Measuring Patterns of Urban Development: New Intelligence for the War on Sprawl

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Abstract

Despite the release of several new sprawl indexes, the measurement of sprawl remains an illusive task. Many measures of urban sprawl, for example, fail to capture differences in development patterns within metropolitan areas and in changes over time. These measures, therefore, cannot help us determine if we are making progress in the battle against sprawl or where such progress is perhaps being made. To provide such information, we compute a variety of measures of urban form (or sprawl) for neighborhoods of varying age in five study areas: Maricopa County, Arizona; Orange County, Florida; Minneapolis-St. Paul, Minnesota; Montgomery County, Maryland; and Portland, Oregon. We then use those measures to illustrate how urban development patterns differ within and across study areas and over time. Our analysis suggests that some characteristics of development patterns differ significantly within and across study areas and over time; this raises doubt about the utility of sprawl indexes for entire metropolitan areas. For advocates of "smart growth", the good news is that single family lot sizes are falling and neighborhoods are becoming more internally accessible. For the same advocates, the bad news, however, is more extensive: houses are becoming larger, neighborhoods are becoming more isolated, land uses remain separated, and pedestrian accessibility to commercial uses is falling. If these trends continue, it is likely that housing will remain unaffordable and traffic congestion will only get worse.

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Introduction

The 2000 census data provided considerable new evidence on the problem of urban sprawl. With these data researchers have shown that urban areas continue to grow faster than their populations, causing urban densities to fall. As a simple measure of urban sprawl, these trends suggest that sprawl is getting worse. Other researchers have developed more complex measures of urban sprawl. These measures capture, for example, differences in jobs-housing balance, street network patterns, development concentration, and much more. These measures provide more detailed information about development patterns, but are generally only available at the county or metropolitan level.

Despite improvements in measurement techniques, the measurement of sprawl remains underdeveloped. Metropolitan- and county-wide measures of sprawl, for example, are strongly shaped by the date at which the county or metropolitan area was developed. Older cities, for example, tend to be denser, have greater mixes of uses, grid street networks, and more rapidly falling densities. Metropolitan- and county-wide measures of sprawl also fail to capture intra-metropolitan differences in development patterns at the neighborhood level. This is a serious limitation, since the urban design qualities that matter most—and those most easily shaped by public policy—are design qualities of neighborhoods.

To improve the debate on urban sprawl, we offer here a neighborhood-level analysis of urban sprawl including measures of development density, land use mix, street network patterns, residential proximity to commercial uses, and pedestrian access to commercial uses. We compute these measures for neighborhoods of varying age in five study areas: Maricopa County, Arizona; Orange County, Florida; Minneapolis-St. Paul, Minnesota; Montgomery County, Maryland; and Portland, Oregon. We then use those measures to illustrate how urban development patterns differ within and across study areas and how development patterns have changed over time. We argue that our neighborhood-level measures provide not only richer information on the design character of U.S. cities and offer new, interesting insights into how character has changed over time, but suggest areas in which land use and transportation policies might be most needed and influential.

Quantitative Research on Patterns of Urban Form

Urban sprawl is a pejorative term that connotes the undesirable features of contemporary urban development patterns. Such features include, for example, low density and separated land uses, automobile orientation, and unsightliness. Many of these features, however, are difficult to measure or define. For the purposes of this paper, therefore, we use the term urban form, and define urban form to include a number of quantifiable spatial characteristics, such as density, land use mix, and street network connectivity.

Attempts to quantify patterns of urban form are not new. Early attempts focused on the growth of suburbs relative to central cities (Chinitz, 1965). These studies showed that suburbs have grown—and continue to grow—more rapidly than the central cities they surround. Another longstanding approach focuses on density. These studies demonstrate that urban population densities have fallen over time, and that the trend is both global and centuries old (Mills, 1980). Several recent studies in this tradition compared growth in urban populations with growth in urbanized land areas (Sierra Club, 1998; Fulton et al., 2002) in attempts to identify "who sprawls the most."

More complex measures of urban form were developed by Galster et al. (2001). They identify eight dimensions of urban form: density, continuity, concentration, clustering, centrality, nuclearity, and proximity. Each dimension reflects spatial relationships among subsectors of the city, where subsectors are defined by one- or one-half mile grids. Then, using GIS, they compute all eight measures for 13 study areas. Finally, they normalize all the measures and, based on equal weights for each normalized measure, compute overall sprawl rankings. While the measures by Galster et al provide new and interesting information about urban form, they provide little information that can be used for public policy. Should government officials in Houston, for example, be pleased or concerned that Houston ranks highest in clustering and lowest in nuclearity?

More policy relevant indices of urban form were developed by Ewing et al (2002) for 448 US counties in the largest 101 metropolitan areas. Specifically, Ewing et al created a sprawl index that combines six sets of variables that measure residential density, land use mix, development concentration, and street network patterns to compute an overall measure of sprawl. Like the index by Fulton et al., the Sierra Club, and Galster et al., the index by Ewing et al. provides information which can be used to compare the urban form of one geographic region to another--that is, an index of which region sprawls the most. Unlike earlier indices, however, the index by Ewing et al is policy relevant. Not only can it be used to explore the influence of urban form on human behavior, human health, and environmental quality—which the authors do—but it also provides information on parameters over which policy makers have influence. That is, policy makers can use the index to inform zoning and subdivision regulations that control density, street network connectivity, and the location of schools and businesses. Like previous measures, however, the index by Ewing et al is geographically coarse. That is, since the index is computed at the county and metropolitan level, it is unable to provide information on how urban form varies within counties and metropolitan areas and how urban form varies over time.

Geographically detailed and policy relevant measures of urban form have been developed by Eliot Allen and his colleagues at Criterion.[i] Allen's measures, part of a planning support system called Smart Growth Index®, include over 70 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 Smart Growth 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 highly 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 to parks, shops and transit is of direct concern to citizens and policymakers. This is why the Smart Growth Index serves well to evaluate alternative development proposals and land use plans.

The Smart Growth index was designed for evaluating specific development proposals. The decision whether to approve a specific development, for example, could be based in part on some combination of its measures of urban form. The index (or some variant thereof), however, has never been used to compare measures of urban form within or across study areas, or to evaluate changes in urban form over time. We attempt to do so here.

Data Availability

To measure sub-metropolitan patterns of development and to evaluate changes in these measures over time we sought to examine a number of metropolitan areas in different parts of the country and with differing, histories, sizes, densities, and growth rates. But for our purposes, we had to have high-quality GIS data for every jurisdiction within the metropolitan area. This limited our choices considerably.

Through a survey of Metropolitan Planning Organizations and Regional Planning Agencies we quickly discovered that very few metropolitan areas had high-quality GIS data available for entire metropolitan areas. In this survey, we contacted the Metropolitan Planning Organization, Council of Government, or other regional agency in the 50 largest metropolitan areas in the country. We then asked, for particular sets of data themes, whether the regional government had GIS data for "all of the counties, parishes, or boroughs in the region;" for "some of the counties, parishes, or boroughs in the region;" or for "none of the counties, parishes, or boroughs in the region." Then for those data layers that were available for at least some of the local governments in the region, we asked whether the data were assembled into a coherent, metropolitan wide data set. We received responses from 49 of the 50 largest metropolitan areas. The results of our survey that addressed Land Use, Regulations, Boundaries, and Transportation, are presented in Table 1.[ii]

As shown in Table 1, very few regional agencies have Land Use and Regulation data for the entire metropolitan area. Just over one half of the respondents have data on existing land use for the entire region; 18 have the data for some jurisdictions and 3 do not have data for any of the local jurisdictions in the region. Only about a third of the respondents have data on vacant and developed land. Even fewer have data on regulations for the entire region. Only 9 respondents have region-wide zoning data and only about a third have data on comprehensive plans and growth boundaries. Most have integrated data on municipal boundaries for the entire region, but only 9 have data on parcel boundaries for the entire region. Most also have transportation data for the entire region, though only about half have the data integrated for the entire region. The relatively greater availability of transportation data (than land use data) probably reflects the support provided by the census bureau and the U.S. Department of Transportation for regional transportation planning.

