

# Measuring Urban Form

## Is Portland Winning the War on Sprawl?

Yan Song and Gerrit-Jan Knaap

Although many have written about urban sprawl, few have sought to measure it. In this article, we present several quantitative measures of urban form and compute these for neighborhoods of varying age in Washington County, the western portion of the Portland, Oregon, metropolitan area. Our results suggest (1) neighborhoods in Washington County have increased in single-family dwelling unit density since the 1960s; (2) internal street connectivity and pedestrian access to commercial areas and bus stops have improved since the early 1990s; (3) external connectivity continues to decline; and (4) the mixing of land uses remains limited. We conclude that while several measures appear to be improving, Portland's war on sprawl is not yet won.

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Many articles on urban sprawl start with the disclaimer that sprawl is ill defined, but we know it when we see it. In this article, we present several measures of urban form and use these to evaluate development patterns and trends of single-family residential neighborhoods<sup>1</sup> in the Portland, Oregon, metropolitan area. In doing so, we seek not only to increase precision in the debate on urban sprawl, but to evaluate whether the Portland metropolitan area—internationally known for its leadership in growth management—is winning its war on urban sprawl.

### Research Context

Portland is Oregon's largest metropolitan area and has an international reputation for its growth management policies.<sup>2</sup> According to Benfield et al. (1999), for example, "Portland has become a sort of living laboratory for efficient urban planning and living. The results are benefiting both the environment and the region's economy" (p. 152).

Portland is perhaps best known for its urban growth boundary (UGB). First established in 1979 and expanded little since then, the boundary encompasses 24 cities, parts of three counties, and approximately 1.3 million people.<sup>3</sup> Under the requirements of Oregon's land use statutes, all land outside the UGB—with exceptions—is designated for resource use and prohibited from urban development. All land both inside and outside the UGB must be planned by the appropriate city or county. Zoning must correspond with plans. This comprehensive form of land use planning and management has been both celebrated and maligned (Abbott, 2002). Proponents argue that Portland's UGB has successfully served to contain urban sprawl, minimize public service costs, and protect natural resources and open space (Nelson, 1994). Opponents argue that the UGB has led to housing price inflation and helped to stifle urban growth (Staley et al., 1999).

Portland is also known for its light-rail transit system, established on the east side of the metropolitan area in 1986. The westside extension was placed in operation in 1998. To increase ridership and accommodate growth within the UGB, a number of policies were adopted to facilitate transit-oriented development, in-

cluding transit area overlay zones with minimum density requirements and several public/private partnerships established to encourage high-density housing and employment growth around station areas. As with the UGB, the light-rail system has been controversial. Proponents claim that the system has been an effective vehicle for creating a less auto-dependent urban development pattern (1000 Friends of Oregon, 1991). Opponents claim that it has survived only because of substantial subsidies by the federal government (O'Toole, 1998).

The Portland area is also distinctive in at least one other regard: It has the only directly elected regional government in the United States. The roles of Metro (formerly the Metropolitan Service District) include management of the urban growth boundary, regional land use planning, transportation planning, and data management. Although Metro lacks authority to zone and impose subdivision regulations, it can require local governments to revise their plans and regulations if it finds that they do not serve regional goals (Metro, 2002a). In 1991, Metro began work on the 2040 Growth Concept designed to shape metropolitan development for a 50-year period. To accommodate the approximately 720,000 new residents and 350,000 additional jobs projected for the area without encouraging urban sprawl, the Concept encourages redevelopment within the UGB, especially in designated urban centers and transit corridors (Metro, 1992). Following principles of New Urbanism, the goals of the Concept include the transformation of the metropolitan area into a multinucleated urban form, the development of a multi-modal transportation system, and the designation of mixed-use regional and town centers (Calthorpe, 2000; Katz, 1994; Metro, 1992).<sup>4</sup> The implementation vehicle, the *Urban Growth Management Functional Plan*, was adopted in November 1996. In it Metro set binding targets and performance measures, such as designating small-lot subdivisions and establishing minimum housing densities, for its subordinate cities and counties. Metro also required cities and counties to change their comprehensive plans to assure compliance with this plan (Metro, 1996).

Our study focuses on Washington County in the western portion of the metropolitan area, the most rapidly growing of the three counties within Metro's jurisdiction. The study area contains the cities of Beaverton, Hillsboro, Tigard, Sherwood, Tualatin, King City, Cornelius, Forest Grove, and Durham (see Figure 1). In response to the *Functional Plan*, local governments in Washington County have revised their comprehensive plans in a variety of ways (City Council of Beaverton, 1997; City Council of Hills-

boro, 1997a). Some, for example, increased planned densities in their comprehensive plans to conform with the functional plan. To promote adequate traffic circulation and full street connections, the subdivision regulations of Beaverton and Washington County state that street intersections should be provided at intervals of no less than eight per mile (excluding barriers); no cul-de-sac streets longer than 200 feet should be designed; no more than 25 dwelling units should be provided on a closed-end street system except when topography and barriers prevent street extension; access to adjacent developments should be provided through street, pedestrian, and bicycle networks; street connections between neighborhoods should be encouraged; block lengths between local and collector streets should not exceed 1000 feet; and the maximum perimeter of the blocks formed by local and collector streets should not exceed 1800 feet (City Council of Beaverton, 1997; Washington County, 1997). Local land use plans and regulations also provide standards for street design, sidewalk width, and shape of blocks. To increase pedestrian/bicycle accessibility, for example, local plans encourage short, directed public rights-of-way to connect residential uses with nearby commercial services, schools, parks, transit stops, and other public facilities. Finally, local land use plans and zoning ordinances encourage mixed-use developments, which include combinations of residential uses, offices, retail and service business, and public and institutional uses (City Council of Beaverton, 1997; City Council of Hillsboro, 1997b). For the unincorporated areas of Washington County, the Community Plan Code includes transit-oriented districts that encourage a mixture of land uses and includes urban design principles, standards, and guidelines (Washington County, 1997).

Despite clear evidence that regional and local governments in the Portland metropolitan area have made significant investments in plans, regulatory structures, and public facilities to mitigate urban sprawl, the extent to which development patterns in the Portland metropolitan area have changed remains in dispute.<sup>5</sup> In this article, we evaluate development patterns and trends in the Portland metropolitan area by computing several measures of urban form and examining how these have changed over time. Our intent is not to conduct a policy analysis of the impacts of a particular plan or regulations. We hold that growth management instruments in Portland are too numerous, too mutually interactive, and too difficult to date stamp to isolate the impacts of any one instrument. Instead we offer a general examination of whether Port-

