The Spatial Structure of Cities in the United States[*]

Gerrit-Jan Knaap[**], Rebecca Lewis[***] and Jamie Schindewolf[****]

Abstract : In recent years, the spatial structure of cities has become the subject of considerable interest, as travel behavior, greenhouse gas emissions, loss of habitat, public expenditures, and more are thought to be influenced by urban spatial structure. In this paper we examine the spatial structure of 35 metropolitan areas in the United States. Based on the 2010 Census data, we focus on the distributions of populations in metropolitan areas in 2010 and on changes between 1990 and 2010. Specifically, we examine population levels and population density at the metropolitan, urbanized area, principal city, and census block group levels. We find that significant differences in recent growth patterns remain between the older and more densely developed cities of the Northeast and cities in the South and West. Most urban growth is now occurring in cities in the South and West causing them to experience increases in density in their principal cities, urbanized area, and nonurbanized areas. We also find, however, that much of the population growth in the largest metropolitan areas of the United States continues to occur at the urban fringe, causing overall densities to decline.

Key Words : spatial structure, population, population density, United States

---

** Gerrit-Jan Knaap is a Professor of Urban Studies and Planning and Director of the National Center for Smart Growth Research and Education at the University of Maryland. (E-mail: gknaap@umd.edu)
*** Rebecca Lewis is an Assistant Professor in Planning, Public Policy and Management at the University of Oregon and an affiliate at the National Center for Smart Growth Research and Education at the University of Maryland. (E-mail: rlewis9@uoregon.edu)
****Jamie Schindewolf is a Graduate Research Assistant in Urban and Regional Planning at Florida State University. (E-mail: jrs11e@my.fsu.edu)

1. Introduction

The structure of urban areas has long been a subject of analysis ever since the seminal work of von Thünen (1826), Chistaller (1933), and Lösch (1940) (Fischer, 2011). Ever since, it has been well understood that the size of urban areas is systematically related to the population of their hinterlands and that the density of urban populations fall with distance from the central city. In more recent years, the spatial structure of cities has become the subject of more than academic interest, as travel behavior, greenhouse gas emissions, loss of habitat, public expenditures, and more are thought to be influenced by urban spatial structure. To minimize automobile travel, greenhouse gas emissions, habitat loss, and public expenditures, for example, many advocate building compact cities, with nodes of mixed use concentrations of activities, and infill development within the urban core (Smart Growth Network, n.d.). Further, in recent years a debate has raged about whether urban growth is beginning to exhibit these more "desirable" development patterns. Following the release of the 2010 Census data, for example, some analysts have proclaimed the beginnings of an urban revival in all or parts of metropolitan America. Cities like Washington, DC and Philadelphia, PA, which lost population for many years, gained population between 2000 and 2010 (U.S. Census, 2011a). Other analysts, however, are skeptical, noting that the

principal cities of Chicago, IL, and Minneapolis, MN, lost population between 2000 and 2010 despite a resurgence in population between 1990 and 2000 (U.S. Census, 2011b).

In this paper we extend earlier work by Lewis and Knaap (2009) and Knaap, Lewis, Carruthers and Lewis (2008) to examine the spatial structure of 35 metropolitan areas in the United States. Based on the 2010 Census data, we focus on the distributions of populations in metropolitan areas in 2010 and on changes between 1990 and 2010. Our examination focuses solely on measures of population. Specifically, we examine population levels and population density at the metropolitan, urbanized area, principal city, and census block levels. Finally we examine the spatial distribution of populations within urban areas, exploring the extent to which population is concentrated in subareas. Our interests are twofold. First, we seek to extend the analysis of urban form in a way that focuses specifically at changes over the last two decades. Second, we seek to explore whether these trends are consistent with the proposition that U.S. cities are now experiencing, in some measure, more "desirable" spatial structure.

2. Previous Research

Careful examination of changes in the structure of metropolitan areas requires measurement of urban structure and an examination of changes in

those measures over time. Urban analysts have taken a variety of approaches toward such measurement (Clifton et. al., 2008). Ecologists tend to focus on aggregate population density, or compactness, noting that more compact growth results in less development on farmland and natural habitat. Economists tend to focus on population and employment density gradients. Gradients that show a more gradual decline in density are typically viewed as evidence of a weakening of the economic attraction to the central city. Transportation planners tend to view urban structure as a way of shaping distances between trip origins and destinations. Short distances between concentrations of activity facilitate carpooling, greater use of public transportation, biking and walking. All of these perspectives are valid, and the choice of measurement tends to reflect both the particular issue of concern and the data that are available for analysis.

In the analysis that follows, we use the recently released data from the census of population to re-examine urban structure and changes in structure over time. We are not the first to have done so. According to Nate Berg (2012), over 80 percent of the United States population resides in urban areas, and almost every urban area in the country expanded physically between 2000 and 2010. Only 50 of United States' approximately 3,500 urban areas declined in land area during this time. According to the Census Bureau, for example, only 24 of the 50 fastest growing metropolitan areas in 2000 were

also among the 50 fastest growing in the 2010 Census. Nearly all of the fastest-growing metro areas from 2010 to 2011 (46 of 50) were located either entirely or partially in the South or West. The South and West accounted for 84 percent of the U.S. population increase from 2000 to 2010. All 10 of the most populous metropolitan areas in 2010 grew over the last decade. Approximately one out of every 10 people in the United States lived in either Los Angeles or New York, the nation's two most populous metro areas and almost two-thirds of the nation's counties gained population between 2000 and 2010. (U.S. Census Bureau, 2012)

Nine of the 10 most populous cities in 2010 gained population over the last decade. Chicago, which grew between 1990 and 2000, was the only one of these cities to decline in population between 2000 and 2010. William Frey of the Brookings Institution notes that growth in sun and snow belts tapered in the 2000s, especially in cities with "bubble economies." According to Frey, suburbs grew faster than cities in the 2000s but both had growth rates lower than the 1990s. Exurban and outer suburban counties experienced both a population boom and bust in the 2000s (Frey, 2012).

Several researchers focus on the question of whether the new century marks the end of urban sprawl. In an article titled "The End of Sprawl?", Richard Florida notes that only two of the 39 counties with 1 million-plus people - Michigan's Wayne (Detroit) and Ohio's

Cuyahoga (Cleveland) - grew from 2006 to 2011. Of these, 28 grew faster than the nation, which as a whole grew at the slowest rate since the Great Depression (0.73 percent). Median growth rate for the 39 counties with 1 million-plus people was 1.3 percent and central metro counties accounted for 94 percent of U.S. growth, an increase from 85 percent before the recession. Eric Jaffe (2011) suggests that some places that experienced an overall decline, such as St. Louis, have downtown areas that showed some residential growth.

Wendell Cox (2012), on the other hand, strongly disputes the notion that the era of urban sprawl has ended. According to Cox, urban density in 2010 remained approximately 27 percent below that of 1950. Many core municipalities lost population while suburban and exurban populations expanded. Urban land area expanded along with this trend; Cox speculates that this may reflect a pervasive American preference for low-density housing. Further, notes Cox, major metropolitan areas added 14 percent to their populations in the 2000s, down from 19 percent growth in the 1990s. The historic core municipalities grew four percent after 2000, compared to the 1990s rate of seven percent. Suburban areas grew 18 percent, compared to the 1990s rate of 26 percent. Kotkin (2011) concurs with Cox. According to Kotkin, the 2010 Census shows that just 8.6 percent of the population growth in metropolitan areas with more than 1 million

people took place in the core cities while the rest took place in the suburbs. In the 1990s, the figure was 15.4 percent. Kotkin indicates that core city growth has declined over time. Regarding housing choices, single-family houses accounted for almost 80 percent of all the new households in the past decade, far exceeding the growth of multifamily or attached homes. In sum, the evidence that the structure of urban growth has changed in the most recent decade is mixed. While there is some evidence of renewed growth in central cities, there is also evidence of continued suburban expansion. In what follows we present a systematic evaluation of the distribution of population and population growth in the 35 largest metropolitan areas using simple measures of urban form.

