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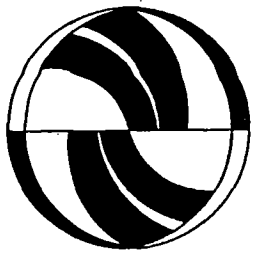
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**The University of California  
Transportation Center**  
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# Suburban Employment Centers: Probing the Influence of Site Features on the Journey-to-Work

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## ■ Introduction

Traffic conditions have markedly worsened in many of America's suburbs during the 1980s, prompting some observers to warn of a "looming crisis" (Orski 1985). In many ways, the suburbanization of congestion has followed the suburbanization of jobs throughout this decade. With suburbs accounting for around 60 percent of all office floorspace in the U.S. today, the predominant commute pattern has become suburb-to-suburb, flooding many under-designed suburban roadways in the process (Urban Land Institute 1987; Cervero 1986; Fulton 1986; Orski 1987). Infuriated by traffic's ever-increasing presence, more and more suburbanites are insisting that future commercial and office growth be regulated, be it through downzoning or caps placed on building permits. In California, forty-seven growth control initiatives were placed before voters in 1986 alone, almost all of which were triggered by frustrations over traffic (Cervero 1989). Opinion polls also reflect the public's scorn for congestion — in Houston, Atlanta, San Francisco, Washington, D.C., and at least a dozen other urbanized areas around the country, residents cite traffic congestion as the number one urban problem today (Dunphy 1985; Orski 1987; Cervero 1989). While only a decade ago congestion was the scourge of downtown commuters, today it appears to be pandemic, pervading the freeway and arterial networks of most American metropolises.

To date, research has generally focused on the economic and demographic forces that have given rise to suburban congestion as well as the most promising demand management and funding programs for correcting the problem. The one area where there has been far less study is how the land use and physical design characteristics of suburban workplaces have directly contributed to the decline in suburban mobility by inducing many employees to drive alone to work. This article postulates that the low-density, single-use character of many subur-

## Abstract

This paper argues that the low-density, single-use character of most suburban workplaces in the U.S. has contributed to worsening traffic congestion by making most workers highly dependent on their own automobiles for accessing jobs. To test this proposition, land use and transportation data are examined for fifty of the largest suburban employment centers in the nation. Differences in the share of trips made by various modes, commuting speeds, and levels of service on major thoroughfares connecting suburban centers are compared among clusters of centers. The densities, sizes, and land use mixtures of suburban workplaces are generally found to be important determinants of worker travel behavior and local traffic conditions.

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ban office centers has compelled many workers to become dependent on their automobiles for accessing work and circulating within projects. These factors, combined with the abundance of free employee parking, inadequate road facilities, and meager levels of suburban transit services, it is argued, have contributed to unprecedented levels of suburban congestion. While vehicles generally circulate freely once inside sprawling suburban office compounds, roadways leading to them are all too often jammed because of the preponderance of automobiles driven by a single occupant. The emergence of suburban workplaces with densities equivalent to those of small downtowns, rich mixtures of land uses, and pedestrian-friendly environments could very well do as much to mitigate congestion over the long run as any mix of traffic management or roadway expansion programs, and perhaps far more.

### ■ Research Methodology

To test the soundness of these propositions, data were gathered in late 1987 on the land use and transportation characteristics of fifty of the largest suburban employment centers (SECs) in the nation (Cervero 1989). The instruments and sources used to compile relevant data included a questionnaire administered among office developers; land use and transportation inventories maintained by local agencies and national associations; and primary data collected locally through site visits and field surveys.<sup>1</sup> Where not available from questionnaire responses, land use and employment data were obtained for the 1985–1987 period from inventories and publications provided by the Urban Land Institute, the Rice Center, the Office Network, local real estate firms, corridor and business associations, city and county planning agencies, and chambers of commerce. Data on commuting characteristics of SEC workers were gathered from survey summaries provided by developers, business and property owner associations, and regional transportation planning agencies. In general, the availability of recent survey data on travel characteristics of SEC workers was the principal factor constraining the choice of case sites.

In all, land use and information on the commuting characteristics of workers were compiled for SECs with at least one million square feet of office floorspace and two thousand or more workers in twenty-six of the nation's largest metropolitan areas. Notable suburban job centers included in the study were Post Oak and Greenway Plaza near Houston, Warner Center and South Coast Metro near Los Angeles, Bishop Ranch and Hacienda Business Park east of San Francisco, Tysons Corner outside of Washington, D.C., and the Denver Technological Center. Since the sampling frame was not purely random (in the sense that not all suburban workplaces in the U.S. were sampled), inferences drawn from this analysis pertain mainly to the very largest suburban office centers in the nation's largest metropolitan areas.

A multistage approach was adopted in studying how the density, land use, and other site features of SECs influence commuting behavior and local traffic conditions. First, SECs were classified into homogeneous groups using the techniques of factor analysis and cluster analysis. Analysis of Variance (ANOVA) was then used to compare mean differences among these groups for several variables that measure modal splits and levels of mobility. Based on the extent to which employee travel behavior and traffic conditions vary significantly among SEC groups, inferences were drawn on how the physical site and land use characteristics of suburban workplaces influence commuting choices.