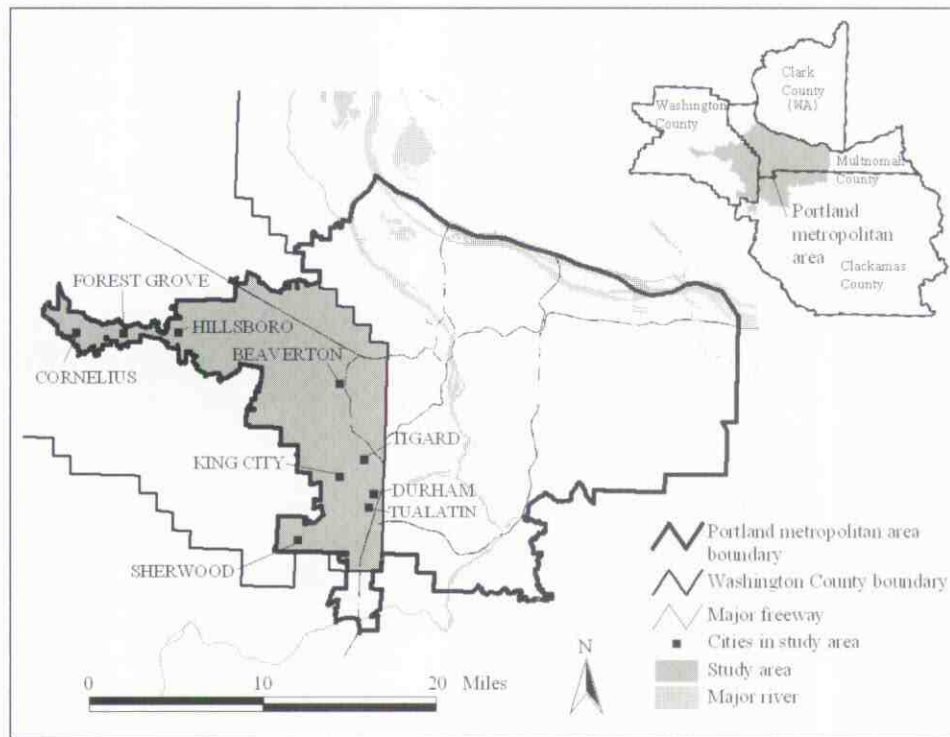


Figure 1. Portland metropolitan area and study area.

Source: Metro (2002b)

land's suite of policy instruments implemented over an extended period have had a measurable influence on various elements of urban form.

## Quantitative Research on Urban Sprawl

Longstanding attempts to quantify urban sprawl focus on the growth of suburbs relative to central cities (Chinitz, 1965). These studies show that suburbs have grown—and continue to grow—more rapidly than the central cities they surround. Such studies provide information about the location of population growth but little specifically about urban form. Another longstanding approach to the study of sprawl focuses on density. Such work demonstrates that urban population density gradients have fallen over time, and that the trend is both global and centuries old (Mills, 1980). Several recent studies compare growth in urban populations with growth in urbanized land areas (Fulton et al., 2002; Sierra Club, 1998) in attempts to identify “who sprawls the most.” But these also reveal only the gross density of new development.

In very recent articles, sprawl has received more detailed quantitative analysis. Wassmer (2000) examined development patterns and trends in Sacramento, California, and a small number of comparable cities. As was done in previous studies, Wassmer computed the share of metropolitan population that lived in the central city, the central county, and the urbanized area at selected points in time. He also computed and compared similar shares for employment, retail sales, farmland, poverty rates, income levels, employment rates, and commuting times. He concluded that Sacramento exhibited a “comparably high degree of centralization as measured by population and employment densities at its center,” and “displayed a high level of negative metropolitan outcomes generally associated with a high degree of urban sprawl” (Wassmer, 2000, p. 16). Like previous studies, however, Wassmer’s research reveals little about urban form.

Galster et al. (2001) conducted perhaps the most detailed analysis of sprawl to date. They identified eight dimensions of sprawl: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. Each dimension reflects spatial relationships among units of analysis. These units are defined by assigning

housing units from 1990 census blocks into 1-mile or 1/2-mile grids. Then, using GIS, they computed each measure for 13 metropolitan areas (the details of the computation methods are too complex to describe here). Finally, they normalized all the measures and, based on equal weights for each normalized measure, computed overall sprawl rankings. The raw scores they reported for six of the dimensions are presented in Table 1.

The results by Galster et al. (2001) offer new and interesting information about urban development patterns in the United States. Consistent with conventional wisdom, Atlanta, Detroit, Miami, and Denver ranked high on the sprawl index while New York, Philadelphia, Boston, and Chicago ranked low. Contrary to conventional wisdom, Los Angeles ranked fairly low on most measures of sprawl. What's more, the sprawl rankings of most cities varied a great deal among measures. Houston, for example, ranked the highest in clustering and lowest in nuclearity.

The measures developed by Galster et al. (2001) provide considerable information about urban form beyond density and suburban population growth. Specifically, they reveal differences in spatial relationships among 1-mile grids within metropolitan areas and thus reveal quantitative insights about urban form. Yet their measures offer little of use to urban residents or policymakers. Should public officials in Houston, for example, be concerned or pleased that it ranked high in clustering and low in nuclearity? If so, how should they respond?

Detailed and policy-relevant measures of urban form have been developed by Eliot Allen and his colleagues at Criterion.<sup>6</sup> Allen's measures, part of a planning support system called INDEX, include over 30 measures computed at a variety of geographic scales (Allen, 2001). When fed into a companion forecast model, these yield forecasts of vehicle miles traveled, ambient air emissions, and jobs/housing balance. Both the original measures and the forecasts they produce can then be used to evaluate alternative development scenarios, formulate plans, and monitor plan implementation.

Allen's indicators offer a number of advantages over previous measures. Like all good indicators, they are well defined, relatively easy to compute (when GIS data are available), and easily interpreted. Perhaps most importantly, however, they are policy relevant. Whereas gross measures of density, nuclearity, and centrality provide interesting information about metropolitan form, measures of transportation options, residential proximity to retail and industrial uses, and accessibility of parks, shops, and transit is of direct concern to citizens and policymakers. This is why INDEX serves well to evaluate alternative development proposals and land use plans.

	Density	Concentration	Clustering	Centrality	Nuclearity	Proximity
Atlanta	806.25	0.28	0.38	177.86	44.17	0.2569
Boston	1000.63	0.47	0.44	191.83	88.80	0.2754
Chicago	1647.09	0.40	0.49	160.30	82.42	0.3392
Dallas	901.57	0.41	0.47	149.40	24.03	0.3311
Denver	1462.90	0.31	0.41	178.22	67.40	0.1656
Detroit	1265.60	0.34	0.39	141.51	69.94	0.2610
Houston	989.45	0.40	0.54	183.16	13.44	0.2539
Los Angeles	1861.84	0.37	0.36	166.97	57.92	0.3800
Miami	1883.26	0.32	0.41	125.91	43.79	0.1793
New York	1946.48	0.51	0.51	202.24	96.56	0.4048
Philadelphia	1483.97	0.41	0.52	192.14	89.98	0.2551
San Francisco	1639.00	0.43	0.37	194.76	70.18	0.2611
Mean	1407.42	0.39	0.44	167.46	62.84	0.2800
Standard deviation	389.56	0.06	0.06	25.36	25.71	0.0700

Table 1. Indicators of urban sprawl (Source: Galster et al., 2001).

## Quantitative Measures of Urban Form

To begin our evaluation of development patterns in metropolitan Portland, we present several measures of urban form. Many are similar to those developed by Allen. To facilitate meaningful comparison, however, we use these attributes to measure the urban form of neighborhoods. A definition of each measure and how it was computed is provided below.<sup>7</sup> Later we return to a discussion of neighborhoods.