We find that significant differences remain between the older and more densely developed cities of the Northeast and cities in the South and West and significant differences in their recent growth patterns. Most urban growth is now occurring in cities in the South and West causing them to experience increases in density in their principal cities, urbanized area, and nonurbanized areas. We also find, however, that much of the population growth in the largest metropolitan areas of the United States continues to occur at the urban fringe, causing overall densities to decline.

3. Data and Methods

To reexamine and explore in some depth the distribution of population and population growth in US metropolitan areas we use data from the 1990, 2000, and 2010 Censuses for the 35 largest metropolitan areas in the United States and compute several measures of urban structure. Our measures include density frequency distributions, and spatial distributions of growth. We used metropolitan area definitions from the U.S. Office of Management and Budget (OMB) released in 2002. Though census boundaries change, we use consistent metropolitan area boundaries for 1990, 2000 and 2010. Specifically

we use "Core Based Statistical Areas[1]" and ignore Metropolitan Divisions and micropolitan areas in our analysis. Within metropolitan areas, we used normalized census block groups in 2000 boundaries. These data were derived from Geolytics, Inc. products which allocate selected 1990, 2000 and 2010 variables to 2000 block groups. Geolytics allows us to use consistent geographies to measure changes in urban form over time (GeoLytics n.d.) .

Our measures include both measures of population distributions in 2010 and measures of changes in those distributions from 1990 to 2010. Specifically, we measure:

<Table 1> List of measurements.

Static Indicators
Metropolitan Area Population (2010)
Urbanized Area Population (2010)
Principal City Population (2010)
Metropolitan Area Density (2010)
Urbanized Area Density (2010)
Principal City Density (2010)
Total Number of Block Groups (2010)
Count of Block Groups at Bus Density (>5,000 ppsm) (2010)
Share of Block Groups at Bus Density (>5,000 ppsm) (2010)
Count of Block Groups at Light Rail Density (>15,000 ppsm) (2010)
Share of Block Groups at Light Rail Density (>15,000 ppsm) (2010)
Index
Rank

Dynamic Indicators
Change in Metropolitan Area Density (1990-2010)
Change in Principal Density (1990-2010)
Change in Urbanized Area Population (1990-2010)
Change in Density in Urbanized Area (1990-2010)
Change in Count of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)
Change in (Share) of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)
Change in Count of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)
Change in Share) of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)
Number of Block Groups Declining in Population (1990-2010)
Share of Block Groups Declining in Population (1990-2010)
Index
Rank

---

1) Core Based Statistical Areas are defined by the U.S. Office of Management and Budget and "consist of the county or counties or equivalent entities associated with at least one core (urbanized area or urban cluster) of at least 10,000 population, plus adjacent counties having a high degree of social and economic integration with the core as measured through community ties with the counties associated with the core." (See: http://www.census.gov/geo/www/2010census/gtc/gtc_cbsa.html)

<Table 2> Population in the U.S. and Study Area - 1990-2010

Table 2: Population in the U.S. and Study Area - 1990-2010			
	Population	1990-2000 % Change	Study Area: Population
1990 U.S. Population	248,709,873	13%	114,468,172 (46%)
Northeast	50,809,229	5%	
Midwest	59,668,632	8%	
South	85,445,930	17%	
West	52,786,082	20%	
		2000-2010 % Change	
2000 U.S. Population	281,421,906	10%	131,866,039 (47%)
Northeast	53,594,378	3%	
Midwest	64,392,776	4%	
South	100,236,820	14%	
West	63,197,932	14%	
		1990-2010 % Change	
2010 U.S. Population	308,745,538	24%	146,259,827 (47%)
Northeast	55,317,240	9%	
Midwest	66,927,001	12%	
South	114,555,744	34%	
West	71,945,553	36%	

In what follows, we present the measures listed above for each of the 35 metropolitan areas. To provide some context for these measures, we start by presenting national data on urban growth in the United States in 1990, 2000, and 2010. As shown in table 1, the population of the United States increased from 250 million in 1990 to nearly 310 million in 2010. Most of that growth occurred in the South and West, a trend that continued in the 2000's. The 35 metro areas used in this study contained 46 percent of the population in 1990 and 47 percent in 2010.

4. Population and Population Density

Population and population density are perhaps the simplest and most common measures of urban structure. By definition, urban areas are places with large populations and high relative populati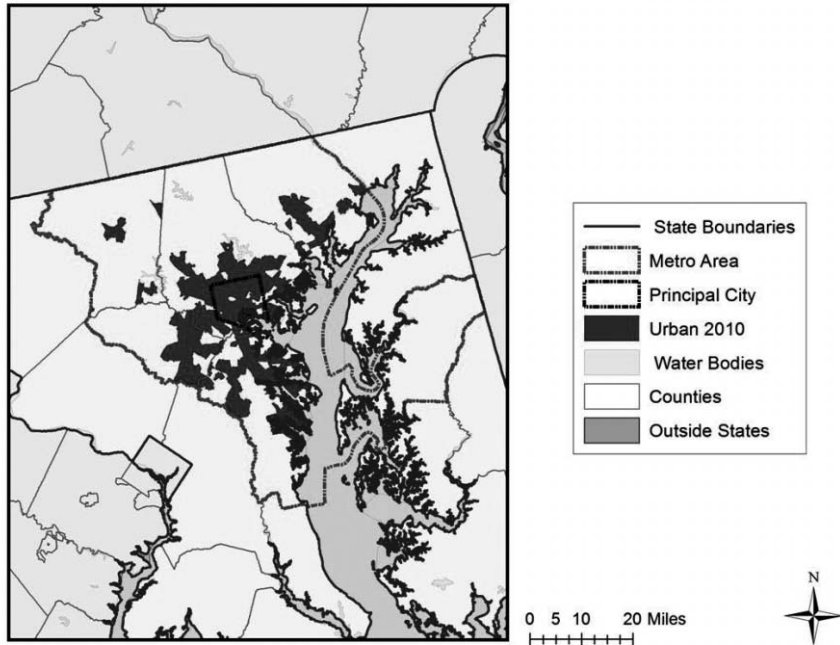on densities (McDonald, 1997). We measure population and population densities for three geographic areas: the metropolitan area, the urbanized area, and the principal city. Metropolitan areas are defined as the aggregate of counties that include an urban core with more than 50,000 residents and adjacent counties "that have a high degree of social and economic integration" with the urban core (U.S. Census, n.d.b). Metropolitan areas often include both urban and rural areas and, because some counties contain large, nonurbanized areas, measures of urban structure at the metropolitan scale often reflect how much of the metropolitan area is rural. In some metropolitan areas, for example, the nonurbanized, rural part of the metro area is relatively large, thus the overall density of the metropolitan area is relatively low.

Urbanized areas are defined as the aggregate of census tracts within a metropolitan area that meet urban density thresholds. An urban area is a place with (1) very high population densities

compared to the surrounding area, and (2) a population greater than some minimum number. (McDonald, 1997). Following the Census, we set the density threshold for urbanized areas at 1,000 persons per square mile. We do not, however, use the same contiguity rules as the Census. Instead we limit our definition of urbanized area to include any Census tract that meets the density threshold. As a result, our definition results in some non urban areas completely surrounded by urbanized areas and some urbanized census tracts that are not contiguous to any other urbanized area.

(Proposed Urban Area Criteria for the 2010 Census, 2010)　The principal city is the central and often the largest and oldest jurisdiction in the metropolitan area. The Census defines the principal city as the "largest incorporated place or Census Designated Place of at least 10,000 population." (U.S. Census, 2011c)　The geographic boundaries are political and not based on population density.[2]　In every metropolitan area, the central city is contained within the urbanized areas. See figure 1.