### ■ Classifying Suburban Employment Centers

Urban geographers, regional scientists, and city planners have long classified metropolitan growth in an attempt to understand both the forces shaping it and the consequences of the evolving pattern (Burgess 1925; Hoyt 1939; Harris and Ullman 1945; Berry 1959; Daniels 1973). Burgess, for instance, saw regions forming as a series of concentric rings of distinct land uses focused on a dominant center, while Hoyt described urbanized areas in terms of linear sectors emanating from the core along major transportation routes such as railroads. Several more recent studies have sought in particular to define types of suburban office growth. In his study of office decentralization in Great Britain, Daniels classified office growth as either small centers, large centers, sprawl, or widely scattered growth. Several other authors have described suburban office growth form as either nodal clusters or strip-like corridors (Baerwald 1982; Hughes and Sternlieb 1986; Leinburger and Lockwood 1986).

The fifty SECs used in this study are classified in this section, with low-to-high ranges of various land use variables presented for each of the groups. The intent is not to create another schema for defining forms of suburban growth, but rather to provide a foundation for sorting out transportation/land use relationships among the sites studied.

### ■ Factors for Classifying SECs

Suburban employment centers can be described along a number of dimensions — size, density, land use composition, site design, ownership patterns, employment base, and so on. Each of these dimensions can be expressed by several different variables, no one of which alone fully portrays that dimension, but which together provide a fairly good perspective into the site characteristics of SECs. In light of the need to capture the numerous dimensions of SECs, factor analysis was employed. Factor analysis allows variables such as floor area ratio<sup>2</sup> (FAR), floor space per worker, and land coverage ratios<sup>3</sup> to be linearly combined to represent the concept of "density." Qualitative dimensions such as site design can

**Table 1** Factor Loadings and Summary Statistics for SECs

	Factor 1	Factor 2	Factor 3	Factor 4
<b>Variables:</b>				
AVGSTORY	.982			
EMP/ACRE	.880			
FAR	.872			
PARK/EMP	-.745			
COVERAGE	.733		-.443	
EMPLOYMENT		.952		
FLOORSPACE		.898		
RESTAURANT		.820		
ACREAGE			.924	
SQFT/EMP			.871	
OFFICE			.730	-.477
USEENTROPY				.641
RETAIL				.554
AVGLOT				-.527
<b>Summary of Factor Statistics:</b>				
Eigenvalue	4.490	3.292	2.171	1.467
Percent of	34.5	25.3	16.7	11.3
Variation Explained				
Cumulative Percent of	34.5	59.9	76.6	87.9
Variation Explained				
<b>Variable Definitions</b>				
AVGSTORY	Number of stories of average building, in terms of most frequent (modal) height			
EMP/ACRE	Employees per acre			
FAR	Floor Area Ratio (building area/land area)			
PARK/EMP	Average number of parking spaces per employee			
COVERAGE	Average proportion of land covered by buildings			
EMPLOYMENT	Size of work force (thousands)			
FLOORSPACE	Square feet of floorspace in office, commercial, and industrial uses (millions)			
RESTAURANT	Number of on-site restaurants and eateries			
ACREAGE	Total land acreage			
SQFT/EMP	Square feet of floorspace per employee			
OFFICE	Proportion of floorspace in office use			
USEENTROPY	Land use mix entropy index			
RETAIL	Proportion of floorspace in retail use			
AVGLOT	Acreage of "average" lot, in terms of most frequent (modal) parcel size			

also be expressed in terms of more than a single variable to capture their full complexity.

In using factor analysis, the intent was to combine sets of variables that could collectively capture at least the following four dimensions of SECs: (1) size, (2) density, (3) land use composition, and (4) site design. In all, thirteen land use variables were available for expressing these four dimensions.<sup>4</sup>

The most interpretable factor matrix that was obtained for defining underlying factors is shown in Table 1.<sup>5</sup> In all, four factors were extracted, explaining about 88 percent of the variation of the original variables. That is, a 12 percent loss of information was incurred by the 70 percent reduction in the number of variables from thirteen to four. Table 1 lists variables in order of the size of

their factor loadings (beginning with factor one, then factor two, and so on) and presents only those loadings higher than 0.40.

From the loadings, it is apparent that the first factor, which accounts for over one-third of the variation in the data, represents "density." Based on both the size and signs of loadings, moreover, one sees that density-related variables have been grouped to represent cases with a high average number of stories, high FARs, high counts of employees per acre, high land coverage ratios, and relatively low numbers of parking spaces per employee.

The second factor, explaining one-quarter of the variation, clearly captures the "size" dimension of SECs. It reflects some of the commonality shared by SECs that have a large number of employees, vast amounts of floorspace, and numerous eateries. The inclusion of the restaurant variable suggests that it picks up some of the mixed-use characteristics of cases as well.

The third factor, explaining 16.7 percent of variation, is more or less a "design" measure emphasizing the degree of spaciousness of projects. It appears to be tapping the dimensions of some cases related to their amount of open space (COVERAGE), working area (SQFT/EMP), and scale (ACREAGE). In this sense, it captures some of the amenity and site design features of SECs, along with some information on size and coverage. From the signs of the loadings, it reflects cases that have large acreages, generous amounts of floor area per worker, low levels of lot coverage, and high shares of office usage — i.e., roomy, high-amenity environments.