### Street Design and Circulation Systems

According to critics of sprawl, contemporary suburban developments contain too many winding streets and cul-de-sacs, creating blocks that are too big and thus lack connectivity. According to this point of view, better connectivity leads to more walking and biking, fewer vehicle miles traveled, better air quality, and a greater sense of community among residents (Benfield et al., 1999). Our measures of connectivity involve the number of nodes and intersections, the distance between points of access into the neighborhood, the number and lengths of blocks, and the lengths of cul-de-sacs. Four measure connectivity within a neighborhood; one measures connectivity between neighborhoods:<sup>8</sup>

- *Int\_Connectivity*—number of street intersections divided by sum of the number of intersections and the number of cul-de-sacs; the higher the ratio, the greater the internal connectivity.
- *Blocks\_Peri*—median perimeter of blocks; the smaller the perimeter, the greater the internal connectivity.
- *Blocks*—number of blocks divided by number of housing units; the fewer the blocks the greater the internal connectivity.
- *Length\_Cul-De-Sac*—median length of cul-de-sacs; the shorter the cul-de-sacs, the greater the internal connectivity.
- *Ext\_Connectivity*—median distance between Ingress/Egress (access) points in feet; the shorter the distance, the greater the external connectivity.

### Density

According to critics of sprawl, contemporary urban development is dominated by single-family dwelling units (SFDUs) on large lots. They believe this low-density development increases automobile dependence, consumes farmland, and raises the cost of public infrastructure (American Planning Association [APA], 1998). We offer

three measures of *single-family* development density: SFDU lot size, density, and floor space. (Note that we excluded multifamily units in computing density measures because the data were not available. We speculate that the inclusion of multifamily units would largely affect total residential dwelling-unit density, since multifamily residential development in higher densities is an important growth management strategy in the area.)

- *Lot\_Size*—median lot size of SFDUs in the neighborhood; the smaller the lot size, the higher the density.
- *SFDU\_Density*—single-family dwelling units divided by the residential area of the neighborhood; the higher the ratio, the higher the density.
- *Floor\_Space*—median floor space of SFDUs in the neighborhood; the smaller the floor space, the higher the density.

### Land Use Mix

According to critics of sprawl, contemporary urban developments are homogeneous and lack a mix of land uses. They believe that greater mixing of uses facilitates walking and biking, lowers vehicle miles traveled, improves air quality, and enhances urban aesthetics (APA, 1998). We offer two measures of land use mix: One measures the actual mix of nonresidential land uses in the neighborhood; the other measures the mix of zoned nonresidential land uses.

- *Mix\_Actual*—acres of commercial, industrial, and public land uses in the neighborhood divided by the number of housing units; the higher the ratio, the greater the land use mix.
- *Mix\_Zoned*—acres of land zoned for central commercial, general commercial, neighborhood commercial, office commercial, industrial, and mixed land uses in the neighborhood divided by the number of housing units; the higher the ratio, the greater the mix.

### Accessibility

According to critics of sprawl, contemporary urban development is characterized by too much separation between uses, creating travel distances that are too long (APA, 1998). Here we offer three measures of accessibility: distance to commercial uses, distance to a bus stop, and distance to a public park. Each is measured as the median distance from the centroid of every single-family parcel in the neighborhood to the centroid of the nearest commercial use, bus stop, or public park.

- *Com\_Dis*—median distance to the nearest commercial use; the shorter the distance, the greater the accessibility.
- *Bus\_Dis*—median distance to the nearest bus stop; the shorter the distance, the greater the accessibility.
- *Park\_Dis*—median distance to the nearest park;<sup>9</sup> the shorter the distance, the greater the accessibility.

### Pedestrian Access

According to critics of sprawl, contemporary development patterns create great distances between destinations and thus discourage walking. They believe that pedestrian access encourages residents to walk, lowers vehicle miles traveled, and improves human health (Frank & Engelke, 2001). Pedestrian access is widely accepted as 1/4-mile network distance (Duany & Plater-Zyberk, 1992). Thus we measure pedestrian access as the percentage of single-family homes that are within 1/4-mile network distance (i.e., walking distance) of all existing commercial uses or bus stops.

- *Ped\_Com*—percentage of SFDUs within 1/4 mile of all existing commercial uses; the higher the percentage, the greater the pedestrian access.
- *Ped\_Transit*—percentage of SFDUs within 1/4 mile of all existing bus stops; the higher the percentage, the greater the pedestrian access.

### Definition of Neighborhoods

The neighborhood has long been regarded as the basic building block of urban form. What constitutes a neighborhood is disputed.<sup>10</sup> Lacking clear theoretical guidance, we explored three data-driven alternatives: census tracts, block groups, and subblock groups. We observe that boundaries of block groups and subblock groups, in most cases, coincide with wide and busy arterials that divide an area into neighborhoods with distinctly different physical and social characteristics. To choose among these, we computed several measures of urban form at these three levels of census geography. That is, we calculated measures of urban form for Washington County's 60 census tracts, 186 block groups, and 237 subblock groups (subblock groups are formed by further partitioning block groups by major arterials). Then we determined the age of the neighborhood defined at each level by the median "year built" attribute of all single-family units it contained.<sup>11</sup>

Figures 2, 3, and 4 illustrate the relationships between internal connectivity and median year built measured at the census tract, block group, and subblock group level, respectively. As demonstrated by observation and statistical tests, "neighborhoods" defined at the census tract level (Figure 2) provide less information about changes in urban form over time than neighborhoods defined at the block group level (Figure 3). The former have less variation in connectivity, due to aggregation, and thus demonstrate smaller changes over time. Neighborhoods measured at the subblock group level (Figure 4), however, reveal little more information than those measured at the block group level. Thus we chose to use block groups as neighborhoods and divided the study area into 186 neighborhoods for the remaining analysis.<sup>12</sup>

### Measures of Urban Form for Two Different Neighborhoods

To test our measures of urban form we first selected two distinctly different neighborhoods from the 186 in the study area (see Figure 5). The first is the Orenco Station neighborhood, located next to an Intel plant and a light rail line. This development has gained a great deal of notoriety as an exemplar of a successful New Urbanist development (National Association of Homebuilders [NAH], 2002). The second is the Forest Glen neighborhood, located in southern Beaverton. In Forest Glen, measures of urban form lie near the median value of all neighborhoods in Washington County, and thus it represents a "typical" neighborhood in our study area. As shown in Table 2, Orenco Station and Forest Glen differ significantly in most measures of urban form. Orenco Station has better internal street connectivity; more mixing of land uses within the neighborhood; better pedestrian access to parks, commercial areas, and bus stops; but lower external connectivity than Forest Glen.

This simple comparison of two neighborhoods does not, of course, provide conclusive evidence that Orenco is a better place to live than Forest Glen. It does, however, demonstrate that differences in urban form can be measured and that such measures appear to capture differences pertinent to the current debate on urban sprawl. The extent to which any characteristic of a neighborhood is desirable, and the extent to which one desirable characteristic should be traded off against others, remain matters of preference we do not resolve here.

**Internal connectivity  
of census tracts**

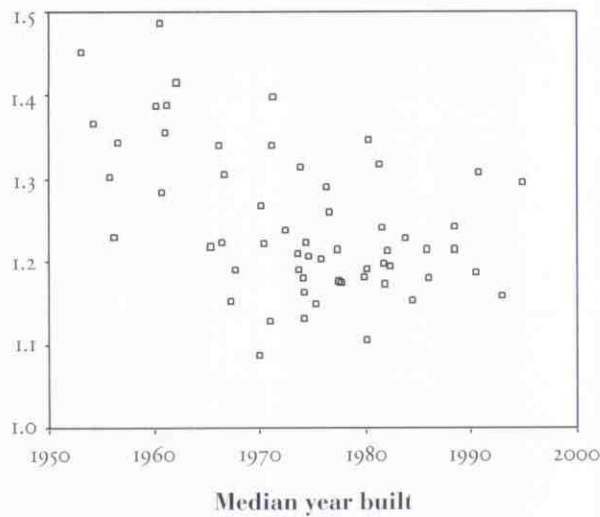


Figure 2. Internal connectivity by age of neighborhood at census tract level.