Site Selection

After further data exploration we were able to obtain data for five study areas: Maricopa County, Arizona; Orange County, Florida; Minneapolis-St. Paul, Minnesota; Montgomery County, Maryland; and Portland, Oregon. Figure 1 presents the locations and sizes of these study areas in the same geographic scale. The sites were clearly not randomly selected, but fortunately the sites still provide a range of locations, sizes, growth rates, and local regulatory environments.

Policy makers in each of these areas have taken unique approaches to the control of sprawl. Portland is perhaps best known for its urban growth boundary and its metropolitan-wide "2040" plan for controlling growth within that boundary. Orange County also has a growth boundary and like all places in Florida has an elaborate concurrency policy that limits development until adequate public facilities are in place. Minneapolis-St. Paul is best known for its tax-base sharing system and its metropolitan-wide urban service boundary. Besides an urban growth limit and an elaborate adequate public facilities ordinance, Montgomery County has a well-known program of transferable development rights. Metropolitan Phoenix is not known for its growth controls but faces limits to growth imposed by the availability of water. Because of our limited sample, we do not attempt to attribute trends in development patterns to the policies adopted in these study areas. But it is important to remember that our sample includes four study areas with some of the most advanced urban growth management systems in the United States.

It is also important to note that our analysis of development patterns in Portland, Minneapolis-St. Paul, and Phoenix include the entire metropolitan area, while our analysis in Montgomery and Orange Counties contain only part of the larger Washington DC and Orlando metropolitan areas, respectively. This is especially noteworthy for Montgomery County since the study area does not contain the central city.

Quantitative Measures of Urban Form

To begin our evaluation of development patterns in five study areas, we compute several measures of urban form. We measure each at the neighborhood level, where neighborhood is defined by Traffic Analysis Zones (TAZs). [iii] TAZs are geographic units designed for use in transportation planning and are roughly coincident with census block groups.

For each TAZ in each study site we then computed several measures of urban form using GIS routines. Our measures fall into three categories: Street Network Design; Land Use Intensity; and Land Use Pattern. A definition of each measure and how they were computed is provided below.[iv] Figure 2, which contains maps of typical[v] TAZs in each of the study sites help illustrate what these measures are intended to capture. For each TAZ we estimated the date the area was built by computing the median value of the "year built" attribute of every single-family house.[vi] This enables us to illustrate how our measures of urban form changed over time.

Street Network Design. Among critics of sprawl, contemporary suburban developments contain too many long winding streets and cul-de-sacs and thus lack connectivity. According to this point of view, better connectivity leads to more walking and biking, fewer vehicle miles traveled, higher air quality, and greater sense of community among residents (Benfield et al., 1999). Our measures of connectivity involve the number of nodes and intersections and the distance between points of access into and out of the neighborhood. Internal connectivity measures transportation route options within a neighborhood; external connectivity measures route options between neighborhoods.[vii]

- *Int_Connectivity* – number of intersections divided by the sum of cul-de-sacs (or dead ends) plus intersections; the higher the ratio, the greater the internal connectivity. In Figure 2, internal connectivity is illustrated by the ratio of red dots (intersections) to the sum of red dots plus blue dots (cul-de-sacs).

- *Ext_Connectivity* – median distance between Ingress/Egress (access) points in feet; the greater the distance, the poorer the external connectivity. In Figure 2, external connectivity is illustrated by the length of the red line segment around the perimeter of the neighborhood; this line represents the median length of the distance between points of access into or out of the neighborhood.

Land Use Intensity. Among critics of sprawl, contemporary urban development is dominated by single family development on large lots. To such critics, low-density development increases automobile dependence, consumes farmland, and raises the cost of public infrastructure (American Planning Association 1998). We offer two measures of development intensity: single family lot size and single family floor space.

- *Lot_Size* – median lot size of single-family dwelling units in the neighborhood; the smaller the lot size, the higher the intensity. In Figure 2, the median lot size is illustrated by the size of the lot highlighted in dark blue.

- *Floor space* – median floor space of single-family dwelling units in the neighborhood; the larger the floor space, the higher the intensity. Median floor space is not illustrated in Figure 2.

Land Use Pattern. Among critics of sprawl, contemporary urban developments are homogeneous and lack a mix of land uses. To such critics greater mixing of uses facilitates walking and biking, lowers vehicle miles traveled, improves air quality, and enhances urban aesthetics (American Planning Association 1998). Similarly, in the absence of land use mixing, single family homes are often located at great distances from commercial establishments, which further discourages walking and increases dependence on the automobile. We offer one measure of land use mix and two measures of accessibility. Our measure of land use mix is based on the concept of entropy – a measure of variation, dispersion or diversity (Turner et al. 2001). Our measures of accessibility capture the distance of single-family homes from commercial uses and the percent of single-family homes that are within walking distance of a commercial use.

- *LU_Mix* – A diversity index $H_1 = \frac{-\sum_{i=1}^{s}(p_i)\ln(p_i)}{\ln(s)}$ where H_1 = diversity, p_i = proportions of each of the five land use types such as SFR, MFR, Industrial, Public and Commercial uses, and s = the number of land uses, in this case s equals to five. The higher the value, the more evenly distribution of land uses. In Figure 2, the mix of land uses is illustrated by the variety in the color of the parcels.

- *Comdis* – median distance to the nearest commercial use; the greater the distance, the lower the accessibility. This measure is not illustrated in Figure 2.

- *Ped_Com* – percentage of SFR units within one quarter mile of commercial uses; the greater the percentage, the greater the pedestrian accessibility. In Figure 2, single family parcels within one quarter mile of a commercial use are colored orange.

Characteristics of Recently Developed Neighborhoods in Five Study Areas

To analyze patterns of recent developments in each study area, we computed the median value and the coefficient of variation of each measure for all neighborhoods developed after 1995. The results are presented in Table 2.[viii]

As shown, some aspects of development patterns vary within and across study areas while others do not. As shown by the coefficients of variation, land use mix, and pedestrian accessibility vary most within metropolitan areas.[ix] The variation in these values is particularly high in Montgomery and Orange Counties. This implies that metropolitan areas have some areas that are characterized by a mixture of uses and commercial areas that are accessible by foot and some areas that are not—and that the intrametropolitan differences are statistically significant. In addition, internal and external connectivity, land use mix, distance to nearest commercial use, and pedestrian accessibility to commercial uses all vary significantly between study areas.[x] Lot size and single-family floor space do not differ significantly across study areas.

Internal connectivity, somewhat surprisingly, is best in Maricopa County and worst in Portland, though the difference is not large and the variation within the Portland metropolitan area is great. In the typical neighborhood developed in Portland after 1995, 35 percent of street nodes are cul-de-sacs (or dead ends), while in Orange County, only 22 percent are cul-de-sacs. External connectivity is greatest in Minneapolis-St Paul and worst in Montgomery County. On average, the distance between points of entry into and out of neighborhoods in Minneapolis-St. Paul is three times shorter than in Montgomery County. Land use mix varies significantly as well. Portland has the greatest overall land use mix and Montgomery County has the least. Commercial accessibility is greatest in Minneapolis-St. Paul and least in Orange County. On average, the distance from a single family residence to a commercial use in Minneapolis-St. Paul is four times shorter than in Orange County. Pedestrian accessibility to commercial uses, however, is greatest in Portland and least in Montgomery County. On average, 30 percent of single-family homes in Portland are within a quarter of a mile of a commercial establishment along the road network; in Montgomery County, only 11 percent of single family homes are that close.