The final factor, which accounts for 11.3 percent of the variation, is primarily a "land use" indicator, capturing information on tenant composition as well as general lotting practices. In addition to OFFICE and RETAIL, it has a high loading on a variable that was created to reflect the degree of land use mixture within each SEC: USEENTROPY. USEENTROPY is an index of "land use entropy," measured as

$$\begin{aligned}
 \text{USEENTROPY} = & \{[\text{OFFICE} \times \log_{10}(\text{OFFICE})] + \\
 & [\text{RETAIL} \times \log_{10}(\text{RETAIL})] + \\
 & [\text{HOUSING} \times \log_{10}(\text{HOUSING})] + \\
 & [\text{OTHER} \times \log_{10}(\text{OTHER})]\}, \\
 \text{where} \\
 0 \leq \text{USEENTROPY} \leq & \log_{10}(K), \\
 \text{OFFICE} = & \text{proportion of floorspace} \\
 & \text{in office use,} \\
 \text{RETAIL} = & \text{proportion of floorspace} \\
 & \text{in retail use,} \\
 \text{HOUSING} = & \text{proportion of floorspace} \\
 & \text{in residential use,} \\
 \text{OTHER} = & \text{proportion of floorspace} \\
 & \text{in industrial, warehousing,} \\
 & \text{restaurants, hotels,} \\
 & \text{and other uses, and}
 \end{aligned}$$

K = number of categories, which in this case is four, with categories removed from calculations if the proportion of floorspace is zero.

USEENTROPY provides a logarithmic index for gauging the degree of land use mixture. As used here, it ranges in value from zero (total homogeneity, with all floorspace in one category) to 0.6021 (maximum heterogeneity, with an even mixture of land uses). Thus, single-use developments (like an office park) will score low on USEENTROPY, while projects with an equal amount of floorspace in office, retail, housing, and other uses will score high values.

The fourth factor, reflecting "land use," shows high values for cases with high shares of retail and a high level of mixed uses (i.e., a high USEENTROPY value), and low values for cases with high shares of office space and large average lot sizes. Thus, it appears to be picking up situations with varied mixed-use, retail-oriented environments that are on relatively small lots and where office space is not the pre-eminent activity.

Overall, the results suggest that there are four key underlying site features of SECs — density, size, design, and land use. Among these dimensions, "density" is dominant, followed by "size." Intuitively, there is a certain degree of correlation among the factors themselves — i.e., cases with high "land use" (i.e., mixed-use) scores could also be expected to have high "density" scores. How such scores can be used to classify cases into distinct clusters is discussed next.

### ■ Classification of SECs

The grouping of the fifty SEC cases into homogeneous groups was carried out using cluster analysis. Factor scores for each of the fifty observations served as the primary inputs to the analysis. The process involved combining cases into clusters on the basis of their "nearness" to each other when expressed as squared Euclidean distances. Using the technique of agglomerative hierarchical clustering, clusters were sequentially formed by grouping cases into bigger and bigger clusters until all cases were members of a single cluster.<sup>6</sup>

The judgmental part of cluster analysis is deciding at what stage to stop joining clusters. This is normally done when the distance coefficients dramatically increase from one agglomeration step to another. For this analysis, this was between the forty-fourth and forty-fifth stages of merging clusters, which meant that five distinct clusters of cases were derived.<sup>7</sup>

The following descriptions seemed to fit the five groups that emerged from the cluster analysis: (1) office parks; (2) office concentrations and centers; (3) large-scale mixed-use developments (large MXDs); (4) moderate-scale mixed-use developments (moderate MXDs); and

(5) subcities. Based on the dendrogram, which portrays the formation of clusters in sequence (Everitt 1980; Norusis 1986), the SEC cases that clustered together within each group are listed in Table 2.<sup>8</sup> The largest single group is large MXDs, which comprise fourteen SECs. Both office parks and subcities have ten cases, while office concentrations and moderate MXDs have eight. Geographically, these projects are spread throughout the U.S., with no one region showing a particular dominance in any one type of SEC.

Table 3 suggests why these particular titles were chosen for describing the SEC groups. This table presents the next-to-lowest to next-to-highest ranges of several key density, size, land use, and design variables.<sup>9</sup> Some of the noteworthy traits of each of the five SEC groups are discussed below.

### Office Parks

The distinguishing characteristics of office parks are their low densities and building profiles, their heavily landscaped, parklike environments, their prodigious supply of parking, and their highly controlled, master-planned appearances. Many attract large corporate tenants who value high quality and spacious surroundings. Often, speculative space is found in buildings that are grouped together in a campus-like cluster while larger, single-tenant structures and company headquarters are typically set off to themselves (McKeever 1970; Urban Land Institute 1984; Cervero 1986).

Office parks have the lowest ranges of density, coverage, and building heights and among the highest levels of single-use activities and parking per 1,000 square feet (Table 3). They frequently have little, if any, on-site housing and at most one small retail center. None has a regional shopping facility on-site. Compared to the other SECs, they are also fairly small in acreage, employment size, and square footage.

Based on these ranges, SECs that are classified as office parks have (1) under 1,000 acres; (2) over 65 percent of space in office use and less than 10 percent in retail; (3) FARs under 0.45 and coverage rates under 0.40; and (4) over four parking spaces per 1,000 gross square feet of floorspace. They also tend to be master-planned, high-quality work environments with closely coordinated building designs.