**Internal connectivity  
of subblock groups**

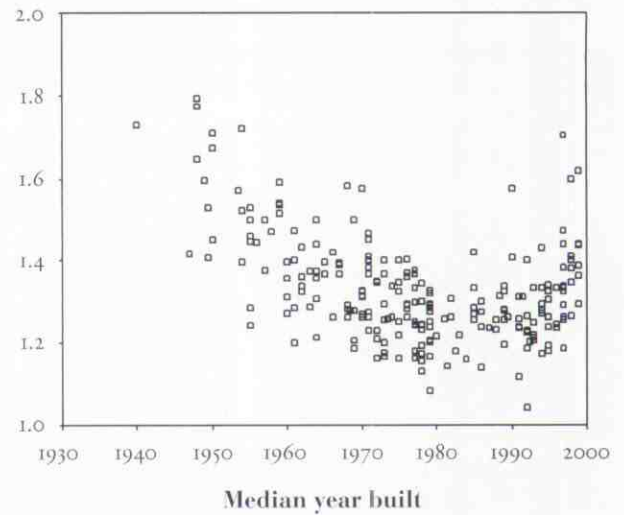


Figure 4. Internal connectivity by age of neighborhood at subblock group level.

**Internal connectivity  
of block groups**

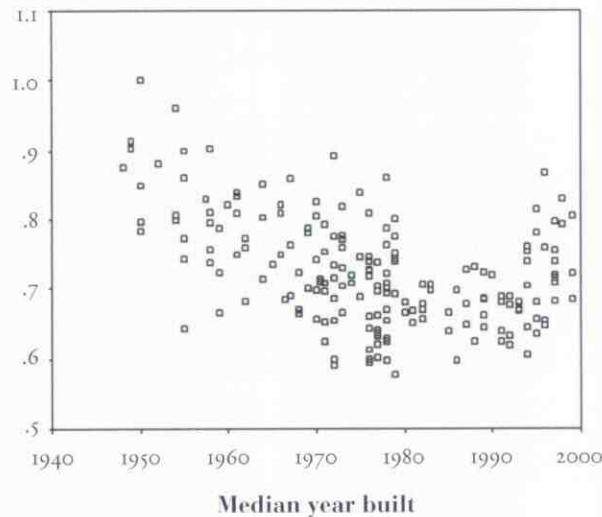


Figure 3. Internal connectivity by age of neighborhood at block group level.

## Comparing the Urban Form of Neighborhoods Built at Different Times

To examine trends in urban form<sup>13</sup> in our study area, we present plots of data and the results of regressions that have measures of urban form as the dependent variable and the age of the neighborhood as the only independent variable.<sup>14</sup> Though statistical analysis is necessary to identify statistically significant relationships, the plots reveal intuitive information that statistical analyses alone often obscure, especially for new, unfamiliar quantitative measures. For economy of exposition, however, we represent plots of data for only one measure of each type of urban form indicator.<sup>15</sup> To illustrate where a New Urbanist and a traditional neighborhood lie in the distribution of each measure, we indicate values for the Orenco Station and Forest Glen neighborhoods with a star and triangle, respectively. The coefficient on age in the regression analysis tells us if the indicator measure is increasing or decreasing over time. We also tested to see whether the relationship between the indicator measure and age changed to a significant degree at any point over the study period. The results of the regression analyses are presented in Table 3.

Table 3 lists the measures of urban form and the intercept and slope coefficients (and corresponding t-statistics) of the following equations:

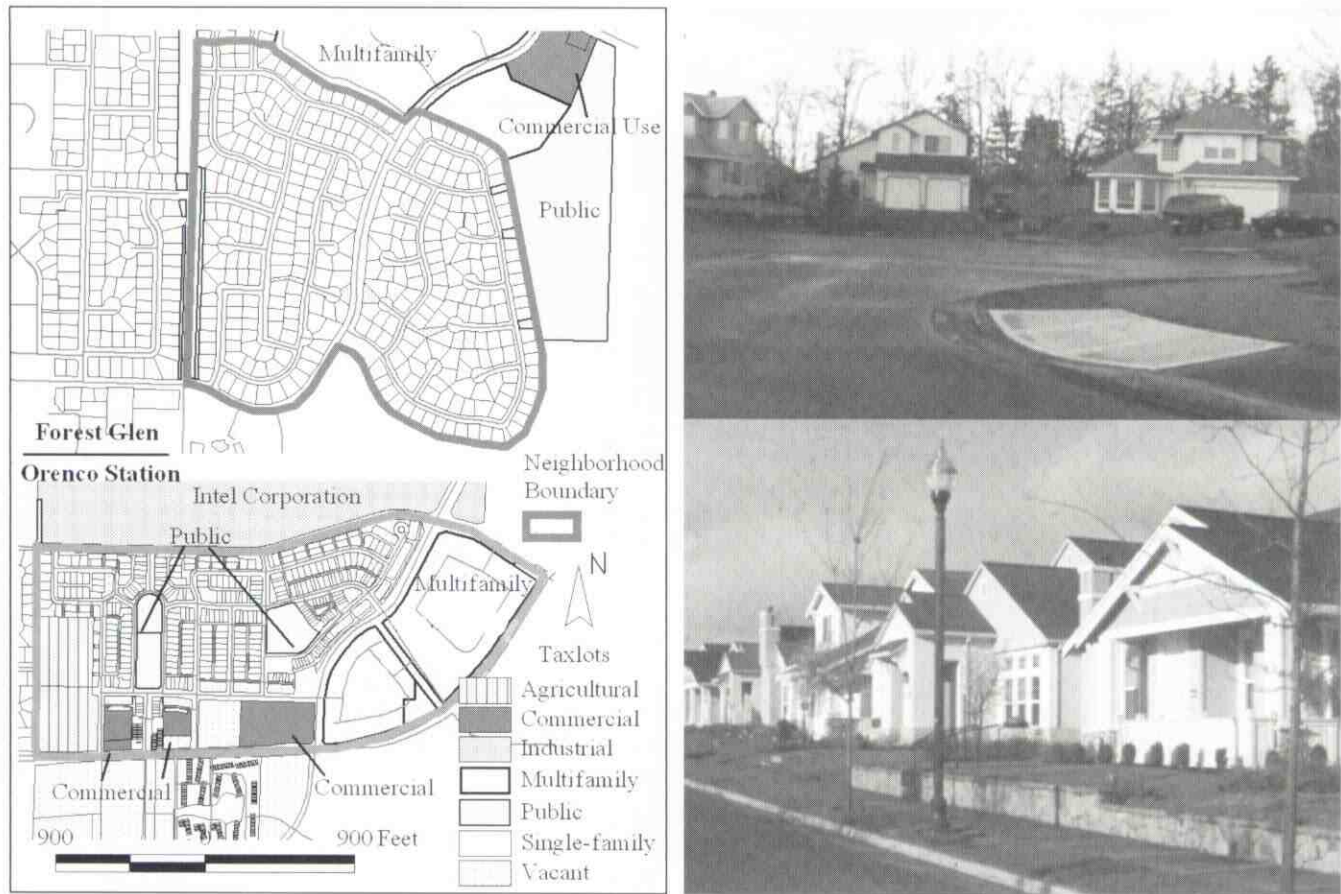


Figure 5. Forest Glen (upper) and Orenco Station (lower) residential neighborhoods. Source: Metro (2002b)