Although our purpose is not to present another ranking of who sprawls the most, our results offer some new insights into the character of recent development patterns in each of the study areas. In general it appears as though recent developments in Portland and Minneapolis-St. Paul exhibit fewer characteristics of sprawl than developments in Montgomery County, Orange County, or Phoenix. Specifically, Portland ranks “best” in lot size, land use mix, and pedestrian accessibility and second in external connectivity. Minneapolis-St. Paul ranks best in external connectivity and distance to commercial use. The case of Portland is, of course, particularly interesting, given all the controversy over its urban growth boundary and other land use controls. These results suggest that development patterns in Portland over the last fifteen years indeed exhibit fewer characteristics of sprawl than other metropolitan areas.

Changes in Neighborhood Development Patterns over Time

To analyze changes in development patterns in each study area, we computed the median value of each measure for neighborhoods in each decade since 1940. The results are presented in Figures 3 to 10 below.

Figure 3 illustrates changes in the pattern of internal connectivity in each of the study areas over time. As shown, internal connectivity not only varies between study areas but displays a consistent temporal pattern across all of the study areas. That is, internal connectivity fell from the 1940s to the 1970s and has risen in all of the study areas since about 1970.

External connectivity displays a distinctly different spatial and temporal pattern, as shown in Figure 4. External connectivity is clearly worse (greater distances between entry points to the neighborhood) in Montgomery and Maricopa Counties throughout most of the post-war period. Further, since the 1970s external connectivity appears to be improving in Portland and Montgomery County, getting worse in Orange and Maricopa Counties, and holding steady at relatively high level in Minneapolis-St Paul.

In every study area, except perhaps Maricopa County, lot sizes rose through the early post-war period but fell after 1970, as shown in Figure 5. In Maricopa County, the trend in falling lot size has perhaps only recently begun. On the other hand, as shown in 6, single-family house sizes, which are measured by square feet of living space, are consistently rising in every study area and consistently largest in Montgomery County.

Land use mix in single family neighborhoods shows no clear pattern. As shown in Figure 7, land uses are less mixed in Montgomery and Maricopa Counties, but in no study area is there a clear temporal trend.

The pattern of accessibility to commercial uses also shows no clear trend across study sites. As shown in Figure 8, accessibility was poorest in Montgomery County in the early post-war period but is improving in recent decades. Improving trends are also evident in Portland and perhaps Minneapolis-St Paul. Worsening trends are evident in Maricopa and Orange Counties.

Finally, as shown in Figure 10, pedestrian accessibility to commercial uses fell rapidly in each of the study areas in the early post-war period, though signs of recent improvement are visible in Portland and Maricopa County.

The patterns and trends described above are illustrated in Figure 10, which visually illustrates patterns of development in the typical Portland neighborhoods for each decade since 1940. As shown, internal connectivity, illustrated by the ratio of red dots (cul-de-sacs) to total dots, was high in the 1940s, fell until the 1970s, and started rising again in 1980. External connectivity, illustrated by the length of the line segments around the edge of the neighborhood, exhibits a similar trend. Single family lot sizes rose from 1940 to 1970 then fell continuously to reach an all time low after the year 2000. As depicted by the mixture of the color of the lots, land use mix has continuously fallen over the same period. A combination of improved proximity to commercial uses and internal street network connectivity has brought increased pedestrian accessibility since 1990.

Implications

The results provide some interesting new information about trends in urban form across the nation. Though urban form varies a great deal between and within metropolitan areas, some general trends appear pervasive. The following trends are apparent in all of the study sites:

- Single family house sizes have grown continuously since 1940 but single family lot sizes began falling in about the 1970s.
- Since about 1970, neighborhoods have become more internally connected but external connectivity remains low in three of the four metropolitan areas.
- Land use mix within neighborhoods exhibits no obvious trends but pedestrian access to commercial uses has consistently fallen over time.

Bigger houses, smaller lots: In every site, single family houses have gotten bigger while lot sizes have gotten smaller. The rise in the size of single-family homes is not a surprise and reflects an increasing demand for residential space as incomes rise. The fall in single-family lot size is perhaps more surprising—especially since overall urban densities continue to fall. Whether the pervasive fall in lot size is the result of market forces or public policy is impossible to determine. Substitution of capital for land is expected when land supplies diminish and land prices rise. Since urban growth is policy constrained, and land values have risen at all of the study sites, both market forces and urban growth policies could have caused lots sizes to fall. But according to the National Association of Homebuilders[xi], house sizes have grown and lot sizes have fallen throughout the nation. Since policy regimes are so different across the nation, this suggests that market forces may be a more probable cause.

These trends are not encouraging for advocates of affordable housing. The fall in lot sizes suggest that land prices are rising--and the rise in house size makes the problem worse. The rise in the size (and quality) of new houses may be one reason why some indexes of housing affordability have fallen. Of course, housing affordability measures are easy to adjust for changes in housing size. But adjusting for housing size in affordability measures solves only a measurement problem. It does not resolve the predicament of low-income residents who cannot find a house at a price and quantity they can afford. Because low-income households cannot afford new houses, they tend to buy houses that have "filtered" down from high-income households. The filtering process has never been perfect. And since low-income households tend to be larger than middle- or high-income households, they too might benefit from increases in the supply of larger houses. If, however, low income households can only buy or rent small houses, it appears that the supply of affordable houses made available through the filtering process is likely to fall.

More internal, less external connectivity: Over the post-war period, internal connectivity, the measure of street network connectedness within the neighborhood, followed a consistent trend in each of the study sites. From 1950 to about 1990 internal connectivity decreased; after 1990 internal connectivity increased. This tend is especially prominent in Montgomery County. Again it is difficult to ascertain the cause of this trend, though market forces seem an unlikely cause in this case. A more likely cause is the growing demand for neo-traditional neighborhoods and changing subdivision regulations. Indeed, in Portland, Metro (Portland's regional government) requires local subdivision regulations to meet regional connectivity standards. Should this improvement in mobility around the neighborhood have the effects claimed by the advocates of New Urbanism, the prospects are good for more leisure walking, fewer vehicle miles traveled, and greater sense of community.

The trends in external connectivity is less pervasive but more problematic. Not surprisingly, external connectivity is greatest in Minneapolis-St Paul which has a less complex landscape, and least in Montgomery County, which has developed along planned wedges and corridors. But greenspace is not the sole determinant of external connectivity. Neighborhoods have long sought isolation; gated communities are only the most extreme case. Even New Urbanist neighborhoods, while highly internally connective, have limited external connectivity.[xii] From a social perspective, this creates an impediment to interaction between neighborhoods and increases social isolation. From a transportation perspective, this means less accessibility between neighborhoods. The implications for traffic congestion are surely adverse. Less external connectivity forces drivers into fewer trans-neighborhood arterials, increases congestion, and increases driving times. Only Portland and Montgomery County appear to be making progress in this area.