Measures of population and population density for the largest 35 metropolitan areas in the US

(Figure 1) Metropolitan Area, Principal City, and Urbanized Area Boundaries in Baltimore-Towson, MD (2010)

2) Due to data limitations, we use 2000 Census principal city area. Thus, we do not consider expansion of principal cities. See: http://www.census.gov/statab/ccdb/cit1010r.txt

from the 2010 Census are presented in tables 3 through 5. Tables 3 and 4 present population and density data for 2010 and table 5 shows changes in population from 1990 and 2010 for the entire

<Table 3> Population at Metropolitan, Principal City, and Urbanized Area Scale, sorted in rank order

Metropolitan Area	Metropolitan Area Population (2010)	Metropolitan Area	Urbanized Area Population (2010)	Metropolitan Area	Principal City Population (2010)
New York	18,897,109	New York	17,685,468	New York	8,175,133
Los Angeles	12,828,837	Los Angeles	12,466,385	Los Angeles	3,792,621
Chicago	9,461,105	Chicago	8,429,648	Chicago	2,695,598
Dallas	6,371,773	Miami	5,302,551	Houston	2,099,451
Philadelphia	5,965,343	Dallas	5,206,669	Philadelphia	1,526,006
Houston	5,946,800	Philadelphia	4,998,187	Phoenix	1,445,632
Washington, DC	5,582,170	Houston	4,889,916	San Antonio	1,327,407
Miami	5,564,635	Washington, DC	4,655,904	San Diego	1,307,402
Atlanta	5,268,860	San Francisco	4,009,381	Dallas	1,197,816
Boston	4,552,402	Atlanta	3,678,746	San Jose	945,942
San Francisco	4,335,391	Detroit	3,675,546	Indianapolis	820,445
Detroit	4,296,250	Boston	3,549,238	San Francisco	805,235
Riverside	4,224,851	Phoenix	3,493,944	Austin	790,390
Phoenix	4,192,887	Riverside	3,457,162	Columbus	787,033
Seattle	3,439,809	Seattle	2,979,517	Charlotte	731,424
Minneapolis	3,279,833	San Diego	2,807,885	Detroit	713,777
San Diego	3,095,313	Minneapolis	2,480,342	Baltimore	620,961
St. Louis	2,812,896	Tampa	2,341,671	Boston	617,594
Tampa	2,783,243	Denver	2,237,312	Seattle	608,660
Baltimore	2,710,489	Baltimore	2,196,557	Washington, DC	601,723
Denver	2,543,482	St. Louis	2,039,944	Denver	600,158
Pittsburgh	2,356,285	Portland	1,846,200	Portland	583,776
Portland	2,226,009	Sacramento	1,782,172	Las Vegas	583,756
Sacramento	2,149,127	Las Vegas	1,744,814	Sacramento	466,488
San Antonio	2,142,508	San Jose	1,730,545	Kansas City	459,787
Orlando	2,134,411	Cleveland	1,694,537	Atlanta	420,003
Cincinnati	2,130,151	San Antonio	1,629,165	Miami	399,457
Cleveland	2,077,240	Orlando	1,601,566	Cleveland	396,815
Kansas City	2,035,334	Cincinnati	1,552,352	Minneapolis	382,578
Las Vegas	1,951,269	Pittsburgh	1,529,077	Tampa	335,709
San Jose	1,836,911	Kansas City	1,482,348	St. Louis	319,294
Columbus	1,836,536	Columbus	1,338,093	Pittsburgh	305,704
Charlotte	1,758,038	Indianapolis	1,255,099	Riverside	303,871
Indianapolis	1,756,241	Austin	1,203,173	Cincinnati	296,943
Austin	1,716,289	Charlotte	1,156,323	Orlando	238,300

<Table 4> Population Density (in persons per square mile) at Metropolitan, Principal City, and Urbanized Area Scale, sorted in rank order

Metropolitan Area	Metropolitan Area Density (2010)	Metropolitan Area	Urbanized Area Density (2010)	Metropolitan Area	Principal City Density (2010)
New York	2,752	Los Angeles	7,418	New York	26,954
Los Angeles	2,625	New York	6,833	San Francisco	17,243
San Francisco	1,711	San Jose	6,415	Boston	12,760
Chicago	1,295	San Francisco	6,046	Chicago	11,870
Philadelphia	1,267	Las Vegas	4,717	Philadelphia	11,295
Boston	1,257	San Diego	4,678	Miami	11,189
Detroit	1,079	Miami	4,624	Washington, DC	9,800
Tampa	1,063	Chicago	4,200	Los Angeles	8,085
Cleveland	1,030	Denver	3,926	Baltimore	7,685
Baltimore	1,030	Washington, DC	3,915	Seattle	7,255
Miami	1,027	Sacramento	3,866	Minneapolis	6,969
Washington, DC	983	Portland	3,840	Tampa	5,633
San Diego	731	Baltimore	3,822	Pittsburgh	5,498
Dallas	686	Philadelphia	3,693	San Jose	5,408
San Jose	683	Boston	3,622	St. Louis	5,158
Houston	644	Seattle	3,551	Las Vegas	5,152
Atlanta	621	Phoenix	3,535	Detroit	5,142
Seattle	574	San Antonio	3,487	Cleveland	5,114
Charlotte	559	Riverside	3,387	Sacramento	4,799
Orlando	532	Houston	3,380	Portland	4,347
Minneapolis	515	Dallas	3,305	San Diego	4,031
Cincinnati	477	Detroit	3,258	Denver	3,912
Columbus	458	Cleveland	3,108	Riverside	3,891
Indianapolis	452	Columbus	3,105	Cincinnati	3,807
Pittsburgh	441	Minneapolis	2,904	Columbus	3,742
Sacramento	405	Austin	2,827	Houston	3,623
Austin	401	Tampa	2,819	Dallas	3,497
Portland	327	St. Louis	2,727	San Antonio	3,257
St. Louis	318	Pittsburgh	2,712	Atlanta	3,189
Denver	301	Kansas City	2,630	Austin	3,143
San Antonio	290	Orlando	2,576	Phoenix	3,044
Phoenix	287	Cincinnati	2,539	Charlotte	3,019
Kansas City	256	Indianapolis	2,492	Orlando	2,549
Las Vegas	241	Atlanta	2,189	Indianapolis	2,270
Riverside	154	Charlotte	2,095	Kansas City	1,467

<Table 5> Change in Population Density at Metropolitan, Principal City, and Urbanized Area Scale (1990-2010), sorted in rank order