Urban form measure	Forest Glen	Orenco Station
Internal connectivity (intersections / [intersections + cul-de-sacs])	0.67	0.81
External connectivity (median distance between access points in feet)	569	1,016
Median block size (median perimeter in feet)	3,365	830
Number of blocks per SFDU	0.026	0.15
Median length of cul-de-sacs (feet)	203	106
Actual nonresidential area per SFDU (sq. ft.)	0	2,068
Zoned nonresidential area per SFDU (sq. ft.)	0	6,837
Median distance to nearest commercial use (feet)	3,184	834
Median distance to nearest park (feet)	1,267	873
Median distance to nearest bus stop (feet)	1,474	247
Percentage of SFDUs within 1/4 mile of all existing commercial uses	0.04	0.78
Percentage of SFDUs within 1/4 mile of all existing bus stops	0.34	1.00

Table 2. Urban form measures for Forest Glen and Orenco Station neighborhoods.

	Data measurement periods								<i>t</i> test for equality of means	Year of trend change
	1940-2000		1940-1989			1990-2000				
	$\alpha$	$\beta$	$\alpha_1$	$\beta_1$	$\bar{X}_1$	$\alpha_2$	$\beta_2$	$\bar{X}_2$		
Int_Connectivity	6.1 (7.9)***	-0.003 (-7.0)***	10.5 (10.3)***	-0.005 (-9.6)***	0.7	-24.8 (-3.0)***	0.013 (3.1)***	0.7	-1.6	1990
Blocks_Per	-11138.9 (-0.6)	7.0 (0.8)	-85389.1 (-3.5)***	44.7 (3.60)***	2840.0	444375 (2.1)**	-221.7 (-2.1)**	2301.7	-1.9*	1991
Blocks	2.4 (4.3)***	-0.0012 (-4.2)***	4.1 (5.5)***	-0.002 (-5.5)***	0.5	-12.4 (-2.0)**	0.006 (2.4)**	0.039	-0.8	1992
Length_Cul-De-Sac	7231.1 (3.8)***	-3.5 (-3.6)***								
Ext_Connectivity	-7573.0 (-3.6)***	4.1 (3.8)***								
Lot_Size	404529 (2.9)***	-199.5 (-2.8)***								
SFDU_Density	-80.9 (-4.9)***	0.040 (5.1)***	-40.2 (-1.8)*	0.022 (2.0)**	4.1	-1083 (-6.1)***	0.6 (6.1)***	5.36	4.6***	1990
Floor_Space	-15026.7 (-2.9)***	8.5 (3.4)***								
Mix_Actual	13848.6 (0.4)	-6.3 (-0.4)								
Mix_Zoned	44118 (0.8)	-21.9 (-0.8)								
Com_Dis	-70991.9 (-5.6)***	36.9 (5.8)***	-74124 (-4.2)***	38.5 (4.3)***	1815.5	459531 (3.2)***	-229.0 (-3.2)***	2733.3	4.3***	1990
Bus_Dis	-63008.7 (-4.2)***	32.7 (4.3)***								
Park_Dis	8091.7 (0.8)	-3.3 (-0.6)								
Ped_Com	20.7 (7.9)***	-0.010 (-7.8)***	30.9 (8.4)***	-0.02 (-8.3)***	0.3	-52.0 (-1.8)*	0.030 (1.8)*	0.2	-2.0**	1990
Ped_Transit	17.7 (6.1)***	-0.009 (-6.0)***	17.5 (4.6)***	-0.009 (-4.5)***	0.5	-103.6 (-2.2)**	0.050 (-2.2)**	0.3	-3.3***	1993

\*  $p < .10$  \*\*  $p < .05$  \*\*\*  $p < .01$   
 $\alpha$  = intercept;  $\beta$  = slope;  $\bar{X}$  = average

Table 3. Regression results for all urban form measures.

$$Y = \alpha + \beta t + \varepsilon$$

and

$$Y = \alpha_1 + \beta_1 t + \alpha_2 + \beta_2 t + \varepsilon$$

Coefficients for the second equation are presented only if Chow tests demonstrated that  $\alpha_1$  and  $\alpha_2$  and  $\beta_1$  and  $\beta_2$  differ significantly. That is, Table 3 presents the results of two sets of coefficients if tests reveal that the trend in urban form changed over time. For the measures that have been identified with a trend change, Table 3 also presents the mean values of the measures in two periods and the results of  $t$  tests for the equality of means. The final column of Table 3 lists the year in which the trend changed—if indeed it did change.

### Connectivity

Figure 6 illustrates the relationship between internal connectivity and the age of the neighborhood. From this figure, it is clear that neighborhoods developed in the 1940s and 1950s had higher internal connectivity than those developed more recently. Further, the results reveal that the internal connectivity fell fairly consistently as the neighborhoods aged from 1940 to 1990. Around 1990, however, the trend appears to change, such that neighborhoods developed in 1999 had internal connectivity measures about equal to those developed in the 1970s. Furthermore, Chow tests confirm that the trend in connectivity changed significantly in 1990. As shown in Table 3, internal connectivity fell by approximately .005 per year until 1990; after 1990, internal connectivity rose by approximately .013 per year.

As also shown in Table 3, similar changes in trends occurred in the number of blocks and the length of block perimeters. Until the early 1990s, the number of blocks in neighborhoods was falling while the perimeters of blocks were rising. Beginning in the early 1990s, however, the number of blocks began to rise while the perimeters of blocks began to fall. Somewhat surprisingly, the lengths of cul-de-sacs fell throughout the postwar period. The trends in cul-de-sacs notwithstanding, these results suggest that the street network in neighborhoods built during the 1990s began to exhibit a pattern less characteristic of urban sprawl. The differences in means, however, in all the measures of internal connectivity before and after 1990, are not statistically significant.

The index of external connectivity, however, exhibits a different pattern. As shown in Figure 7, external connectivity appears to have fallen over the entire postwar period. Indeed regression analysis reveals that the measure of external connectivity fell by about 4.06 feet per year. That is,

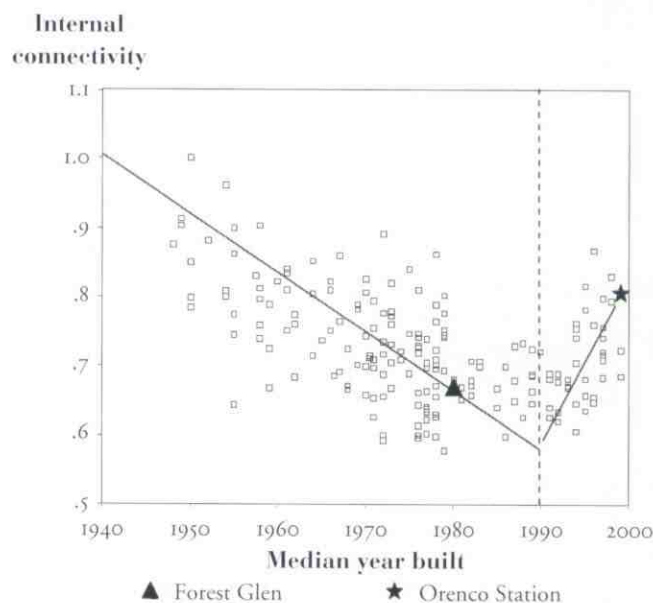


Figure 6. Internal street connectivity by age of neighborhood.

the distance between access points into the neighborhood increased by approximately 4 feet per year. Again, it is noteworthy that even the Orenco Station neighborhood ranks low in external connectivity.