Constant mix, less pedestrian access: The results reveal no clear pattern of change in land use mix. This could be for several reasons. First, our measure of land use mix captures mix only at the parcel scale—e.g., the interspersing of commercial establishments among residential lots. It does not capture land use mixing that occurs within a parcel, as is common for example, in a planned unit development. It also does not capture mixtures of use within buildings (e.g., commercial uses on the street level and residential uses above), which is more in keeping with smart growth principles. Second, many subdivision ordinances and zoning codes remain outdated--and still prohibit land use mixing without a variance. Third, economies of scale in most form of retailing have increased. Big-box retail outlets are only the most obvious manifestation. Finally, many homeowners retain a preference for exclusively single-family neighborhoods. A recent study by Song and Knaap (2003) revealed that housing prices decreased as land use mix in the neighborhood increased.

Caveats and Qualifications

It is important to recognize that our measures and analyses have significant limitations. First, our sample size is limited to five geographic regions—three metropolitan areas and two counties within metropolitan areas. From these it is impossible to generalize to all metropolitan areas. It is also hazardous to compare Montgomery and Orange Counties with entire metropolitan areas. This is especially true for Montgomery County which does not contain the high-density, grid patterned urban core of Washington, D.C. Second, our measures of land use mix are based on parcel-level data, thus we do not capture mixtures of land uses within parcels nor mixture of uses within buildings—the type of mixing smart growth and New Urbanist advocates prefer. Finally, our measures of proximity and pedestrian accessibility to commercial uses apply only to single family homes. Thus we do capture similar measures of accessibility for multifamily residents.

Summary and Conclusions

Urban sprawl remains a hotly debated subject. Concern about sprawl alters land use decisions and shapes urban policy. But the definition of sprawl, its causes, and consequences remain elusive. In attempts to clarify these issues a number of scholars have made significant strides toward defining and measuring urban form. In this paper, we attempt another step in that direction.

Our analysis suggests that urban development patterns can be measured and that such measures can be used to describe differences in development patterns within study areas, between study areas, and within study areas over time. Specifically, our measures capture differences in street network patterns, development intensity, land use mix, proximity to commercial uses, and pedestrian access to commercial uses. Our analysis of these measures suggests that some characteristics of development patterns differ significantly within and across study areas and over time.

It is tempting to construct another aggregate sprawl index to rate the five communities on the degree to which they sprawl. But that is not our intent. Instead our intentions are these: (1) to demonstrate that patterns of urban form—or urban sprawl—are a complex, multidimentional problem. This suggests that simple assessments of who "sprawls the most" based purely on changes in urban density miss important features of urban form. (2) To show that, at least for our limited sample of five study areas, measures of urban form vary extensively within and across study areas. This suggests that all metropolitan areas have sub-areas that exhibit varying degrees of what might be called sprawl. What's more, such variation is not likely to disappear and may in fact be desirable. (3) To demonstrate that some measures of urban form vary consistently in all study areas over time. This suggests that measures of urban sprawl for entire study areas are largely determined by the era in which much of the study area was built. That is, Minneapolis-St Paul is a more densely developed metropolitan area than Phoenix largely because much of Minneapolis-St. Paul was built long before much of Phoenix. The density of recent developments and the size of houses in recent development, however, in every study area has risen at about the same rate and to about the same level—despite widely differing planning and regulatory contexts. This suggests that the density and size of new housing units may be more strongly affected by national market trends than local land use policies.

Policy implications

Our results are based on analyses of just five study areas and are based on measures that are new and somewhat difficult to interpret. Still, we believe our measures are sound, and the trends we found in our study areas are probably not unusual. Thus we believe our results have national policy implications.

For a variety of reasons, the rise we found in internal connectivity has favorable ramifications. Whether this rise in internal connectivity reflects more progressive subdivision regulations, growing preferences for New Urbanist designs, or simply the changing customs of subdivision developers is unknown. But there is some evidence to suggest that better internally connected neighborhoods foster a greater sense of community, more walking and biking, and more equitable exposure to traffic—at least within the neighborhood. The lack of progress on external connectivity, however, implies greater neighborhood balkanization and more regional transportation gridlock. **Clearly what is needed are better regional transportation plans, regional "official" maps that protect rights of ways, and better integrated local land use plans.** Once again, MPOs are perhaps the best suited to implement these actions.

The decline we found in single-family lot sizes and the growth we found in the size of single family houses are both good and bad. Overall, a decline in lot size represents a more efficient use of land resources. And for those with high incomes the combined trend simply reflects the substitution of interior for exterior living space. For those with low incomes, however, the combination of falling lot sizes—the likely result of rising land prices—and bigger homes diminishes the prospects for affordable housing. The problem of housing affordability, of course, is complex and multifaceted. Better land use planning is unlikely to resolve the problem. But to mitigate these particular trends, a number of options are possible**. First, local government could better manage the land supply. By monitoring land supply and demand local government could maintain a balance between preventing sprawl and providing sufficient land for housing development.**[xiii] **Second, local government could loosen restrictions on housing density, enabling developers to build multifamily homes instead of multistory mansions. Third, local governments could permit or encourage the conversion of large homes into multi-family units.** As is common in university towns, the conversion of large homes into multifamily units is an efficient way to make housing affordable to a larger set of households. In short, the answer is not more sprawl but relaxing restrictions on density and better management of the filtering process.

The trends regarding land use mix and pedestrian accessibility are also not encouraging from a smart growth perspective. According to smart growth advocates, the lack of progress towards mixed use, pedestrian friendly neighborhoods bodes ill for human health and physical activity. Once again, a reformation of zoning codes that currently prohibit land use mixing might help. But these are trends caused by forces that will be hard to counteract. Simply loosening regulatory constraints is unlikely to have significant impacts if market forces continue to favor land use separation. And they appear to do so. Economies of scale in retailing continue to erode the viability of neighborhood commercial establishments. Only those in high density environments are likely to survive in residential areas. Further, there remain strong popular preferences for homes in exclusively residential neighborhoods. Thus, public policies that encourage mixed use and pedestrian accessible commercial uses are only likely to succeed if they focus on specific, high-density, transit rich corridors. The Portland 2040 plan is a good example. In this plan high-density mixed uses are encouraged in city centers, town centers, and main street corridors. But there is no attempt to increase densities in established single-family neighborhoods or any attempt to introduce into these neighborhoods commercial uses that are not likely to survive**. In short, public policy should encourage mixed and commercial uses that are accessible by foot. But for such policies to succeed, those policies should focus on specific centers and corridors and not applied universally to every new development proposal.**

Finally, our focus on five study areas was not by choice. If there were good GIS data available for many metropolitan areas we would have analyzed many more. Unfortunately, the data are not available. Sadly, this lack of regional data is not the result of technological limitations or even resource constraints. In many places good data are available at the local level but the data have not been aggregated and are not maintained at the regional level. This not only limits our ability to understand and address issues of regional development, but surely limits the quality of regional transportation models and policies. **This problem could be easily resolved if metropolitan planning organizations (MPOs) served as a clearinghouse and distribution center for regional GIS data.** This is but a logical extension of their responsibility to prepare transportation plans based on the best available land use and transportation data.