Metropolitan Area	Change in Metropolitan Area Density (1990-2010)	Metropolitan Area	Change in Principal City Density (1990-2010)	Metropolitan Area	Change in Urbanized Area Population (1990-2010)
Las Vegas	163%	Las Vegas	126%	Las Vegas	159%
Austin	103%	Charlotte	85%	Austin	109%
Phoenix	87%	Austin	70%	Charlotte	103%
Orlando	74%	Phoenix	47%	Atlanta	87%
Atlanta	72%	Orlando	45%	Orlando	77%
Charlotte	72%	San Antonio	42%	Phoenix	77%
Riverside	63%	Riverside	34%	Riverside	70%
Dallas	60%	Portland	33%	Dallas	63%
Houston	58%	Houston	29%	Houston	62%
Denver	53%	Denver	28%	Portland	57%
San Antonio	52%	Sacramento	26%	Denver	51%
Portland	46%	Columbus	24%	Sacramento	46%
Sacramento	45%	San Jose	21%	San Antonio	46%
Miami	37%	Tampa	20%	Seattle	42%
Indianapolis	36%	Dallas	19%	Indianapolis	39%
Washington, DC	35%	Seattle	18%	Miami	39%
Tampa	35%	San Diego	18%	Tampa	37%
Seattle	34%	New York	12%	Washington, DC	36%
Columbus	31%	Miami	11%	Columbus	35%
Minneapolis	29%	San Francisco	11%	Minneapolis	27%
Kansas City	24%	Indianapolis	11%	San Diego	26%
San Diego	24%	Los Angeles	9%	Kansas City	22%
San Jose	20%	Boston	8%	San Jose	21%
San Francisco	18%	Atlanta	7%	Cincinnati	18%
Chicago	16%	Kansas City	6%	San Francisco	17%
Cincinnati	15%	Minneapolis	4%	Chicago	15%
Los Angeles	14%	Washington, DC	-1%	Baltimore	15%
Baltimore	14%	Chicago	-3%	Los Angeles	14%
New York	12%	Philadelphia	-4%	New York	13%
Boston	10%	Baltimore	-16%	Boston	10%
Philadelphia	10%	Pittsburgh	-17%	Philadelphia	9%
St. Louis	9%	Cincinnati	-18%	St. Louis	6%
Detroit	1%	St. Louis	-20%	Detroit	-1%
Cleveland	-1%	Cleveland	-22%	Cleveland	-3%
Pittsburgh	-5%	Detroit	-31%	Pittsburgh	-8%

metropolitan area, urbanized area, and principal city. The data for each geographic area are presented in descending order by population. As shown, the New York metropolitan area is the largest in the nation with a population of over 18 million people, followed by Los Angeles, Chicago and Dallas. In general, but with exception, cities with large metropolitan-area populations have large populations in their urbanized areas and central cities.

Most of the differences in rank between these areas reflect differences in the extent to which the metropolitan area contains rural as well as urbanized areas. For this reason, for example, Miami ranks ninth in metropolitan population but third in the population of its urbanized area. New York, Los Angeles, and Chicago remain the three largest principal cities and only nine central cities have more than one million people. Because the central cities of Houston and Phoenix include a large share of their urbanized population, they rank relatively high in principal city population.

Population and population density are highly correlated at every level of geography; the largest metropolitan areas, urbanized areas and principal cities tend to be the most dense metropolitan areas, urbanized areas, and principal cities.[3] The metropolitan area of New York is the most dense, followed by Los Angeles, San Francisco, and Chicago. Los Angeles has the most densely populated urbanized area, followed by New York, San Jose, San Francisco, and Las Vegas. New York, San Francisco, Boston, and Chicago have the most densely populated principal cities, in that order. The relative ranking of the size of metropolitan area, urbanized area, and principal city populations have changed very little over the last two decades.

5. Growth Distribution and Threshold Densities

To examine the distribution of population and growth in smaller geographic areas, we examine population and population growth by block groups. Densities in smaller geographic units are considered important because certain densities are viewed as thresholds for bus and rail transit service. According to Pushkarev and Zupan (1977), for example, a density of 15,000 persons per square mile is necessary to be viable for rail transit service and 5,000 persons per square mile is necessary for bus service to be viable. Cervero and Guerra (2011) utilize the same densities offered by Pusharev & Zupan to examine critical densities for transit investment. Farr (2008) illustrates that the work of Pushkarev & Zupan (1977) is still relevant today as he suggests using these coefficients to

---

3) At the metropolitan level, the correlation between population and density equals 0.83; at the urbanized area, the correlation equals 0.67; at the principal city level, the correlation equals 0.69.

encourage sustainable urbanism.

Tables 6 and 7 presents the number and share of block groups that meet the rail and bus density thresholds in 2010 and the percent difference in the share block groups that met these critical thresholds from 1990 to 2010, as well as the new block groups meeting the thresholds. As shown, over 80 percent of block groups in Los Angeles, San Jose, San Francisco, Miami, New York, Las Vegas, and San Diego met the critical threshold for bus service in 2010. In Charlotte, less than 25 percent of block groups met this threshold. For light rail, nearly half of the block groups in New York met the transit density threshold in 2010. In San Francisco, Los Angeles, and Philadelphia more than 30 percent met this threshold. In Boston, Chicago, Baltimore, San Diego, San Jose and Washington more than 20 percent of block groups met this threshold. In all other metro areas, less than 10 percent of block groups met this threshold in 2010.

In Las Vegas, Phoenix, Portland, Denver and Austin, an additional 10 percent of block groups met the bus threshold between 1990-2010. In several cities, including Pittsburgh, Detroit, St. Louis, Cleveland, Indianapolis, Kansas City, and Cincinnati, the number and share of block groups meeting the critical threshold for bus service declined between 1990-2010. San Jose, Los Angeles and San Francisco showed the highest increases in the percentage of block groups at light rail density, while the number of

block groups at light rail density declined in 15 metropolitan areas between 1990-2010.

Another critical dynamic threshold is zero. When block groups lose population it leaves housing units vacant and creates the potential for urban blight. As shown in table 8, for the period from 1990 to 2010, Las Vegas had the smallest share of block groups that lost population, followed by Riverside, Portland and Austin. Cleveland, Detroit, St. Louis and Cincinnati had the highest share of the block groups that lost population.

<Table 6> Share and Count of Block Groups at Bus Density in 2010; Change in Share and Count of Block Groups at Bus Density (1990-2010), sorted in rank order

Metropolitan Area	Share (Count) of Block Groups at Bus Density (>5,000 ppsm) (2010)	Metropolitan Area	Change in Share (Count) of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)
Los Angeles	90% (7,379)	Las Vegas	34% (287)
San Jose	88% (915)	Phoenix	13% (289)
San Francisco	85% (2,304)	Portland	11% (137)
Miami	82% (2,070)	Denver	11% (180)
New York	82% (11,431)	Austin	10% (74)
Las Vegas	80% (668)	Riverside	9% (176)
San Diego	80% (1,414)	Seattle	9% (227)
Chicago	76% (5,002)	Miami	8%(202)
Denver	74% (1,240)	Washington, DC	8%(229)
Phoenix	72% (1,610)	Sacramento	8% (88)
Philadelphia	69% (3,301)	Dallas	7% (258)
Washington, DC	67% (1,969)	Houston	7% (191)
Portland	66% (833)	San Antonio	7% (78)
Seattle	65% (1,716)	San Diego	6% (114)
Sacramento	65% (756)	Orlando	6% (41)
San Antonio	65% (778)	Atlanta	5% (92)
Baltimore	64% (1,212)	Tampa	4% (62)
Detroit	64% (2,522)	Los Angeles	4% (295)
Dallas	63% (2,255)	Columbus	3% (44)
Cleveland	62% (1,101)	San Jose	3% (33)
Boston	60% (2,035)	Baltimore	2% (45)
Riverside	58% (1,111)	Chicago	2% (149)
Houston	58% (1,596)	San Francisco	2% (60)
Columbus, OH	57% (719)	Charlotte	2% (15)
Tampa	57% (897)	New York	2% (247)
Minneapolis	53% (1,193)	Minneapolis	1% (28)
Austin	51% (393)	Philadelphia	1% (46)
St. Louis	50% (1,025)	Boston	1% (28)
Cincinnati	45% (690)	Cincinnati	-1% (-14)
Pittsburgh	43 (887)	Kansas City	-1% (-19)
Kansas City	43% (649)	Indianapolis	-2% (-22)
Orlando	39% (272)	Cleveland	-3% (-51)
Indianapolis	39% (401)	St. Louis	-3% (-61)
Atlanta	28% (535)	Detroit	-3% (-132)
Charlotte	22% (174)	Pittsburgh	-4% (-75)

<Table 7> Share and Count of Block Groups at Light Rail Density in 2010; Change in Share and Count of Block Groups at Light Rail Density (1990-2010), sorted in rank order