### Development Density

Figure 8 illustrates the relationship between single-family lot size and neighborhood age. The figure suggests that lot sizes have fallen fairly consistently over time from an average of 12,000 square feet in 1960 to 4,800 square feet in 2000. Figure 8 also shows that while the rate of decline does not appear to accelerate, the number of extremely low-density neighborhoods diminished after 1990. As shown in Figure 9, the SFDU density increased from an average of 4 dwelling units per acre in 1960 to an average of 10 in 2000. The rate of increase in SFDU density accelerated after 1990. This, however, may reflect a decline in the area of the neighborhood not developed for single-family use. Not surprisingly, the floor space per SFDU has risen consistently over time, from an average of 1,500 square feet in 1950 to an average of 2,200 square feet in 1998, as shown in Figure 10. But some neighborhoods continue to have homes with less than 2,000 square feet of floor space. These results suggest that SFDUs have increased in size and density over the entire postwar period, indicating the presence of smaller lots and larger houses. The rate of increase in density of single-family units in a neighborhood accelerated in the early 1990s, but this may

Median distance between access points (feet)

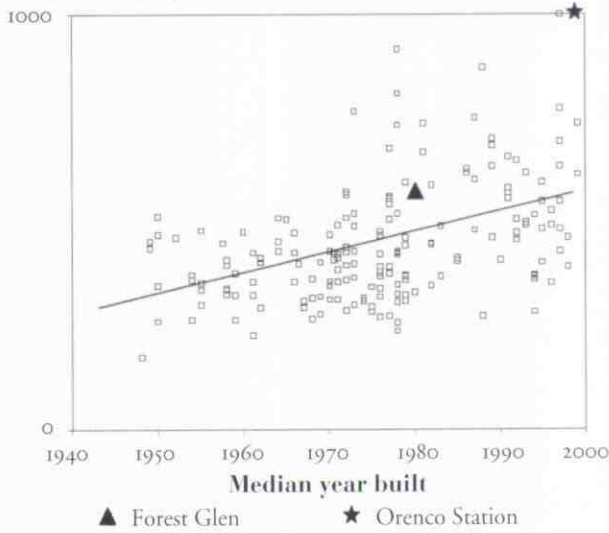


Figure 7. External connectivity by age of neighborhood.

reflect higher proportions of land developed for single-family use and the elimination of extremely low-density developments. Nevertheless, the mean density in the period after 1990 was significantly higher than the mean density of development before 1990.

Median single-family lot size (sq. ft.)

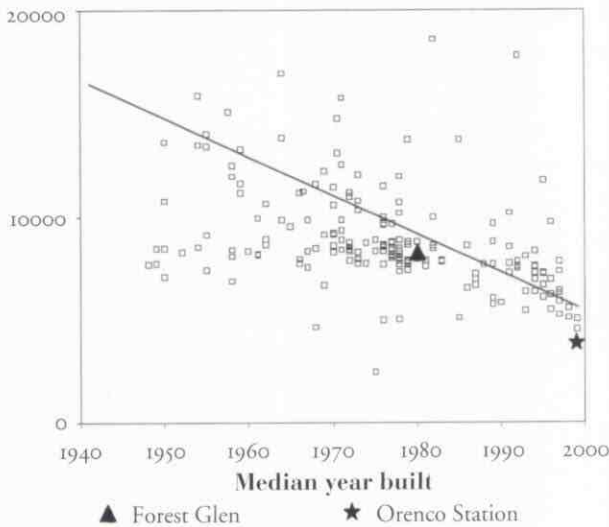


Figure 8. Single-family lot size by age of neighborhood.

SFDU density

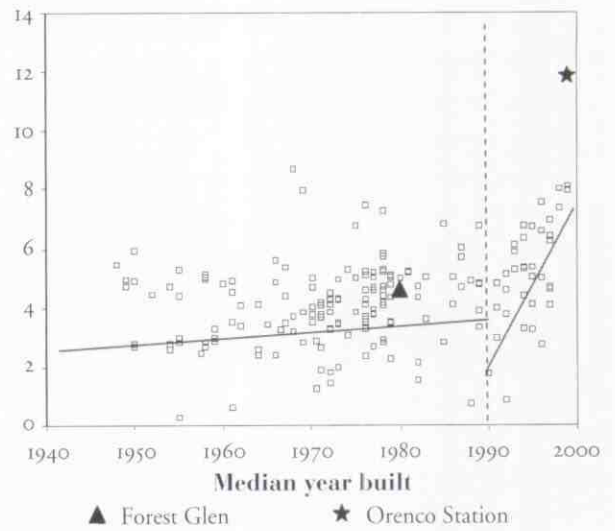


Figure 9. SFDU density by age of neighborhood.

### Land Use Mix

To explore relationships between land use mix and age of neighborhood, we computed the number of square feet in each neighborhood not used or zoned for residential purposes per SFDU. Actual nonresidential land uses of neighborhoods built at different times are presented in Figure 11. As shown, the range is large, with no apparent systematic relationship, which is confirmed in Table 3.

Median SFDU floor space (sq. ft.)

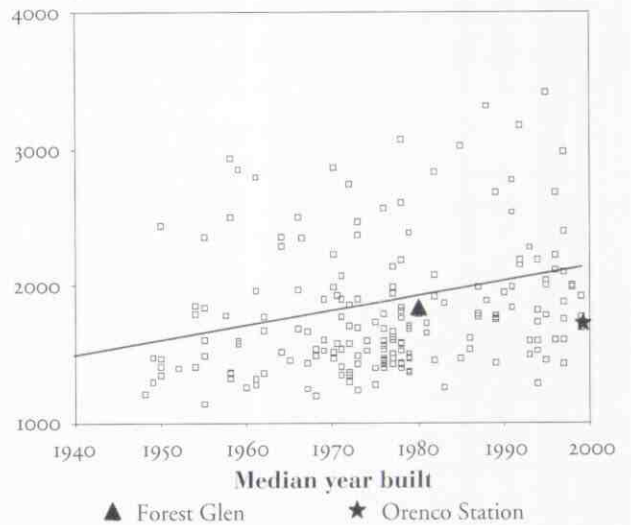


Figure 10. Median SFDU floorspace by age of neighborhood.

The same is true for zoned land uses. These results suggest there has been little change in the zoned or actual mix of land uses in these neighborhoods over time. The fact that single-family neighborhoods generally lack mixed uses is perhaps a vivid reflection of NIMBYism.

### Accessibility

To explore associations between accessibility and age of neighborhood, we computed the median value of the distance from every SFDU to several potential destinations in each neighborhood, including commercial land uses, public parks, and public transit. As shown in Figure 12, distance to the nearest commercial land use has risen until fairly recently. As shown in Table 3, distances to commercial uses indeed rose until 1990 and then began to fall. Once again, however, the recent fall appears to reflect the elimination of outliers more than a fall in the average. Indeed, the average distance to commercial uses remains higher after 1990 than before. As also shown in Table 3, distance to the nearest bus stop is greater in newer neighborhoods, while distance to public parks appears unrelated to neighborhood age. Neither trend changed over the study period.