### Office Centers and Concentrations

These SECs have some of the characteristics of office parks. They tend, however, to be much larger and denser. Notably, they generally have about the same proportion of office and retail space as office parks and comparatively fewer retail centers and on-site housing units. While office parks are centrally controlled and master-planned, these SECs are mostly agglomerations of freestanding office buildings that have sprouted, usually independently, in a reasonably well-defined geo-

Table 2

SEC Cases within the Five SEC Groups Derived from Cluster Analysis<sup>a</sup>

Office Parks	Large Office Concentrations	Moderate Mixed-Use Developments	Mixed-Use Developments	Subcities
APOC FL	Central Ave. Corridor AZ	BWI Area MD	Bel-Red Corridor WA	Central Bellevue WA
Bishop Ranch CA	Central Ft. Lauderdale FL	Camelback Corridor AZ	Chagrin Blvd. Corridor OH	Central Stamford CT
Corporate Woods KN	Central Walnut Creek CA	Cyprus Creek FL	Chesterbrook Village PA	Central Towson MD
Hacienda Business Park CA	Greenway Plaza TX	East Farmingdale NY	College Blvd. Corridor KY	Denver Tech Center CO
Inverness Business Park CO	Greenwood Plaza CO	East Garden City NY	Fairlane Town Center MI	North Dallas Parkway TX
Maitland Center FL	Lake-Cook Corridor IL	Edina/I-494 Corridor MN	Hunt Valley MD	Perimeter Center GA
New England Exec. Park MA	Research Triangle NC	Gwinnett Place GA	North Lake GA	Post Oak Galleria TX
Technology Park GA	Rocksprings Park MD	The Meadowlands NJ	Rockside/I-77 Corridor OH	South Coast Metro CA
3M Park MN	Naperville/I-88 Corridor IL		Tysons Corner VA	
3M Park TX	Oak Brook/I-88 Corridor IL		Warner Center CA	
	Plantation/Broward County FL			
	Schaumburg Village IL			
	West Houston Energy Corridor TX			
	The Woodlands TX			

■ Note

a. The two-letter code signifies the postal code of the state (e.g., GA = Georgia).

graphic space. Some, such as Greenway Plaza near Houston and Greenwood Plaza outside of Denver, have been master-planned and have an architecturally unified character. Others, such as Phoenix's Central Avenue corridor, have evolved in an ad hoc manner and thus represent concentrations of growth.

To fit into the office centers and concentrations category, then, SECs should (1) be larger, have generally higher densities, and offer less parking per worker than most office parks; (2) have at least two million square feet of floorspace, with at least 85 percent in office use; and (3) have more the character of agglomeration than a highly controlled, master-planned office development that is focused on a single cluster of buildings.

### Large Mixed-Use Developments (Large MXDs)

The two distinguishing features of these SECs are that they feature a mix of land use activities and encompass a fairly large territory, at least three square miles and usually much more. Most large MXDs are widely recognized as being primary growth centers within their respective regions.

Some of the large MXDs are oriented along freeways and major arterials, and thus have a corridor form (e.g., Edina/I-494 south of Minneapolis and Oak Brook/I-88 west of Chicago). Others are more nodal (e.g., the Meadowlands near Newark and Schaumburg Village northwest of Chicago). Many resemble some of the subcities listed in Table 2, but have far more acreage

and generally less of a high-rise profile. Many are also similar to office concentrations in density and work force size, although MXDs generally enjoy a far greater balance of office, commercial, and light industrial activities. All have at least one major retail center, and most feature a regional shopping center of at least 500,000 square feet. Moreover, most have at least several thousand housing units within their perimeters.

While in no instance do offices constitute more than two-thirds of the floorspace for the cases in this group, non-office functions are not always dominated by banks, restaurants, and retail outlets. Some of the large MXDs (e.g., BWI between Baltimore and Washington, D.C.; Oak Brook/I-88; East Farmingdale on Long Island) have well over 30 percent of their floorspace supporting light-industrial and warehousing functions. In all instances, the land use entropy index for large MXDs was at least 0.45 (compared to an average index for all fifty cases of 0.42). The hallmarks of this SEC group, then, are (1) a large territory of at least 2,000 acres in size and (2) a mixture of activities, with offices comprising no more than two-thirds of total floorspace.

### Moderate-Scale Mixed-Use Developments (Moderate MXDs)

In almost every respect, these SECs resemble the large MXDs discussed above, with the notable exception that they have far less acreage. Most have only one-third the acreage of the smallest member of the large MXD cate-



Table 3

Low-to-High Thresholds for Five SEC Groups<sup>a</sup>

Size	Office Parks	Office Centers	Large MXDs	Medium MXDs	Subcities
Acreage (thousands)	.25-1.0	.25-2.8	2.6-19.7	.35-.86	.33-2.24
Employment (thousands)	4.1-11.9	6.0-20.3	5.0-53.0	2.2-15.3	16.0-59.5
Square feet office, commercial, and industrial floorspace (millions)	1.7-4.3	2.0-10.8	3.6-29.0	1.3-7.1	6.5-25.3
<b>Density</b>					
Floor Area Ratio	.24-.42	.30-2.7	.50-1.30	.33-.92	.85-3.10
Number of stories of highest building	5-10	8-30	6-27	3-13	20-28
<b>Design</b>					
Parking spaces/1,000 square feet	4.0-5.0	3.3-4.0	3.3-5.0	4.0-4.6	3.0-4.0
Coverage ratio	.20-.40	.20-.75	.25-.55	.25-.48	.33-.75
<b>Land Use Mix</b>					
Percent floor space:					
Office	65-99	85-99	16-66	30-60	50-70
Commercial	1-10	2-10	8-26	10-30	12-34
Number of retail centers	0-1	0-2	1-20	1-4	2-8
Number of on-site dwelling units	0-100	0-380	0-9,000	0-500	200-5,600
Land use mix entropy index <sup>b</sup>	.25-.35	.22-.35	.45-.58	.47-.56	.41-.51

## ■ Notes

a. Based on range of the next-to-lowest to the next-to-highest values for each variable.

b. Ranges from 0 (least mix) to 0.60 (most mix).

gory. In addition, these more moderate-sized developments tend to be less dense, featuring a varied low-rise and mid-rise skyline. Many, moreover, have a well-defined core, with clusters of buildings that are architecturally unified.