Figure 1. Five study regions in the same geographic scale

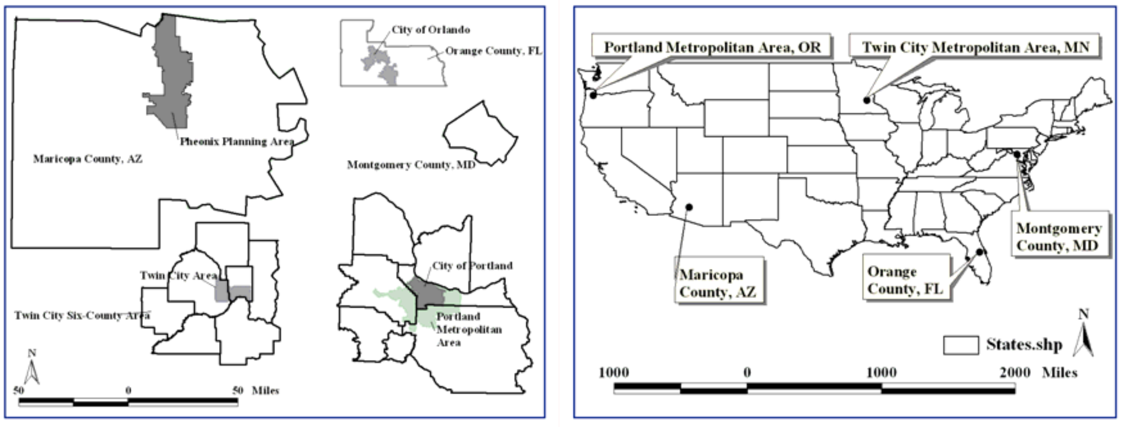


Table 1

Table 1: GIS Data Availability and Integration in the 50 Largest Metropolitan areas

DATA THEME								
LAND	**All**		**None**		**Some**		**Yes**	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Land Use-Existing	26	53	3	6	18	37	25	51
Developed Land	18	37	7	14	19	39	18	37
Vacant Land	16	33	8	16	19	39	16	33
REGULATION	**All**		**None**		**Some**		**Yes**	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Zoning	9	18	9	18	28	57	9	18
Local Comprehensive Plan Designations	13	27	13	27	19	39	12	25
Growth Boundaries / Service Areas	14	29	19	39	11	22	14	29
BOUNDARIES	All		None		Some		Yes	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Municipal	41	84	0	0	6	12	33	67
Parcel Boundaries	14	29	7	14	25	51	12	25
TRANSPORTATION	All		None		Some		Yes	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Street/Road Network	39	80	0	0	7	14	25	51
Transit Lines	39	80	2	4	5	10	22	45

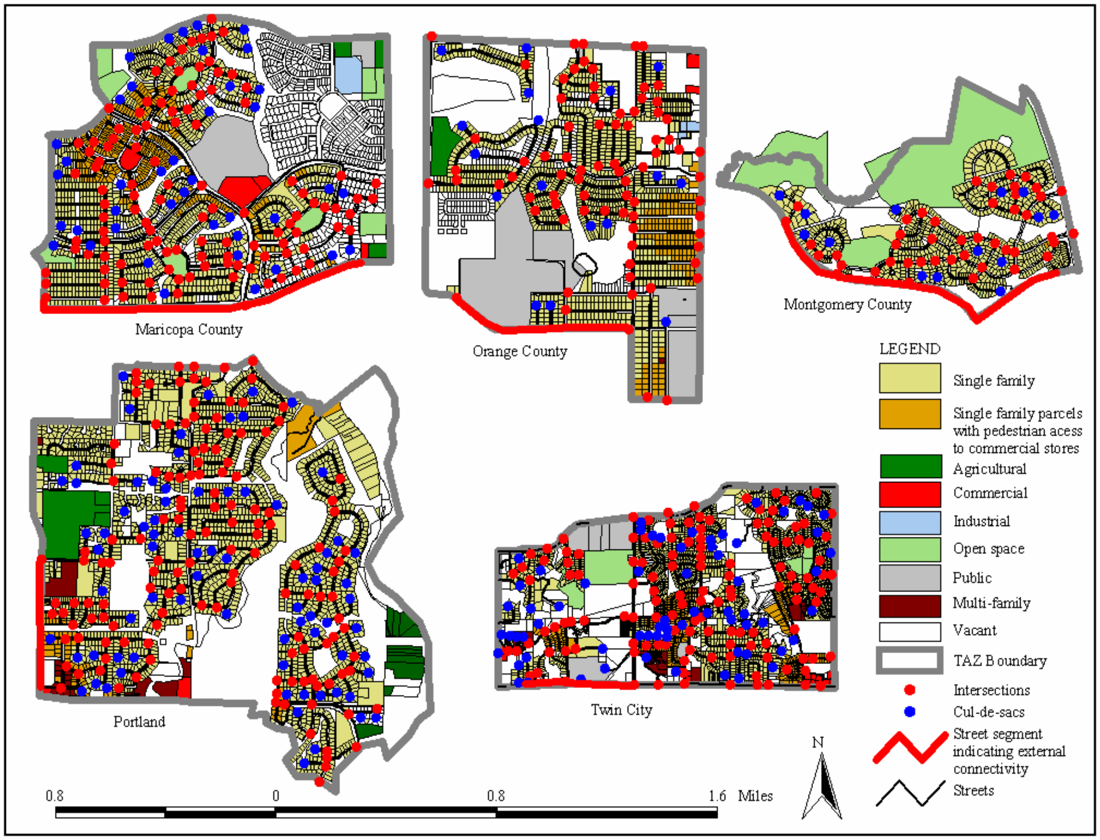
Table 2. Urban Form median values and Coefficients of Variation for neighborhoods built after 1995

	Montgomery County	Orange County	Maricopa County	Portland	Twin City	F-test
Int_Connectivity	0.76 (0.16)	0.78 (0.11)	0.79 (0.18)	0.65 (0.22)	0.77 (0.13)	18.3*
Ext_Connectivity	989 (0.36)	631 (0.43)	937 (0.42)	392 (0.46)	389 (0.43)	21.9*
Lot Size	8035 (0.32)	7695 (0.45)	8165 (0.45)	6838 (0.36)	missing data	not sig
Floor Space	2900 (0.26)	2107 (0.29)	2047 (0.33)	1883 (0.26)	missing data	not sig
Land use Mix	0.36 (1.81)	0.39 (1.46)	0.45 (1.13)	0.48 (0.98)	0.42 (1.45)	13.8*
Distance to Commercial	2545 (0.68)	3653 (0.31)	1676 (0.67)	1851 (0.46)	965 (0.72)	11.9*
Pedestrian Accessibility	0.11 (1.80)	0.28 (2.13)	0.19 (1.47)	0.30 (0.66)	0.22 (1.00)	13.3*

* stands for significance at 95% Confidence Interval; Coefficients of Variation are provided in parenthesis.

Internal Connectivity =	Percent of nodes that are not cul-de-sacs or dead ends.
External Connectivity =	Distance between access points to the neighborhood;
Lot Size =	Single family lot size in square feet;
Floor Space =	Square feet of floor space in single family houses;
Land Use Mix =	Entropy measure: 0 = single use; 1 = highly mixed use;
Distance to Commercial =	Median straight-line distance from single family homes in the neighborhood to nearest commercial use;
Pedestrian Accessibility =	Percent of homes in neighborhood within ¼ mile of commercial use along road network.