### Pedestrian Access

To assess pedestrian access, we calculated the percentage of SFDUs in each neighborhood located within 1/4 mile (walking distance) of all existing commercial uses and bus stops. As shown in Figure 13, the percentage of SFDUs within 1/4 mile of commercial uses falls over time. The results in Table 3, however, suggest that this relationship changed in 1990. After 1990, the percentage of dwellings within walking distance to commercial uses rose. Figure 14 suggests, however, that this result reflects the influence of a few highly accessible neighborhoods, including Orenco Station. Access to bus stops exhibits a similar trend, though the change occurred 3 years later. However, the mean percentage of homes with access to both commercial uses and bus stops was lower after 1990 than before.

### Study Limitations

For several reasons the research results must be interpreted with some caution. First, because of the lack of important data on multifamily developments, such as the number of units in a multifamily building and the year it was built, we were not able to include multifamily units in our urban form measures. The exclusion of multifamily

### Median nonresidential area (sq. ft.)

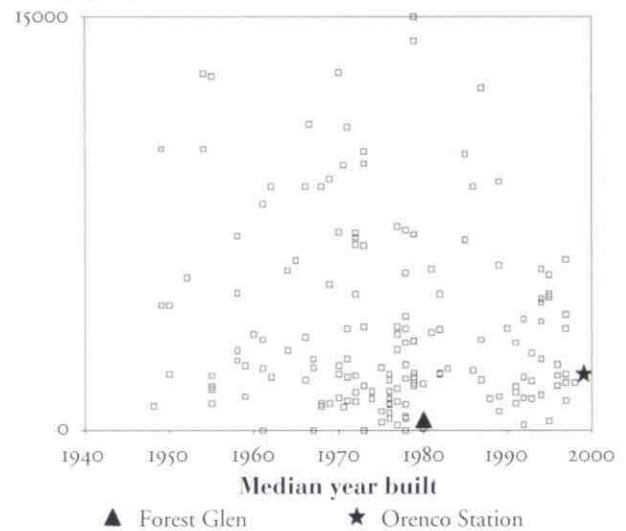


Figure 11. Actual nonresidential area per SFDU by age of neighborhood.

developments affects our results in several ways. Our street network design and circulation measures are based on street networks only; therefore, the exclusion of multifamily housing would not have any impact on these measures. Since the land use mix measures treat all residential areas the same, the omission of multifamily units would also not affect these results. For accessibility measures, however, the

### Median distance to nearest commercial use (feet)

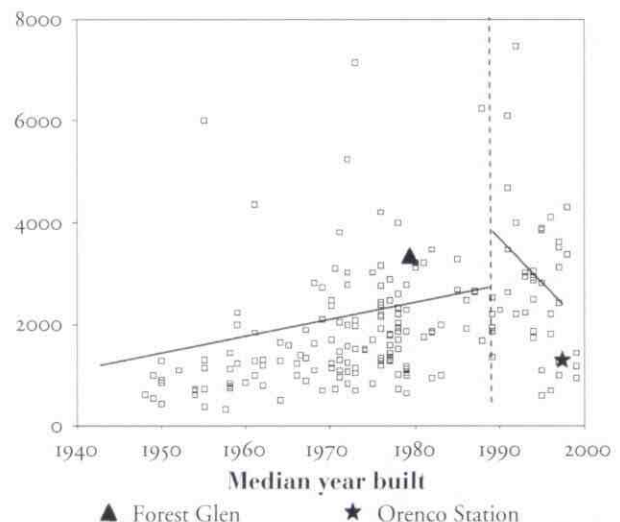


Figure 12. Median distance to nearest commercial use by age of neighborhood.

### Percentage of SFDUs within 1/4 mile of commercial uses

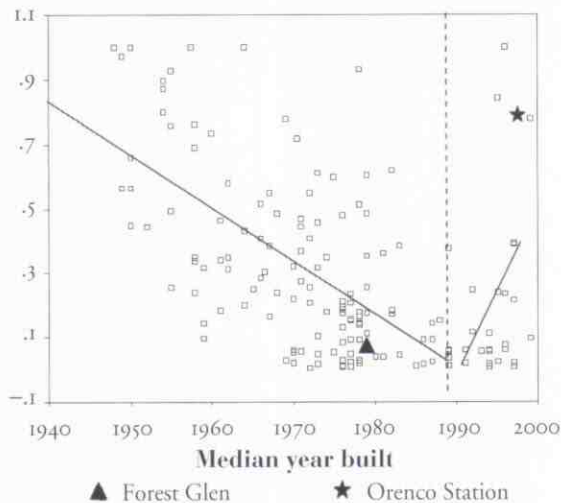


Figure 13. Pedestrian access to commercial use by age of neighborhood.

exclusion of multifamily units could affect our results. We observed that multifamily units are located closer to commercial uses, parks, and bus stops than single-family units.

For our 186 neighborhoods, the median distances from multifamily parcels to the nearest commercial areas, parks, and bus stops are 793, 699, and 563 feet, respectively, compared to 2,219, 895, and 2,518 feet for single-family units. For measures of density, our omission of multifamily units also has potentially significant impacts. If we measured density in *all* residential units, instead of only single-family units, we suspect that we might find an even more rapidly rising trend over time. For pedestrian access measures, the inclusion of multifamily units might also show a more promising trend. We observed that more multifamily parcels are located at shorter distances to commercial uses and bus stops than single-family units. In our study area, 52% of multifamily parcels are within 1/4 mile of commercial uses, compared to only 18% of single-family units; 68% of multifamily parcels are within 1/4 mile of bus stops, compared to only 34% of single-family units. We propose to do more research to include multifamily units in measuring urban form when relevant data become available.

Second, it is possible that some of our measures—such as commercial land uses, density, and proximity to bus stops—reflect redevelopments or changes in bus routes. As our measure of neighborhood age is based on the median age of single-family homes in the neighborhood, it is

### Percentage of SFDUs within 1/4 mile of bus stops

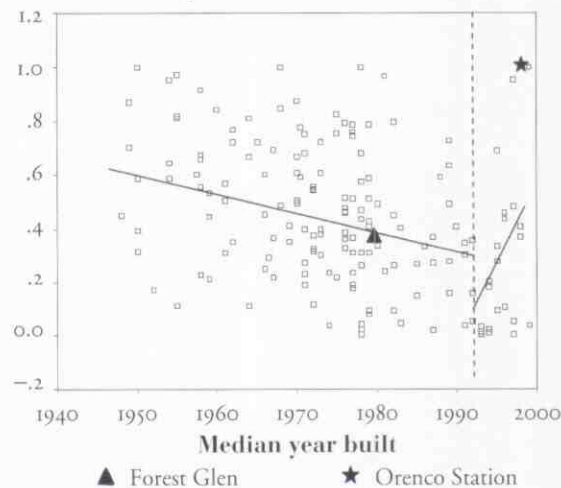


Figure 14. Pedestrian access to bus stops by age of neighborhood.

possible that, for example, a neighborhood first developed in the 1940s but partially redeveloped for commercial use in recent years could cause us to overestimate the mixture of land uses in the 1940s.