Metropolitan Area	Share (Count) of Block Groups at Light Rail Density (>15,000 ppsm) (2010)	Metropolitan Area	Change in Share (Count)of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)
New York	48% (6,723)	San Jose	5% (53)
San Francisco	34% (939)	Los Angeles	5% (406)
Los Angeles	32% (2,656)	San Francisco	4% (115)
Philadelphia	30% (1,442)	New York	3% (405)
Boston	25% (838)	Las Vegas	3% (22)
Chicago	24% (1,596)	Denver	1% (25)
Baltimore	19% (364)	Seattle	1% (38)
San Diego	18% (318)	Riverside	1% (27)
San Jose	16% (171)	San Diego	1% (24)
Washington	15% (437)	Washington, DC	1% (36)
Miami	9% (238)	Portland	1% (14)
Las Vegas	7% (61)	Phoenix	1% (20)
Seattle	5% (134)	Austin	1% (6)
Minneapolis	4% (94)	Minneapolis	1% (14)
Denver	4% (68)	Houston	1% (17)
Dallas	4%(128)	Boston	1% (20)
Columbus	3% (39)	Dallas	1% (21)
Riverside	3% (58)	Miami	<1% (10)
Pittsburgh	3% (62)	Orlando	<1% (1)
Houston	3% (82)	Atlanta	<1% (1)
Phoenix	3% (65)	Charlotte	-1% (-1)
Cleveland	2% (44)	Kansas City	-1% (-5)
Austin	2% (19)	Sacramento	-1% (-5)
Portland	2% (29)	San Antonio	-1% (-6)
Sacramento	2% (21)	Tampa	-1% (-8)
St. Louis	2% (34)	Philadelphia	-1% (-41)
Cincinnati	2% (25)	Indianapolis	-1% (-9)
Detroit	1% (49)	Chicago	-1% (-82)
Atlanta	1% (14)	Columbus	-2% (-25)
San Antonio	<1% (5)	Cincinnati	-3% (-42)
Indianapolis	<1% (4)	St. Louis	-3% (-61)
Tampa	<1% (5)	Detroit	-3% (-130)
Kansas City	<1% (3)	Pittsburgh	-4% (-77)
Orlando	<1% (1)	Baltimore	-5% (-91)
Charlotte	0% (0)	Cleveland	-8% (-147)

<Table 8> Total Block Groups in 2010; Count & Share Declined (1990-2010), sorted in rank order

Metropolitan Area	Total Number of Block Groups (2010)		Metropolitan Area	Count (Share) Block Groups Declined (1990-2010)
New York	14,009		Las Vegas	142 (17%)
Los Angeles	8,177		Riverside	379 (20%)
Chicago	6,590		Portland	271 (22%)
Philadelphia	4,793		Austin	166 (22%)
Detroit	3,942		Atlanta	483 (25%)
Dallas	3,552		Seattle	711 (27%)
Boston	3,378		Pittsburgh	576 (28%)
Washington, DC	2,949		San Jose	291 (28%)
Houston	2,739		Charlotte	225 (28%)
San Francisco	2,724		Denver	486 (29%)
Seattle	2,631		Houston	846 (31%)
Miami	2,516		Dallas	1110 (31%)
Minneapolis	2,241		Phoenix	715 (32%)
Phoenix	2,229		Los Angeles	2625 (32%)
Pittsburgh	2,053		Washington, DC	949 (32%)
St. Louis	2,050		Miami	823 (33%)
Atlanta	1,923		San Francisco	892 (33%)
Riverside	1,902		Orlando	231 (33%)
Baltimore	1,893		New York	4887 (35%)
Cleveland	1,766		San Diego	619 (35%)
San Diego	1,762		Tampa	569 (36%)
Denver	1,667		San Antonio	446 (37%)
Tampa	1,585		Sacramento	438 (38%)
Cincinnati	1,536		Boston	1288 (38%)
Kansas City	1,507		Minneapolis	956 (43%)
Columbus	1,259		Chicago	3107 (47%)
Portland	1,253		Baltimore	922 (49%)
San Antonio	1,199		Baltimore	922 (49%)
Sacramento	1,162		Columbus	629 (50%)
San Jose	1,037		Philadelphia	2420 (50%)
Indianapolis	1,033		Kansas City	786 (52%)
Las Vegas	832		Cincinnati	859 (56%)
Charlotte	792		St. Louis	1237 (60%)
Austin	765		Detroit	2664 (68%)
Orlando	695		Cleveland	1234 (70%)

6. Combined Indicator Analysis

To analyze how metropolitan areas compare across indicators we compute a combined indicator rank for each metropolitan area. We compute the combined rank by assigning each metropolitan area a quintile- rank for each urban form indicator (as described above) and computing the sum of the quintile-rank across the 11 static and 10 dynamic indicators. Recognizing the well-known limitations of combined rankings, we compute this ranking not to offer an overall normative assessment of urban form, but to serve as a basis for comparing metropolitan areas across indicators. Specifically we color code every metropolitan areas for every indicator, and the combined ranking, on a continuum from green (the lowest value) to red (the highest value) then sort the metropolitan areas by the average rank. We present the results for the static and dynamic indicators in tables 9 and 10 respectively.

As shown in table 9 and not surprisingly, the larger older cities received the highest combined rank among the static measures. The large Northeastern metropolitan areas, New York, Chicago, and Philadelphia, and the large Western cities of Los Angeles and San Francisco stand atop the static ranks. Also not surprisingly, the smaller Southern cities of Charlotte and Orlando have among the lowest combined ranks low combined rankings also belongs to the smaller Midwestern cities of

Kansas City, Indianapolis and Cincinnati. Perhaps also not surprising, but more interestingly, the rankings of almost all the static indicators are highly correlated.

Patterns in the variation of dynamic measures are less obvious or systematic. Table 10 presents the dynamic index and rank for metropolitan areas. As shown, metropolitan areas with the lowest dynamic scores are metropolitan areas in the Midwest and Northeast: Detroit, Cleveland, St. Louis, Cincinnati, Philadelphia, Pittsburgh and Baltimore. In general these are cities growing very slowing or losing population. As also shown, the fast-growing Western cities of Riverside, Portland, Seattle, Phoenix, and Las Vegas have the highest average ranks, Orlando is the only Eastern city with high dynamic scores. As evident by the color coding in table 10, the various dynamic measures are also highly correlated but less so than the static measures. In general, the metropolitan areas that grew most had the greatest increases in population and population densities in their urbanized area and principal cities, the fewest number of block groups that lost population, and the greatest number of block groups that met density thresholds.

Many of the metropolitan areas that ranked high on the static measures ranked low on the dynamic measures. These include Baltimore, Boston, Philadelphia, and Detroit. These slow growing or declining Eastern cities built at high densities during the industrial age and with little room for infill, were unable to sustain their densities in the

inner areas of their metropolitan areas. Conversely, several metropolitan areas that ranked high on the dynamic measures ranked low on the static measures. These include Atlanta, Austin, and Orlando. These newer cities were built after the industrial age and more recent robust growth has led to densification. Cincinnati stands out as performing poorly on both static and dynamic measures; Seattle stands out as performing well on both.