The mixture of land uses among these SECs spans office, commercial, industrial, residential, and institutional activities. Offices remain the prominent activity in all cases, comprising as much as 60 percent of the floorspace. The land use entropy indices for all of the moderate MXDs exceed 0.47.

SECs that are members of this group, then, tend to (1) be less than 1,000 acres in size and have relatively well-defined boundaries; and (2) have a variety of land uses, with office space constituting no more than two-thirds of the total floor area.

### Subcities

These places, also known as urban villages, megacenters, suburban downtowns, and satellite cities, are noted for being like downtowns in their densities and land use mixtures, yet retaining suburban qualities (e.g., new buildings, strict zoning controls, wide separations between buildings, plentiful parking, and a "white-collar" character). Located on the fringes of America's largest cities, all subcities remain secondary office and retail centers within their respective metropolitan markets. In this sense, they are second-tier markets, or subcenters, even though they rival the downtowns of many medium-sized cities in size and density. Thus, the term

"subcity," which suggests the idea of both a submarket and a suburban city, has been chosen here.

The activities found in subcities read like an inventory of traditional downtown uses: offices, corporate headquarters, hotels, boutiques, convention halls, performing arts centers, doctors' offices, health clubs, and more. Offices, however, are always a prominent land use. Tysons Corner has more office space than downtown Baltimore or Miami (Urban Land Institute 1987). Nationwide, Houston's Post Oak-Galleria area ranks ninth in office inventory, exceeding that of downtown Atlanta. In many cases, new office towers have gone up at a dizzying pace, with as much as five million square feet being added in as few as three years. The North Dallas Parkway, for instance, witnessed a quadrupling of floorspace between 1980 and 1986 (Orski 1986). Because of this rapid growth, grass roots opposition to new commercial projects has generally been more vocal around subcities than around any other SEC group.

The subcities defined in this article vary in several ways, despite the fact they were grouped together in the cluster analysis. While most are fairly new (e.g., Perimeter Center north of Atlanta and Tysons Corner), others have existed for decades (e.g., Central Stamford, Connecticut and Central Towson north of Baltimore). Densities also vary somewhat. Some are punctuated by a series of high-rise towers, with only limited amounts of open space (e.g., Post Oak and Central Bellevue, Washington). Others are more like high-density, multiuse versions of campus-style office parks, featuring attractively

landscaped open spaces and prominent signature buildings (e.g., Denver Tech Center and Warner Center).

Because of their relatively high densities and land values, all subcities have decked parking structures, with going commercial rates charged for most parking spaces. All subcities feature premium quality regional shopping malls, generally of well over one million square feet in total retail space; and at least one hotel with convention facilities can be found in each. In addition, all subcities have a significant housing component, usually consisting of condominiums and townhouses that are priced for the professional worker.

To qualify as a subcity, then, an SEC must have (1) over ten thousand workers and over five million square feet of office and commercial floorspace; (2) fairly high average densities, with the tallest office tower being at least fifteen stories high and with some buildings falling within the twenty- to thirty-story range; (3) a mixed-use character, with retail and commercial activities constituting at least 10 percent of floorspace; (4) a regional indoor shopping mall and convention hotel; (5) on-site housing; and (6) a reputation for being the "other" central place within the region, second only to downtown.

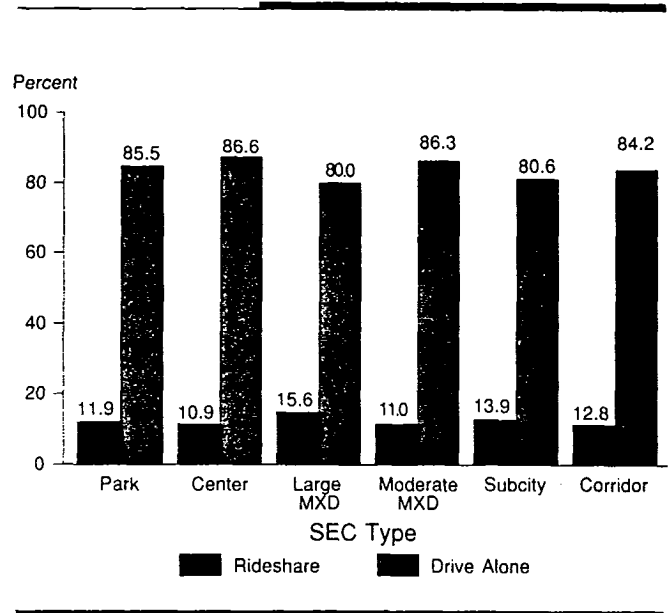
### ■ Comparison of Commuting Choices and Conditions

This section uses the five groups as a lens for exploring how SEC site characteristics are associated with the commuting choices of workers and local traffic conditions. To the extent that there is significant variation in the commuting characteristics of workers from each of the five groups, inferences can be drawn regarding how the physical design and land use characteristics of SECs influence transportation conditions. This section seeks to illuminate any such patterns that exist.

