service traditional downtowns, which cover the entire range of both distances and densities.[2] Subcenters apparently play important roles within subregions as well as within the larger region, requiring a mix of center types at both scales.

Even more than the other mixed service centers, Downtown Los Angeles has a strong base in public administration and the finance, insurance, and

[2]The average of the distances between all pairs of centers within each cluster is between 25 and 30 miles for Clusters 1, 4, and 5, and nearly 47 miles for Cluster 2.

real estate sector. Its share of the region's employment in these sectors (not shown in the table) is about twice as great as its 10 percent share of its employment in all sectors. This tendency is even more marked in the CBD, which has 9 percent of the region's jobs in these sectors, compared to 3 percent of all jobs. Manufacturing is correspondingly low in the CBD.

Overall, the cluster analysis suggests that subcenters play diverse roles within the regional economy. Downtowns continue to function as administrative, service, and retail centers with substantial amounts of other industry. The centers most heavily specialized in services, including the two entertainment centers, are located close to but not in the older downtowns of Los Angeles and Santa Ana. These specialized subcenters, as well as the manufacturing centers appearing around airports, may be indicative of spatial differentiation that occurs as regions become heavily urbanized.

Finally, these results suggest that agglomeration economies exist for many types of economic activities, but that congestion effects (including land costs) may repel production-oriented activities as the level of concentration increases. Thus, although our centers are rather evenly divided between manufacturing and services, all of the core centers have a service orientation. At the same time, the four large centers in the core are in four different clusters, suggesting further that even at this level the urban system requires a variety of types of centers.

5. Conclusions

Using an objective and consistent method for identifying employment centers, we have identified 32 centers within the Los Angeles region in 1980. We find that economic activity is heavily concentrated along a linear core area, especially around the Los Angeles central business district; and that the density and frequency of centers declines with distance from this core. Larger and more centrally located centers tend to have longer work trips, and workers in most centers have longer commutes than workers in comparable locations outside of centers.

The employment in subcenters occurs in recognizable industry-mix patterns ranging from highly specialized to diversified. The more service-oriented centers tend to be at higher densities and somewhat closer to the core area, but there are many diversified, somewhat service-oriented centers that are downtowns of older cities scattered throughout the region.

Overall, our results suggest a highly complex space economy characterized by a system of specialized centers, distributed within a pattern of economic activity that is dispersed yet strongly influenced by the pull of the Los Angeles central area.

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