<Table 9> Static Measures Sorted by Metropolitan Area, Color Coded by Quintile

Metropolitan Area	Metropolitan Area Population (2010)	Urbanized Area Population (2010)	Principal City Population (2010)	Metropolitan Area Density (2010)	Urbanized Area Density (2010)	Principal City Density (2010)	Total Number of Block Groups (2010)	Count of Block Groups at Bus Density (>5,000 ppsm) (2010)	Share of Block Groups at Bus Density (>5,000 ppsm) (2010)	Count of Block Groups at Light Rail Density (>15,000 ppsm) (2010)	Share of Block Groups at Light Rail Density (>15,000 ppsm) (2010)	Index	Rank
Atlanta	5,268,860	3,678,746	420,003	621	2,189	3,189	1,923	535	28%	14	1%	22	29
Austin	1,716,289	1,203,173	790,390	401	2,827	3,143	765	393	51%	19	2%	19	30
Baltimore	2,710,489	2,196,557	620,961	1,030	3,822	7,685	1,893	1,212	64%	364	19%	39	14
Boston	4,552,402	3,549,238	617,594	1,257	3,622	12,760	3,378	2,035	60%	838	25%	46	7
Charlotte	1,758,038	1,156,323	731,424	559	2,095	3,019	792	174	22%		0%	15	34
Chicago	9,461,105	8,429,648	2,695,598	1,295	4,200	11,870	6,590	5,002	76%	1,596	24%	53	4
Cincinnati	2,130,151	1,552,352	296,943	477	2,599	3,807	1,536	690	45%	25	2%	18	31
Cleveland	2,077,240	1,694,537	396,815	1,030	3,108	5,114	1,766	1,101	62%	44	2%	28	21
Columbus	1,836,536	1,338,093	787,033	458	3,105	3,742	1,259	719	57%	39	3%	23	28
Dallas	6,371,773	5,206,669	1,197,816	686	3,305	3,497	3,552	2,255	63%	128	4%	43	9
Denver	2,543,482	2,237,312	600,158	301	3,926	3,912	1,667	1,240	74%	68	4%	31	18
Detroit	4,296,250	3,675,546	713,777	1,079	3,258	5,142	3,942	2,522	64%	49	1%	39	13
Houston	5,946,800	4,889,916	2,099,451	644	3,380	3,623	2,739	1,596	59%	82	3%	39	12
Indianapolis	1,756,241	1,255,099	820,445	452	2,492	2,270	1,033	401	39%	4	0%	15	33
Kansas City	2,035,334	1,482,348	459,787	256	2,630	1,467	1,507	649	43%	3	0%	13	35
Las Vegas	1,951,269	1,744,814	583,756	241	4,717	5,152	832	668	80%	61	7%	28	20
Los Angeles	12,828,837	12,466,385	3,792,621	2,625	7,418	8,085	8,177	7,379	90%	2,656	32%	54	2
Miami	5,564,635	5,302,551	399,457	1,027	4,624	11,189	2,516	2,070	82%	238	9%	46	6
Minneapolis	3,279,833	2,480,342	382,578	515	2,904	6,969	2,241	1,193	53%	94	4%	33	17
New York	18,897,109	17,685,468	8,175,133	2,752	6,833	26,954	14,009	11,431	82%	6,723	48%	55	1
Orlando	2,134,411	1,601,566	238,300	532	2,576	2,549	695	272	39%	1	0%	15	32
Philadelphia	5,965,343	4,998,187	1,526,006	1,267	3,693	11,295	4,793	3,301	69%	1,442	30%	53	3
Phoenix	4,192,887	3,493,944	1,445,632	287	3,535	3,044	2,229	1,610	72%	65	3%	36	16
Pittsburgh	2,356,285	1,529,077	305,704	441	2,712	5,498	2,053	887	43%	62	3%	23	27
Portland	2,226,009	1,846,200	583,776	327	3,840	4,347	1,253	833	66%	29	2%	27	22
Riverside	4,224,851	3,457,162	303,871	154	3,387	3,891	1,902	1,111	58%	58	3%	29	19
Sacramento	2,149,127	1,782,172	466,488	405	3,866	4,799	1,162	756	65%	21	2%	25	26
San Antonio	2,142,508	1,629,165	1,327,407	290	3,487	3,257	1,199	778	65%	5	0%	25	25
San Diego	3,095,313	2,807,885	1,307,402	731	4,678	4,031	1,762	1,414	80%	318	18%	42	10
San Francisco	4,335,391	4,009,381	805,235	1,711	6,046	17,249	2,724	2,304	85%	939	34%	51	5
San Jose	1,836,911	1,730,545	945,942	683	6,415	5,408	1,037	915	88%	171	16%	36	15
Seattle	3,439,809	2,979,517	608,660	574	3,551	7,255	2,631	1,716	65%	134	5%	39	11
St. Louis	2,812,896	2,039,944	319,294	318	2,727	5,158	2,050	1,025	50%	34	2%	25	24
Tampa	2,783,243	2,341,671	335,709	1,063	2,819	5,633	1,585	897	57%	5	0%	25	23
Washington, DC	5,582,170	4,655,904	601,723	983	3,915	9,800	2,949	1,969	59%	437	15%	45	8

<Table 10> Dynamic Measures Sorted by Metropolitan Area, Color Coded by Quintile

Metropolitan Area	Change in Metropolitan Area Density (1990-2010)	Change in Principal Density (1990-2010)	Change in Urbanized Area Population (1990-2010)	Change in Density in Urbanized Area (1990-2010)	Change in Count of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)	Change in (Share) of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)	Change in Count of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)	Change in Share) of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)	Number of Block Groups Declining in Population (1990-2010)	Share of Block Groups Declining in Population (1990-2010)	Index	Rank
Atlanta	72%	7%	87%	-5%	92	5%	1	<1%	483	25%	39	9
Austin	103%	70%	109%	-16%	74	10%	6	1%	166	22%	41	7
Baltimore	14%	-16%	15%	-16%	45	2%	-91	-5%	922	49%	17	29
Boston	10%	8%	10%	-6%	28	1%	20	1%	1,288	38%	22	26
Charlotte	72%	85%	103%	-10%	15	2%	-1	-1%	225	28%	38	12
Chicago	16%	-3%	15%	-19%	149	2%	-82	-1%	3,107	47%	19	28
Cincinnati	15%	-18%	18%	-21%	-14	-1%	-42	-3%	859	56%	13	32
Cleveland	-1%	-22%	-3%	-21%	-51	-3%	-147	8%	1,234	70%	11	34
Columbus	31%	24%	35%	-21%	44	3%	-25	-2%	629	50%	23	24
Dallas	60%	19%	63%	-9%	258	7%	21	1%	1,110	31%	37	14
Denver	53%	28%	51%	-9%	180	11%	25	1%	486	29%	40	8
Detroit	1%	-31%	-1%	-21%	-132	-9%	-130	-3%	2,664	68%	10	35
Houston	58%	29%	62%	-5%	191	7%	17	1%	846	31%	38	11
Indianapolis	36%	11%	39%	-18%	-22	-2%	-9	-1%	515	50%	22	25
Kansas City	24%	6%	22%	-15%	-19	-1%	-5	-1%	786	52%	19	27
Las Vegas	163%	126%	159%	-11%	287	34%	22	3%	142	32%	45	2
Los Angeles	14%	9%	14%	0%	295	4%	406	5%	2,625	32%	33	18
Miami	37%	11%	39%	-3%	202	8%	10	<1%	823	33%	37	13
Minneapolis	29%	4%	27%	-11%	28	1%	14	1%	956	43%	25	23
New York	12%	12%	13%	-6%	247	2%	405	3%	4,887	35%	31	21
Orlando	74%	45%	77%	-1%	41	6%	1	<1%	231	33%	41	6
Philadelphia	10%	-4%	9%	-17%	46	1%	-41	-1%	2,420	50%	16	31
Phoenix	87%	47%	77%	-12%	289	13%	20	1%	715	32%	41	5
Pittsburgh	-5%	-17%	-8%	-19%	-75	-4%	-77	-4%	576	28%	16	30
Portland	46%	33%	57%	7%	137	11%	14	1%	271	22%	42	4
Riverside	63%	34%	70%	-4%	176	9%	27	1%	379	20%	47	1
Sacramento	45%	26%	46%	-11%	88	8%	-5	-1%	438	38%	32	20
San Antonio	52%	42%	46%	-6%	78	7%	-6	-1%	446	37%	34	16
San Diego	24%	18%	26%	-11%	114	6%	24	1%	619	35%	33	17
San Francisco	18%	11%	17%	-3%	60	2%	115	4%	892	33%	32	19
San Jose	20%	21%	21%	5%	33	3%	53	5%	291	28%	38	10
Seattle	34%	18%	42%	-3%	227	9%	38	1%	711	27%	42	3
St. Louis	9%	-20%	6%	-17%	-61	-3%	-61	-3%	1,237	60%	11	33
Tampa	35%	20%	37%	-13%	62	3%	-8	-1%	569	36%	29	22
Washington, DC	35%	-1%	36%	-7%	229	8%	36	1%	949	32%	36	15

7. Summary and Conclusions

Every metropolitan area in the US is unique. Its urban form and changes in its urban form reflect unique natural features, economic forces, and political and social dynamics. Still our analysis of static and dynamic urban form measures reveals some clear and systemic patterns.