Third, some of our results may reflect the influence of outliers on both ends. For example, some of the increases in density may reflect the elimination of extremely low-density neighborhoods, and some of the increases in pedestrian accessibility may reflect the influence of a few recently developed New Urbanist neighborhoods. The plots of data reveal that the median values of several measures have not changed a great deal. Even so, this does not diminish the statistically significant changes in trends. In fact, it is quite likely that the absorption of land within the UGB has made extremely low-density development infeasible. And it is quite likely that several recent new urbanist developments have not changed the form of the typical suburban development but have altered average county-wide trends.

## Summary & Conclusions

In this article, we presented several measures of urban form and computed them for neighborhoods in Washington County, Oregon. We first tested these measures in two select neighborhoods and found that they appear to measure meaningful differences between a typical neighborhood

and a highly touted New Urbanist neighborhood. We then examined whether our measures of urban form varied systematically with the age of neighborhoods.

We found systematic changes over time in most measures of urban form, excluding measures of land use mix and distance to parks. Further, we found that many of these measures improved in the early 1990s. Specifically, we found increases in measures of connectivity, pedestrian access, and density—especially after 1990. The results suggest that neighborhoods in Washington County are becoming better internally connected, more pedestrian friendly, and denser but remain relatively homogeneous in land uses. Taken at face value, the results suggest that either market forces or the many growth management policies in the Portland metropolitan area are causing significant changes in urban form. As mentioned before, we emphasize that our intent in this article was not to conduct a policy analysis of the impacts of a particular plan or regulations. Because of the complex nature of growth management strategies, we do not attempt to isolate the impacts of any one instrument nor to answer the question of which specific instruments of the region's growth management program are connected to the identified urban form changes noted here. Nevertheless, we speculate that recently developed neighborhoods have relatively higher internal street connectivity and better pedestrian access, and this might be attributed in part to street connectivity policies adopted in 1996 by Metro as part of the *Urban Growth Management Functional Plan* (Daisa et al., 2001). External connectivity is decreasing, and this might be due to the Access Management Program (AMP) in state and county road departments. The AMP has limited local street connections to the arterial network over the past 20 years. Another factor is that since the late 1980s, most single-family developments have been sited on parcels abutting existing development. In many cases, these abutting developments lacked future street connections.<sup>16</sup> The UGB in the Portland metropolitan area might in part cause the density of single-family development to increase over time. As Abbott (2002) pointed out,

Data . . . suggest that the UGB is continuing to work. In 1994, the Portland area was building new housing at a density of five dwelling units per acre. By 1997 and 1998, the density of new development averaged eight dwellings per acre, actually exceeding the 2040 Plan target. (p. 221)

These results, which characterize a trend in urban

form toward denser, more internally connected, and more pedestrian friendly yet relatively homogenous neighborhoods with poor external connectivity are rather encouraging for the neighborhoods, but less so for the region. At the regional level, we speculate, better land use mixing and regional connectivity is constrained by economies of scale in commercial uses and transportation infrastructure. The results are consistent with the concerns expressed by previous studies. According to Bookout (1992a, 1992b), Fulton (1996), Lehrer and Milgrom (1996), Furuseth (1997) and Southworth and Balaji (1997), the traditional neighborhoods that New Urbanists hope to replicate are characterized by compactness, small scale, and diversity of buildings, but the economic and lifestyle demands of urban and suburban life seem to require certain facilities on a massive scale. In sum, Portland is winning the war on urban sprawl at the neighborhood scale, or at least appears to have won some important battles; but progress remains elusive at the regional scale.

#### Acknowledgements

We express our appreciation for the support from the Lincoln Institute of Land Policy and the U.S. Department of Housing and Urban Development. We alone are responsible for any remaining errors.

#### Notes

1. Because of the lack of important data on multifamily residential units, such as the number of units in a multifamily building and the year built, we were not able to include multifamily units in our urban form measures. This exclusion has some effects on our measures, as we discuss near the end of the article.
2. For a historical review of land use policies in Oregon, see Abbott (2002).
3. For more on the UGB, see Knaap (2000) and Abbott (2002).
4. In addition to employing neotraditional architectural design principles, New Urbanism also refers to larger scale planning issues (Furuseth, 1997; Katz, 1994). Attempting to redefine urban landscapes by addressing criticisms of suburban development and urban sprawl, regional-scale New Urbanism includes the following major elements: (1) high-density development; (2) proximity of residences, jobs, and retail destinations to public transit facilities to encourage pedestrian-oriented development; (3) mixed land uses, with retail and employment locations close to residential areas; and (4) grid street networks, which are not divided into the arterial collector/local road classification system found in most suburban areas (Ryan & McNally, 1995; Southworth, 1997).
5. For example, in a widely circulated email message, Andrés Duany states:

I have visited Portland five times. All of them were invitations to public speaking and so in all cases I was . . . shown the many wonderful places that make it a great, livable city. I agreed that Portland was great and livable and praised the city accordingly. . . .

On the fifth trip, however, before my engagement, I "escaped" my hosts and went out to visit the famous urban boundary on my own. What did I find, to my surprise? That as soon as one left the prewar urbanism (to which all my prior visits had been confined) the sectors all the way to the urban boundary were chock full of the usual sprawl that one finds in any American city, no better than in Miami. So the outcome wasn't that different after all; in Portland most of the prewar urbanism is excellent and most of the postwar version is junk. But can't we say that, despite that, an urban boundary is an achievement in itself? That depends on where you draw it, and from that point of view, Portland's was not a great achievement. It was drawn 20 years out; which is to say slack enough to include 20 years of future growth. (Charles, 2000, p. 133)

6. Criterion Planners/Engineers Inc., Portland, Oregon. More information is available on-line at <http://www.crit.com/index/index.html>.
7. All the calculations were computed using ArcInfo and ArcView, with data from Metro's Regional Land Information System (RLIS).
8. For more on connectivity, see Allen (2001) and Southworth (1997).
9. Parks are defined as in Metro's RLIS as public parks, greenways, and neighborhood parks.
10. For more on neighborhood definition, see Cervero and Gorham (1995), Crane and Crepeau (1998), and Olson (1997).
11. The median "year built" attribute for all single-family units in a neighborhood is, of course, an imperfect measure of neighborhood age. A neighborhood with half its housing built in the 1940s and half built 2000 could have the same median year built attribute as one with all its houses built in the 1970s, though the former is certainly much older. Such limitations are important to remember in the interpretation of the results, but we found less variation in the year built attribute within neighborhoods than across neighborhoods; and we know of no better way to estimate a neighborhood's relative age with the available data.
12. We do not argue that census blocks are the best aerial unit for measuring urban form. We only claim that it is a convenient unit that illustrates the effects we seek to capture.
13. All urban form measures in this project are calculated by employing 2001 RLIS data rather than data over time. Therefore, a more accurate statement would be that we are measuring associations between urban form measures and the median age of single-family dwellings in neighborhoods. However, we use the term *trend in urban form* in this section to keep the interpretation concise. Based on our methods, to state that "trends in urban form measures changed" is a valid inference.
14. We use age as the only independent variable because in most cases we have no theoretical basis for including other variables and because we are primarily interested in changes over time.
15. Other plots of data are available from the authors.
16. We thank an anonymous referee for this explanation of why the external connectivity has been decreasing.

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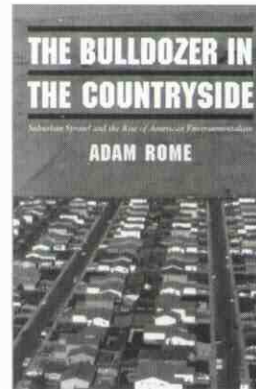
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