#### Commuting Speeds

From Table 4, average commuting speeds were found to vary somewhat among groups, although the relationship was not statistically significant at the .05 probability level. The slowest average commutes are experienced by those who work in subcities and, to a lesser extent, in large MXDs. This no doubt reflects the fact that both of these types of SECs are relatively dense and consequently more crowded, both inside buildings and out on the street. The fourteen subcities used in this analysis average FARs and employees per acre that are more than 15 percent higher than for any other SEC group. Additionally, both subcities and large MXDs were found to have low road capacities per employee<sup>10</sup> compared to other SEC groups. Thus, higher densities and comparatively limited amounts of road space, in part, likely account for these lower average commuting speeds.

**Figure 1**  
Average Percent of Work Trips Made to SECs by Drive Alone Versus Ridershare Modes



■ Note

a. Ridersharing includes carpooling and vanpooling.

### ■ Modal Choices for Work Trips

The built environment likely has as much influence on the travel modes workers choose as does any single aspect of commuting (Pushkarev and Zupan 1977). Figure 1 compares the average percent of work trips made by the two dominant modes of commuting: drive-alone auto and ridesharing (carpooling and vanpooling combined).<sup>11</sup> Two things stand out in this figure. First, driving alone is by far the dominant means of commuting for all SEC groups, constituting at least four out of five work trips made to SECs within each group, on average. Second, the SEC groups with the lowest average levels of solo commuting are large MXDs and subcities. These groups, by no coincidence, also average the highest shares of vehicle pooling. In the case of large MXDs, on average, slightly over 15 percent of all journeys-to-work take place in carpools or vanpools.

The comparatively high incidence of ridesharing among large MXDs and subcities seems to support several hypotheses set out in this research. First, the SEC groups with the highest densities average the highest share of vehicle pooling. Second, these two groups also tend to utilize the greatest variety of land uses, and in particular the largest retail components. One might infer, then, that SECs that are denser and have restaurants, shops, banks, and other consumer services on-site (e.g., subcities and MXDs) are better able to lure workers out of their private automobiles and into carpools and vanpools.

Table 4

**Comparison of Workforce Travel Characteristics and Areawide Traffic Volumes among SEC Groups**

Variable	Means of SEC Groups					F Statistic (Probability)
	Office Park	Office Center	Large MXDs	Moderate MXDs	Subcity	
Work Trip SPEED	29.1	30.6	27.4	32.2	22.9	1.21 (.317)
VANSHARE	3.4	2.1	3.6	2.0	2.6	1.16 (.340)
WALKSHARE	0.3	0.5	1.2	0.5	1.4	2.01 (.053)
DRIVEDIFF	9.1	13.0	6.4	10.9	6.8	1.43 (.229)
BUSRIDE	139.4	525.6	1614.3	248.3	3041.1	2.89 (.036)
ARRIVALTIME	8:10	8:10	8:25	8:26	8:05	1.51 (.205)
DEPARTIME	4:49	4:57	4:58	5:00	5:01	1.10 (.371)
<b>Traffic</b> ADT	45.3	70.3	61.5	45.6	113.0	3.29 (.012)

**Variable Definitions**

SPEED	Average travel speed for work trip in m.p.h.
VANSHARE	Percentage of work trips in vanpools
WALKSHARE	Percentage of work trips by walking
DRIVEDIFF	Drive alone work trip percentage minus regional drive alone percentage
BUSRIDE	Average weekday ridership of all bus runs serving SEC
ARRIVALTIME	Most frequently occurring time of arrival, a.m. peak
DEPARTIME	Most frequently occurring time of departure, p.m. peak
ADT	Average daily directional traffic volume on main freeway or roadway serving SEC

For specific nonauto modes (e.g., carpools, vanpools, transit, walking, and cycling), variations in mode splits among SEC classes were generally found to be modest, in part because these individual modes represent such a small share of total trips. The largest group differences were for vanpooling and walking. From Table 4, the share of commutes via carpools is the highest in large MXDs, followed closely by office parks. Vanpooling's relative popularity in large MXDs can be partly attributed to density and the existence of retail services. Company support of vanpools in large MXDs has also likely induced vanpooling. For office parks, supply appears to explain, at least in part, vanpooling's relatively high market share. Office parks were found to average more company vans per worker than any other SEC group. For the variable WALKSHARE, the SEC groups with the highest densities and land use mixtures — large MXDs and subcities — again average the highest shares. The relatively high proportion of walk commutes made to large MXDs and subcities is consistent with the finding that both groups tend to have the highest shares of multifamily housing nearby.<sup>12</sup> A possible inference, then,

is that the close proximity of apartments and townhouses has enabled larger shares of MXD and subcity workers to reside close by and walk to work.

Of course, modal splits are influenced by far more than the site characteristics of individual SECs. For instance, the quality of regional bus services, along with a host of other contextual factors, could be expected to influence transit modal splits. So far, such factors have been treated as constants. One way to account for regional differences in the quality of transit services and other commute alternatives is to include a control variable. This is done with the variable DRIVEDIFF (Table 4). DRIVEDIFF is equal to the percent of work trips to an SEC that are drive-alone minus the percent of drive-alone work trips for the entire region in which the SEC lies. Thus, a positive value indicates that a larger share of employees solo-commute to the SEC than do the region's "typical" employees.<sup>13</sup>

Office center employees appear to be most dependent on their automobiles for commuting relative to all other workers in the region (Table 4). On average, workers in office centers solo-commute 13 percentage points more

than employees in other work settings in the region. Employees in large MXDs and subcities, on the other hand, seem to be less heavily dependent on their cars than workers in other SEC groups. Thus, even when controlling for factors such as quality of regional transportation services, large MXDs and subcities prevail as the SEC environments that are least oriented to solo driving.