First, the urbanization process in the United States continues. With a few Rust Belt exceptions, most metropolitan areas have grown in population and, hence, density. Further, though with largely the same exceptions, the populations of urbanized areas have grown; and in about three fourths of the 35 largest metropolitan areas the population of principal cities have grown. Three thousand net new block groups met transit density thresholds; and over 500 net new block groups met bus density thresholds. These results suggest that when metropolitan areas grow, growth is distributed across the metropolitan area causing existing

cities and urbanized areas to grow and densities to rise.

On the other hand, most metropolitan areas continue to grow at the fringe. While some growth has gone to existing urban areas, the urbanized areas of all metro areas have expanded, in some places by quite a lot. In some Southern and Western metropolitan areas, urbanized areas nearly doubled over the last 20 years. The bottom line is this: while fast growing cities grew throughout their metropolitan areas, most growth in the 35 largest cities over the last 20 years has taken place at the urban fringe, at relatively low population densities by historical standards.

The policy implications of these results are difficult to identify given the small sample size and relatively coarse level of analysis. But if population density is taken as normatively favorable, then the most crucially important factor appears to be population growth. Growing metropolitan areas in the South and West scored "well" on most dynamic urban indicators. Declining cities in the Midwest and Northeast scored poorly. But if sprawl is defined as population growth at the urban fringe at relatively low urban densities, sprawl has continued unabated over the last two decades.[4]

References

Berg, N. (2012, March 28). America's growing urban footprint. Retrieved November 13, 2012, from http://www. theatlanticcities.com/neighborhoods/ 2012/03/americas-growing-urban-footprint/1615/

Cervero, R., & Guerra, E. (2011). Urban densities and transit: A multi-dimensional perspective. Berkley: Institute of Transportation Studies.

Clark, C. (1951). Urban population densities. *Journal of the Royal Statistical Society, 114*, 490-496.

Clifton, Kelly, Reid Ewing, Gerrit-Jan Knaap, and Yan Song (2008). Quantitative Approaches to Urban Form: A Multidisciplinary Review, Journal of Urbanism, 1,1: 17-46.

Cox, W. (2012, April 27). Staying the same: Urbanization in America. Retrieved November 13, 2012, from http://www.newgeography.com /content/002799-staying-same-urbanization- America.

Farr, D. (2008). *Sustainable urbanism: Urban design with nature*. Hoboken, NJ: Wiley & Sons.

Fischer, K. (2011). Central places: The theories of von Thunen, Christaller, and L?sch. In H. A. Eiselt & V. Marianov (Eds.), *International Series in Operations Research & Management Science: Vol. 115. Foundations of location analysis* (pp. 471-505). Springer.

Florida, R. (2012, April 5). The end of sprawl? Retrieved November 13, 2012, from

---

4) It is important to note that we do not test for whether patterns in urban growth changed after 2000 or after 2006, when the housing market collapsed. We leave this for future work.
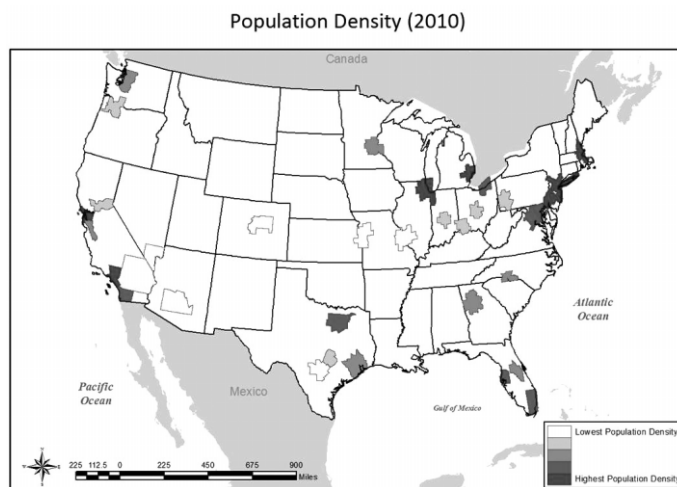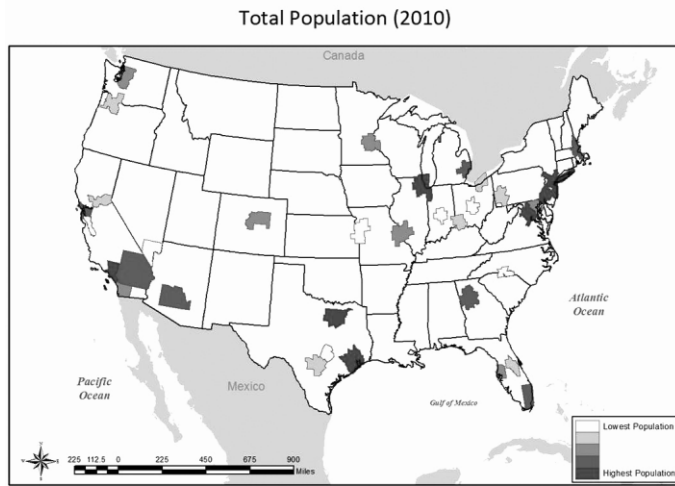
http://www.theatlanticcities.com/housing/2012/04/end-sprawl/1692/

Frey, W. H. (2012, March 20). Population growth in metro America since 1980: Putting the volatile 2000s in perspective. Retrieved November 13, 2012, from http://www.brookings.edu/research/papers/2012/03/20-population-frey

GeoLytics. (n.d.). 2010 summary file (SF1) in 2000 boundaries. Retrieved November 14, 2012, from http://www.geolytics.com/USCensus,2010-Normalized-Data,Products.asp

Jaffe, E. (2011, November 14). So are people moving back to the city or not? Retrieved November 13, 2012, from http://www.theatlanticcities.com /arts-and-lifestyle/2011/11/so-are-people-moving-back-city-or-not/487/

Knaap, G-J., & Lewis, R. (2009). Growth Patterns and Trends. In G. K. Ingram, A. Carbonell, Y-H. Hong, & A. Flint (Eds.) *Smart Growth Policies: An Evaluation of Programs and Outcomes*. Cambridge, MA: Lincoln Institute of Land Policy.

Knaap, G-J., Lewis, S., Carruthers, J.I, & Lewis, R. (2008, October). *The spatial structure of cities in the US: a multi-indicator analysis*. "Are cities more important than countries?" conference, Rotterdam, Netherlands.

Kotkin, J. (2011, November 30). Is suburbia doomed? Not so fast. Retrieved November 13, 2012, from http://www.newgeography.com/content/002550-s-suburbia-doomed-not-so-fast

McDonald, J. F. (1997). *Fundamentals of urban economics*. New York: Prentice Hall.