Figure 2. A "typical" neighborhood built after 1995 in each study area



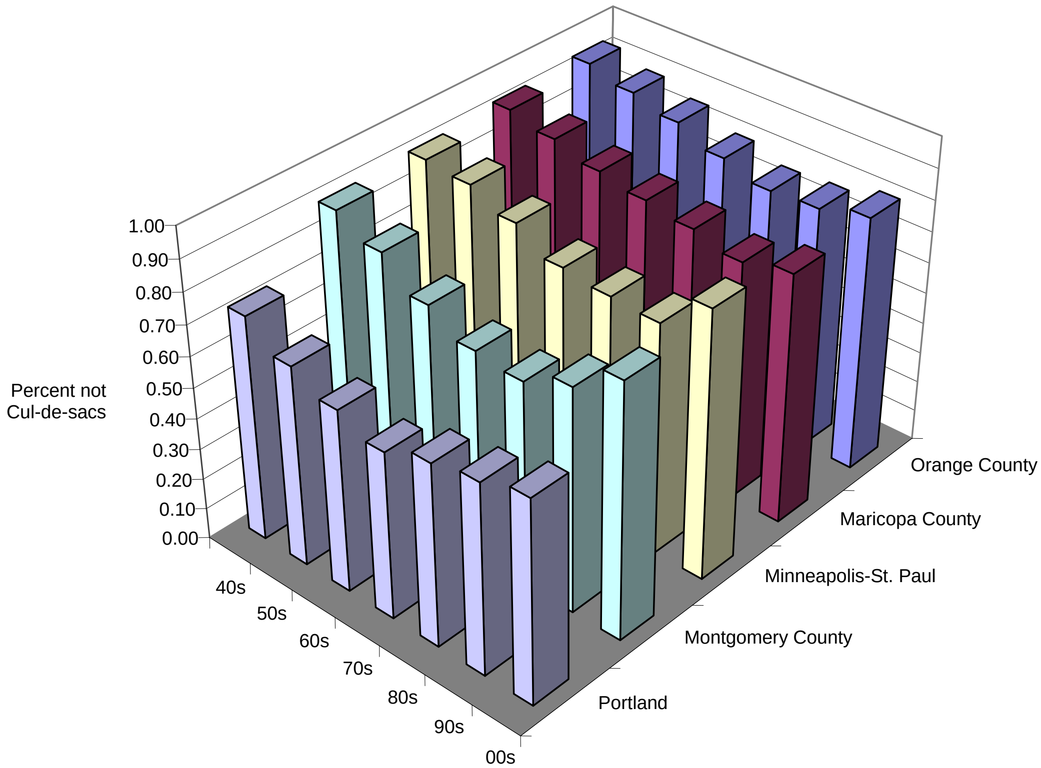


Figure 3. Internal Connectivity by Decade

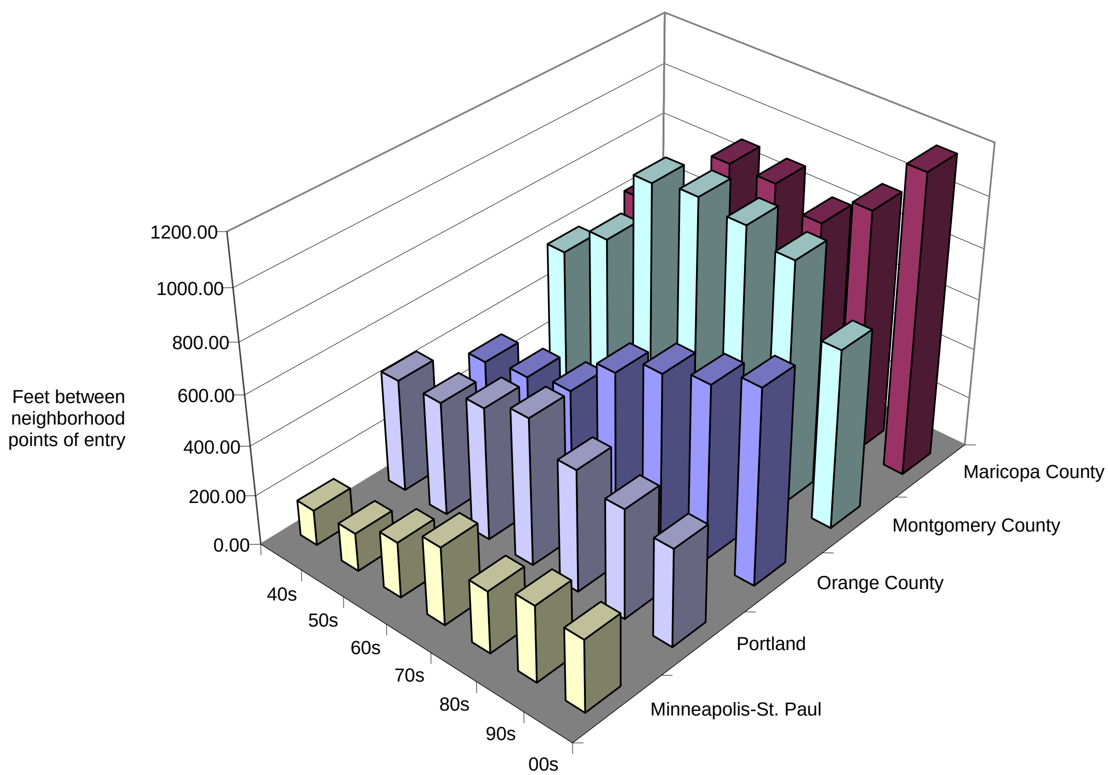


Figure 4. External Connectivity by decade

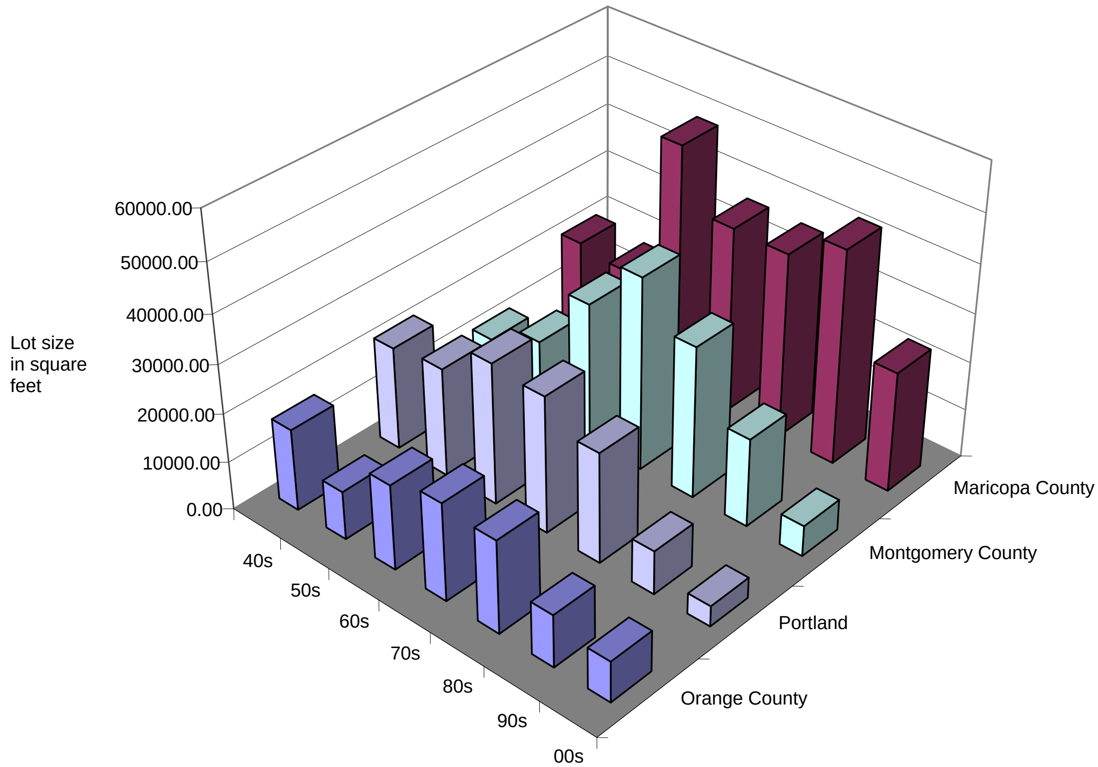


Figure 5. Single Family Lot Size by Decade

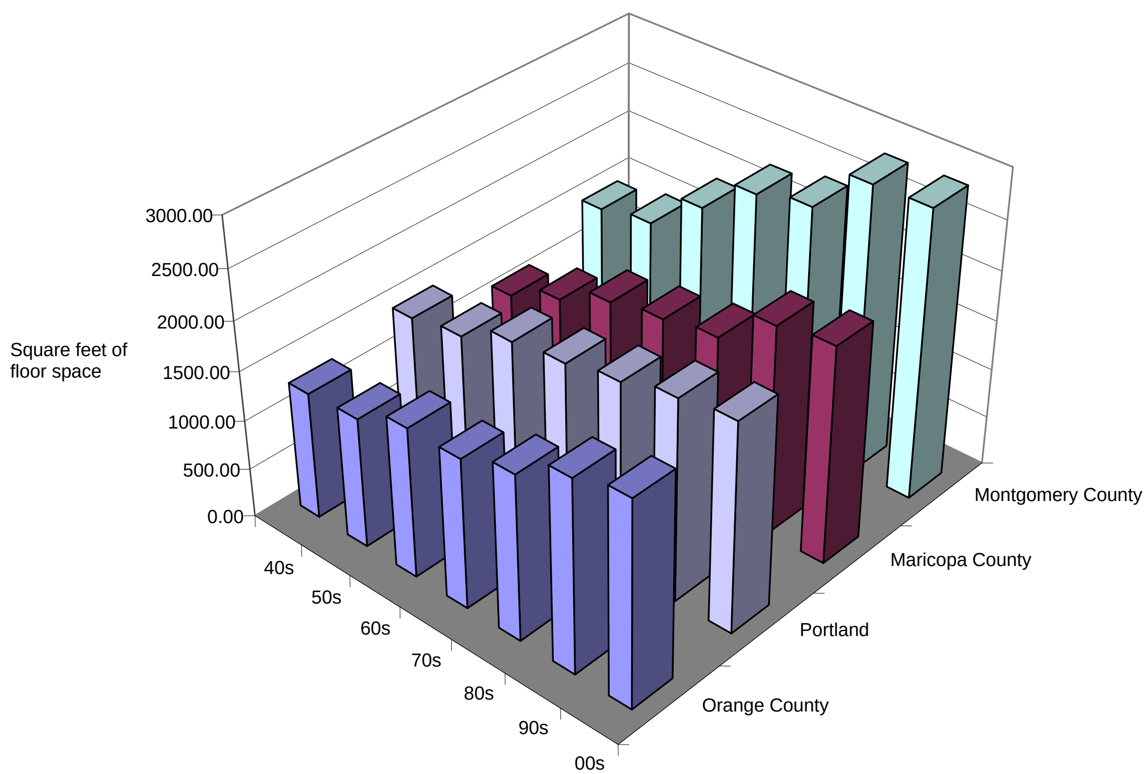


Figure 6. Single Family Floor Space by Decade

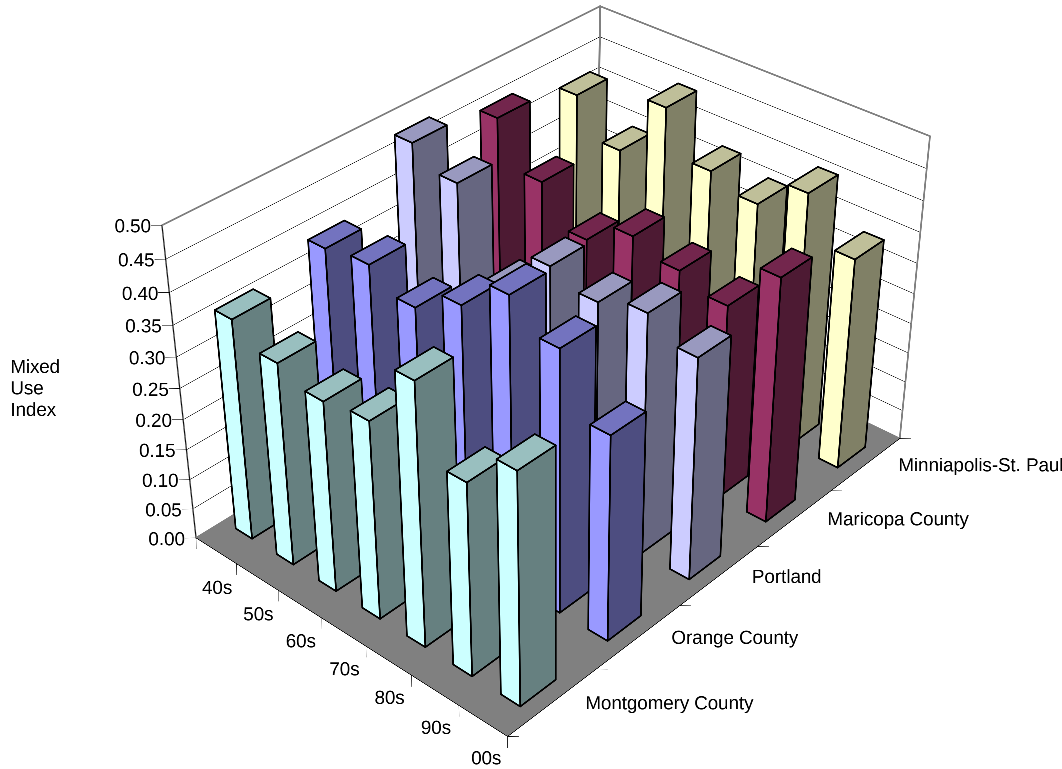


Figure 7. Land Use Mix by Decade

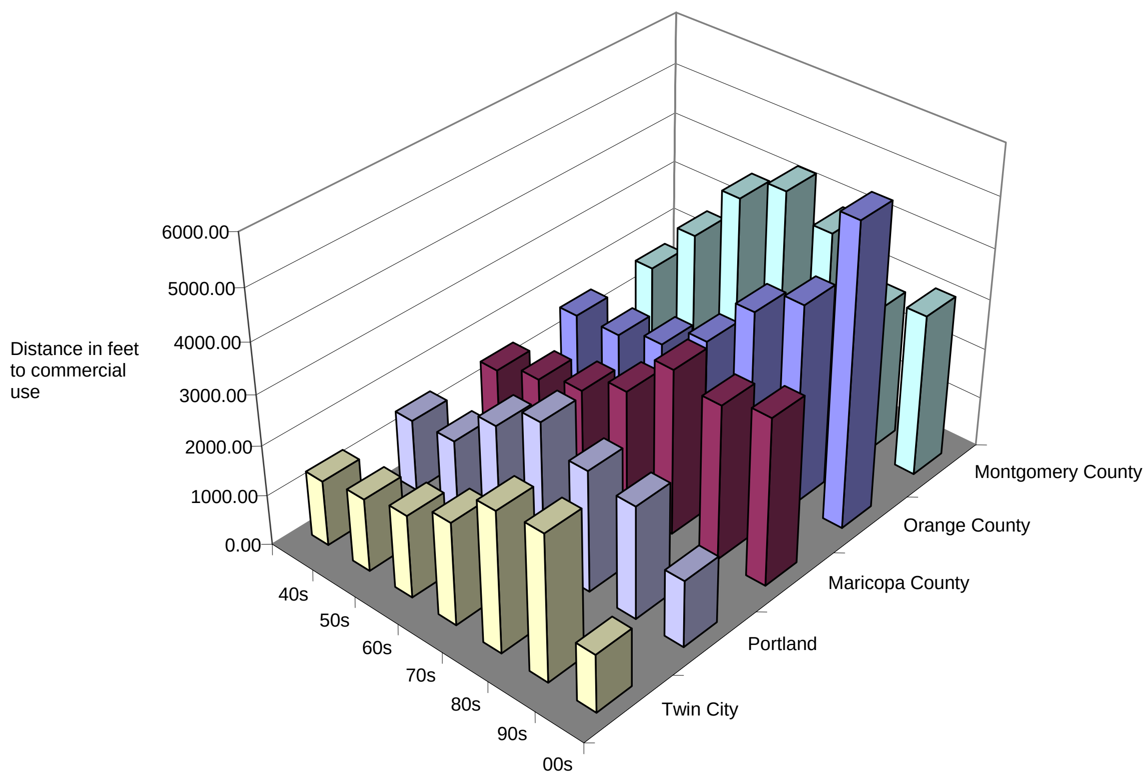


Figure 8. Proximity to Commercial Uses by Decade

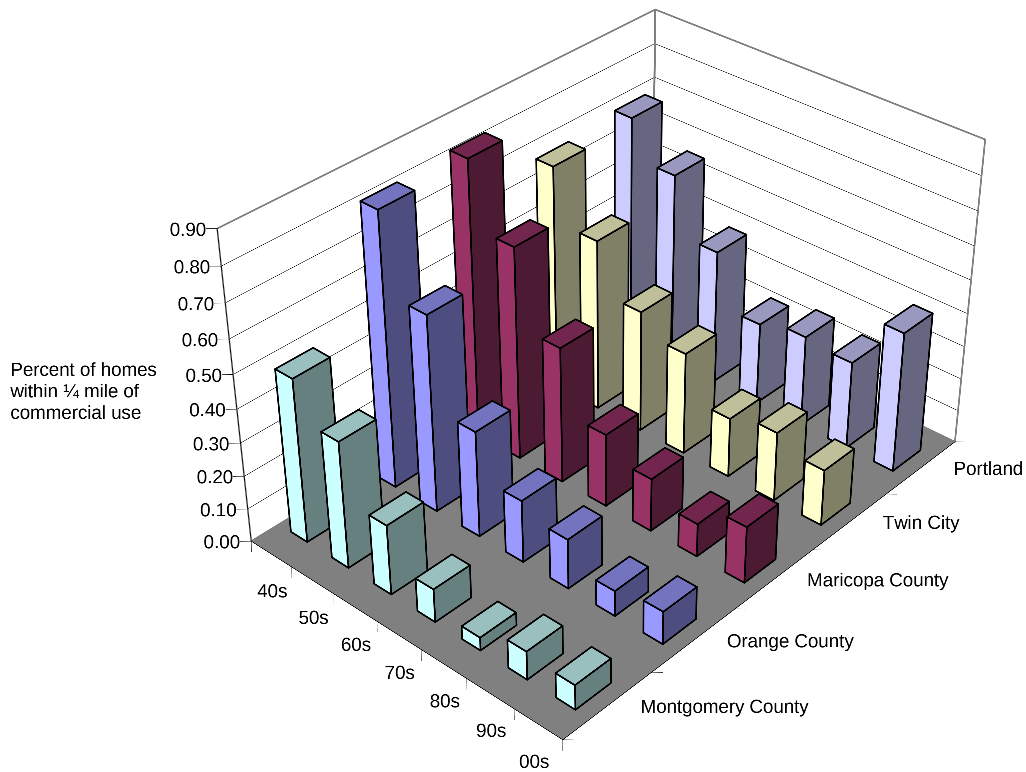


Figure 9. Pedestrian Accessibility to Commercial Uses by Decade

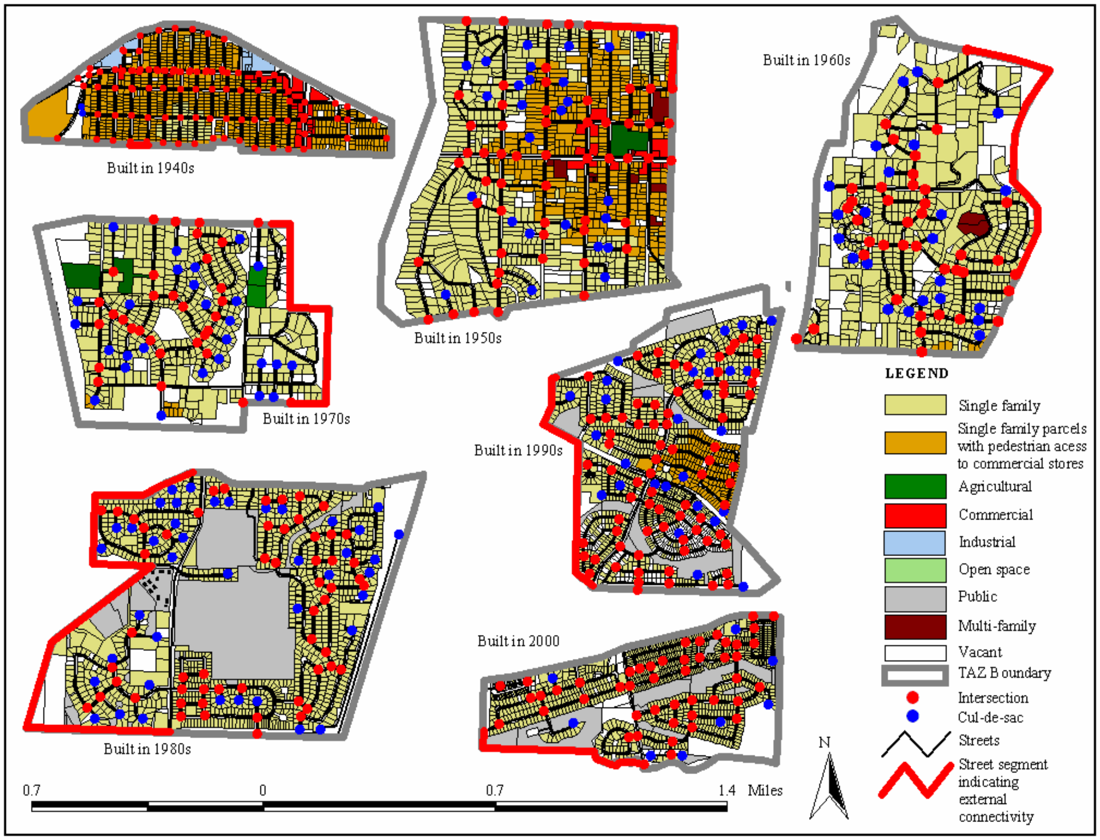


Figure 10. Typical neighborhoods by each decade in Portland metropolitan area

Endnotes

i Criterion Planners/Engineers Inc.; Portland, Oregon. More information are available online: http://www.crit.com/home_index.htm

ii For the complete survey results see, Knaap and Budic (2003).

iii In previous work we explored alternative definitions of neighborhood. Our analysis showed not that TAZs are necessarily the best geographic unit but that they were useful for demonstrating differences in development patterns that were not inconsistent with alternative geographic units.

iv All the calculations were computed using ArcInfo and/or ArcView.

v We define "typical" here as the TAZ that comes closest to the median value in all the measures of urban form.

vi Year build is an attribute of residential improvements often recorded by tax assessors. We measure the age of TAZs by the median value of the year built attribute of every single family improvement in the TAZ.

vii For more on connectivity, see Allen (2001) and Southworth (1997).

viii The last column of Table 1 also presents the results of F tests which are used to test the equality of means across study areas. In other words, the results of F tests indicate whether the measures of urban form vary significantly across study areas.

ix For these variables in most of the study areas, the standard deviation is greater than the mean value.

x These differences were statistically confirmed using F tests.

xi See: NAHB (2004).

xii See, e.g., Song and Knaap (2003).

xiii See, e.g., Knaap (2001).

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