### Other Worker Commuting Characteristics

Group differences for several other indicators of employee travel behavior are compared in Table 4. Consistent with findings so far, the SEC groups with significantly higher ridership levels for bus routes serving their employees (BUSRIDE) are subcities and large MXDs. Thus, these two groups average comparatively high levels of transit usage in both absolute and percentage terms.

Table 4 also shows differences in average employee arrival and departure times among groups. Although differences are not statistically significant, several time values are noteworthy. The later average arrival times for MXDs reflect their higher shares of retail workers, many of whom do not arrive at work until after 9:00 a.m. Also, the workforces of subcities average the earliest arrival times and the latest departure times. What these figures most likely reflect is the variety of occupational roles found in subcities, giving rise to atypical average arrival and departure times.<sup>14</sup> The presence of stockbrokers who punch in early time clocks, for instance, might deflate the average arrival time figure for some subcities. The relatively high share of, say, restaurant and theater employees during the evening, on the other hand, might skew the average evening departure time for others. Most importantly, it may be the case that the mixed-use character of subcities has served to spread out worker arrival and departure times, thereby reducing the intensity of peaking.

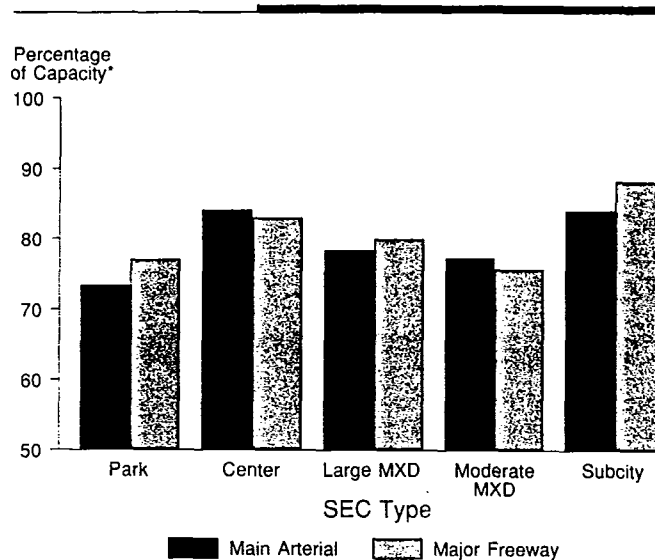
### Areawide Traffic Conditions

The final set of comparisons made among SEC groups looked at differences in areawide traffic volumes and conditions. The last entry in Table 4 reveals a significant difference in average daily traffic volumes in the vicinity of subcities relative to average daily traffic volumes for other SEC groups. Subcities average well over 100,000 daily vehicle trips per direction on the main freeway or arterial serving them. Major roadways serving office parks and moderate MXDs, by comparison, average less than half this volume.

Traffic conditions are best reflected, of course, when vehicle volumes are indexed to road capacity. Average peak-period volume-to-capacity ratios for the major surface arterials and major freeways serving SECs are compared among the five groups in Figure 2.<sup>15</sup> Along both surface streets and freeways, peak traffic conditions are

Figure 2

Average Traffic Volumes as Percent of Capacity on Main Roadways Serving SECs



■ Note

a. Average hourly volumes/hourly capacity × 100.

generally the worst around subcities. On average, peak traffic volumes on the primary freeway serving subcities are at 89 percent of capacity, whereas the major connecting arterial operates at around 83 percent of capacity. The next most congested SEC setting is office centers, wherein nearby freeways and arterials operate, on average, at around 82 percent of capacity. Thoroughfares serving large MXDs are generally the third most congested. Office parks, on the other hand, average the least congestion on adjoining surface streets while moderate MXDs tend to have the least congested adjoining freeways. For both office parks and moderate MXDs, the primary connecting roadways tend to operate at volumes that are less than 80 percent of capacity, with relatively stable flow conditions.

The common feature of the SEC groups with the most congested traffic conditions is their relatively high employment densities. In SEC settings, density appears to be a double-edged sword: while it works in favor of ridesharing and other commuting alternatives, it at the same time generates traffic volumes that often saturate local thoroughfares. Thus, the SECs with the highest shares of transit usage and ridesharing are also the most congested.

The decision of local policy-makers to restrict densities in most SECs reflects the preference given to accommodating the automobile over the encouragement of ridesharing or transit commuting. Within the two- to four-year terms for which many officials are elected, this is a

rational choice, because the marginal gains from vehicle pooling induced by higher densities are usually insufficient to make up for the higher levels of nodal congestion. Density, however, must be viewed within a time context. Although denser suburban work environments may increase congestion in the short run, in the long run, they concentrate activities so as to make ridesharing and mass transit viable alternatives to solo commuting. When it comes to density in suburban work settings, a general tenet might be: short-term pain is necessary for long-term gain.

## ■ Summary and Conclusion

The comparison of differences in commuting behavior and conditions among SEC groups yielded several insights that appear to support some of the propositions set out at the beginning of this article. Invoking the *ceteris paribus* assumption, the following can be said:

- The share of commutes made in some manner other than by driving alone generally increases as an SEC becomes denser and it features a wider variety of land uses. Large MXDs and subcities average the highest share of nonsolo commuting. These averages are maintained even when one controls for the quality of transportation services and other contextual variables.
- The incidence of ridesharing is the highest in settings with substantial commercial components, most notably in subcities and MXDs. The availability of retail activities appears to induce a number of suburban workers to carpool and vanpool to work because in these settings they can get to banks, shops, restaurants, and the like without a motor vehicle.
- Subcities appear to have the smallest degree of peaking of commuting trips. This is most likely because highly varied land uses can shift trips outside the core of the peak and thus achieve a more even temporal distribution of travel.
- SECs with the slowest average speeds for employee commutes and the most congested local streets and freeways are subcities and large MXDs, the two groups with the highest employment densities.