Proposed Urban Area Criteria for the 2010 Census, 75 Fed. Reg. 52174 (August 24, 2010) . Retrieved from: http://www.gpo.gov/fdsys/pkg/FR-2010-08-24/html/2010-20808.htm.

Pushkarev, B.S. & Zupan, J.M. (1977), *Public Transportation and Land Use Policy*, Indiana University Press (Bloomington).

Smart growth network. (n.d.). Retrieved November 13, 2012, from http://www.smartgrowth.org/engine/convo.php

U.S. Census Bureau (2012). Census Estimates Show New Patterns of Growth Nationwide. Retrieved November 14, 2012 from: http://www.census.gov/newsroom/releases/archives/population/cb12-55.html/

U.S. Census Bureau. (2011a). Residential Population Data: Population Change. Retrieved November 14, 2012 from: http://2010.census.gov/2010census/data/ apportionment-pop-text.php.

U.S. Census Bureau (2011b). 2010 Redistricting Data SF (PL 94-171.) Retrieved November 14, 2012 from: http://factfinder2.census.gov/.

U.S. Census Bureau. (n.d.). County and city data book: 2000. Retrieved November 14, 2012, from http://www.census.gov/statab/ccdb/cit1010r.txt

U.S. Census Bureau. (n.d.). Metropolitan and micropolitan statistical areas main. Retrieved November 14, 2012, from http://www.census.gov/population/metro/

Appendix

In this appendix we present figures and maps that illustrate urban spatial structure and changes in spatial structure over time for selected metropolitan areas. In most cases we present figure and maps for metropolitan areas at the extremes of the distribution. We show maps and figures, for example, for metropolitan areas that are the most and the least concentrated and the metropolitan areas that concentrated most and least. Similar figures are available from the authors for all of the 35 metropolitan areas in the study sample.

(Figure A1) Total Population in 2010

(Figure A2) Average Population Density: 2010

Figures A1 and A2 above illustrate the location of the 35 largest metropolitan areas and their total population and population densities in 2010. As shown, the largest metropolitan areas are distributed across with nation with a concentration of large metropolitan areas in the Northeast, only one large metropolitan area in the intermountain west, only two in the Northwest. The pattern reflects a central place hierarchy and illustrates a high degree of correlation between total population and population density at the metropolitan scale. That is, big cities tend to be dense cities.

(Figure A3) Percent Change in Population Density (1990-2010)

(Figure A4) Percent Change in Principal City Density (1990-2010)

As shown in figures A3 and A4, changes in population and population densities from 1990 to 2010 follow clear regional patterns: increases in population and population density over the last two decades were considerably greater in the Southern and Western regions of the nation. The Western and Southern cities of Las Vegas, Austin, Phoenix, Orlando, Atlanta and Charlotte had the largest increases in population at the metropolitan area, urbanized area, and principal city levels, although the rank order varies across geographies. Rust belt cities--Detroit, Cleveland, and Pittsburgh--had the lowest, and in some cases negative, rates of growth of population and population densities at all three levels.

(Figure A5) Frequency Distribution - Charlotte (2010)

(Figure A6) Change in Population Density Frequency   Distribution - Charlotte - 1990-2010

To gain additional insights into the distribution of populations within metropolitan areas we constructed density histograms. These histograms display the frequency of block groups in categories defined by population density in 2010 and by changes in density over the last two decades. As shown in figure A5 for the Charlotte metropolitan area, most block groups in 2010 have population densities less than 3000 persons per square mile. Only 174 block groups met the density threshold for bus service (5,000 persons per square mile) only one block group met the rail density threshold. (15,000 persons per square mile)

As shown in figure A6, Charlotte gained 15 block groups with densities above 5,000, from 1990 to 2010 and gained 81 block groups with population densities between 3,000 and 5,000. It gained no block groups that met the rail density threshold and had a net loss of block groups that met the bus density threshold.

(Figure A7) Population Density Frequency Distribution - New York (2010)
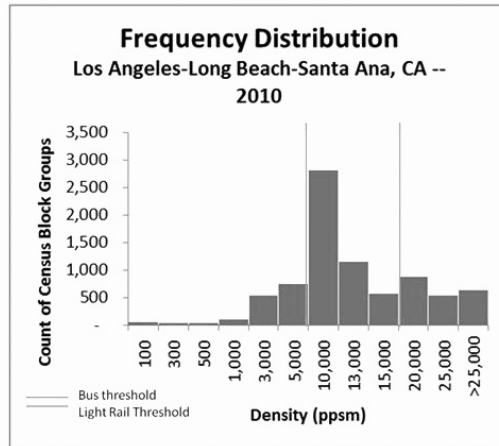

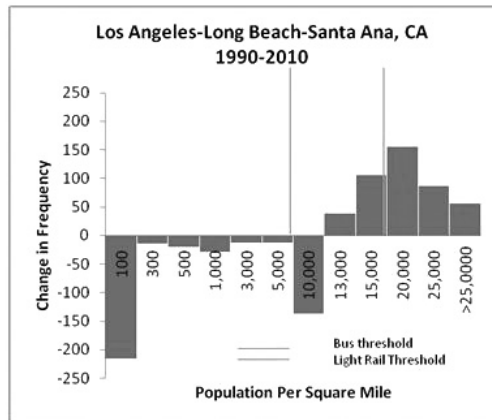(Figure A8) Change in Population Density Frequency Distribution - New York - 1990-2010

The majority of block groups in New York in 2010, by contrast, had population densities that met the rail transit threshold; 11,431 block groups met the bus density threshold. From 1990 to 2010, the number of block groups with population densities over 25,000 grew most rapidly.

Figures A9 to A12 illustrate the stark difference in growth patterns between Los Angeles and Detroit. In 2010 most block groups in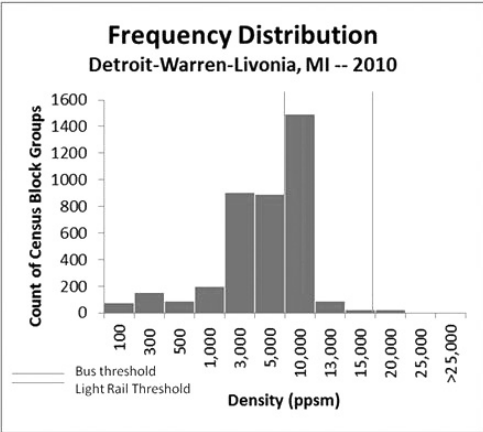 Los Angeles met the bus density threshold and many met the rail transit threshold. What's more from 1990 to 2010, Los Angeles lost 445 block groups with densities less than 10,000 persons per square mile and gained 445 block groups with more than 10,000 persons per square mile. Detroit, by contrast, had 2,522 block groups that met the bus density threshold in 2010, but from 1990 to 2010 lost 399 block groups with densities greater than 13,000 persons per square mile.
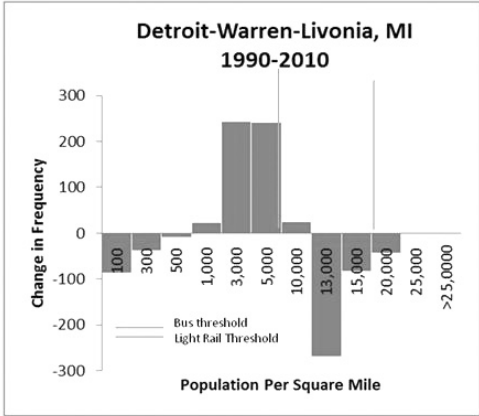

(Figure A9) Population Density Frequency Distribution - Los Angeles (2010)

(Figure A10) Change in Population Density Frequency Distribution - Los Angeles - 1990-2010

(Figure A11) Population Density Frequency Distribution - Detroit (2010)

(Figure A12) Change in Population Density Frequency Distribution - Detroit - 1990-2010