Several caveats on the generalizability of these findings need to be addressed. Many other factors that influence travel behavior, such as the price of tripmaking, were not directly included in the analysis, so the findings offer only a partial view of the effects of site and land use features on suburban commuting choices. In addition, since many SECs are still at an embryonic stage of development, commuting behavior no doubt will change as they evolve and mature. As a cross-sectional study, then, the preceding analysis provides a

snapshot of transportation-land use relationships in and around SECs during the latter half of the 1980s.

The density, size, and land use mixtures of SECs were all found to influence employee travel behavior and local traffic conditions around SECs, although in some cases to a modest extent. The SEC groups with the highest densities have not only the highest incidences of ridesharing and transit usage, but also the most congested streets. The paradox of density in suburban work settings appears to be that in the short term, as long as most employees drive to work, local streets become more congested as activities intensify. Over the long haul, however, density is necessary to build up a ridership base to sustain transit and ridesharing services. Additionally, ridesharing tends to be most prevalent in large SECs, suggesting that a critical mass of employees is necessary for mounting successful vanpool and carpool programs in suburbia. Land use mixing also emerged as a significant determinant of travel choice. Those SECs with the greatest variety of activities were found to average the highest shares of nonsolo commutes, including walk trips. In closing, high densities, a large concentration of workers, and mixed-use development appear to be necessary, though probably not sufficient, prerequisites if reasonable levels of ridesharing, transit usage, cycling, and foot travel are to be achieved in suburbia.

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## ■ Notes

1. For a detailed discussion of the research methodology and a presentation of the survey instrument, see chapter 2 and appendix I of Cervero (1989).
2. FAR represents the ratio of gross floorspace of all buildings divided by the total land area of the development.
3. Coverage ratio is the proportion of land covered by buildings — i.e., the footprint of buildings divided by the land area.
4. Not all of the candidates for representing the dimensions collected in the survey entered into the analysis, because some variables had missing cases. Their inclusion would have whittled the data set down to those SEC observations for which complete information was available, a fairly small subset. An exploratory analysis of the correlation matrix of remaining variables resulted in a further elimination of some variables in order to prevent certain pairs with high multicollinearity from dominating the analysis. See Dunteman (1984) for a further discussion of this.
5. This is the final pattern matrix based on Varimax rotation. Communalities were iteratively estimated by initially using R-squared values for each variable regressed against all other variables. Only factors with eigenvalues above 1.0 were extracted.
6. The measure used for joining clusters was the average linkage between groups, often called UPGMA (unweighted pairgroup method using weighted averages). Here, the distance measured between two clusters is the average of distances between all pairs of cases in which one member of the pair is from each of the clusters.
7. Between the forty-second and forty-third stages, the coefficients rose from 6.69 to 6.88, a modest 2.8 percent increase. Between the forty-third and forty-fourth stages, there was a marked increase in

- the coefficients from 6.88 to 8.38, a 21.8 percent jump. The sharp rise, however, was between the forty-fourth and forty-fifth stages, whereby the coefficients rose 32.3 percent, from 8.37 to 11.08. At this stage, the coefficients were getting comparatively high, nearly two-thirds more than what they were just two stages earlier — an indication that the merging process should cease. This was confirmed by the fact that the coefficients increased by less than one-tenth of one percent between the forty-fifth and forty-sixth stages.
8. See Cervero (1989, chapters 2 and 4) for a detailed discussion of these cases.
  9. The ranges are windsorized, meaning the far tails of the distribution have been "clipped" so as to reflect the range of more representative cases and to remove possible outlying cases.
  10. Expressed in terms of employees per directional mile of freeway within five miles of a SEC.
  11. The summary statistics for variation across groups were as follows: drive-alone (F-statistic = 1.78; probability = .163) and ride-sharing (F-statistic = .708; probability = .620).
  12. Large MXDs and subcities were found to average over 2,500 housing units within a three-mile radius of individual SECs, over four times the average found for any other SEC group. In the case of subcities, 87 percent of nearby housing consisted of multifamily units.
  13. The magnitude of this percentage point difference reflects roughly just how much more suburban workers appear to be auto-dependent than all other workers in the region. Since mode shares for both worker groups are influenced by the quality of regional transit services, the cost of automobile usage, and other factors, these influences are controlled for when differences are taken between the two percentages.
  14. The relatively large extremes in arrival and departure times for subcities could reflect a more negatively skewed distribution of arrivals in the morning and a more positively skewed distribution of departures in the evening than for other SEC groups. Median times of arrival and departure would likely be more similar among SEC groups.
  15. These were estimated by computing the "average" level of service within each group, wherein a level of service A was assigned a value of 1, B was assigned a value of 2, C was assigned a value of 3, and so forth. The average level of service of 3.30 for main arterials serving office parks, for instance, was translated as 73 percent of capacity because it was three percentage points above the floor for level of service C (70 percent of capacity) and seven percentage points below the floor for level of service D (80 percent of capacity). For discussions on the level of service concept, see Transportation Research Board (1985).

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