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Spatial transformation of metropolitan cities

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Abstract. This study investigates the relationships between neighbourhood change and spatial transformation in the North Carolina Piedmont region between 1980 and 2010. The dominant patterns of neighbourhood change, on the one hand, conform to some classical models of metropolitan structure, and, on the other hand, provide new insights on what has been ignored by those models. Trajectories of neighbourhood change reflect both persistent segregation and increasing diversification. A detailed analysis of trajectories of neighbourhood change points to interesting patterns in both central-city and suburban ecological succession and transformation.

Keywords: neighbourhood change, spatial transformation, succession and transformation

1 Introduction

Until the middle of the 20th century the social ecologies of metropolitan America could be conceptualized accurately by the textbook models of Alonso (1964), Burgess (1925), and Hoyt (1939), in terms of processes of congregation, segregation, bid-rent, and sequent occupancy—all of which pivoted tightly around a dominant central business district and transportation hub. Since the middle decades of the 20th century, however, remarkable changes have transformed metropolitan America. In spite of these considerable changes, only passing attention has been given to how these changes have been transcribed into the settlement patterns of cities and metropolitan areas. Have the stereotypical patterns of the Chicago School and of Murdie's famous model (1969) shown signs of giving way to a more complex social spatial structure? Or should Los Angeles be considered the paradigmatic postmodern American city? All these questions remind us to reevaluate the contemporary importance of traditional theories and to test our longstanding ideas about how cities grow and change.

In this study, a set of cluster analysis and GIS-based spatial analyses have been developed to capture the spatiotemporal patterns of neighbourhood change in the North Carolina Piedmont region based on an analysis of decennial census tract data between 1980 and 2010. This study will address the following issues: (1) the spatial patterns of neighbourhood distribution, (2) neighbourhood transformation over the past three decades, and (3) the spatial patterns of neighbourhood transformation over time. This study examines the spatiotemporal patterns of high-resolution changes of socioeconomic development and how macrolevel socioeconomic changes reshape neighbourhoods and alter the spatial structure of the metropolis. By introducing a socially and spatially integrated framework, this paper makes a contribution to the literature by investigating how well the Chicago School models of the social ecologies of the early and mid-20th century explain contemporary metropolitan structure.

2 Research context

An enormous body of theories contributes to a comprehensive understanding of how different types of people and businesses are located within the urban setting. These theories can be traced back to the Chicago School's concentric zonal model (Burgess, 1925), the sectoral model (Hoyt, 1939), the multiple nuclei model of Harris and Ullman (1945), and the social space concept of Bourdieu's (1985) model. Unlike earlier models that emphasized single diagnostic variables, social area analysis (Shevky and Bell, 1955) discovered both common characteristics and their variations within cities by constructing a composite index of variables, including social rank, urbanization, and segregation. The stereotypical American metropolis, the sectors and zones described in Murdie's famous model (1969) of factorial ecology, embodies mid-20th horizons of experience. Since the 1960s, using factor analysis to uncover underlying dimensions, factorial ecology has offered idealized three-factor models across Western cities: the sectoral pattern of socioeconomic status, the zonal gradient of family status, and a clustered pattern of ethnicity (Davies, 1984). Generalizations about urban structure have been made from comparative analyses of factorial ecologies, which show that the spatial expression of the major dimensions tends to persist over decades (Knox, 1982).

Due to the social and economic changes in the United States, a number of criticisms have been raised against the classical models of the Chicago School. Kearsley's (1983) model of urban structure, for example, updated Burgess's model by including contemporary urban processes, such as inner-city decline, gentrification, and decentralization. Marcuse (1989) suggested a 'quartered city' model with exclusionary and ethnic enclaves, gentrified areas, suburbs, and tenement areas. In particular, many critics have pointed to changes in transportation and information technology as the reason cities are no longer organized with clear zones or sectors. Thus, contemporary importance of the Chicago School is largely overshadowed by the LA School.

Rather than simply focusing on cross-sectional patterns of cities and metropolitan areas, some models have investigated changes in population composition, land use, or activities in neighbourhoods. The fundamental assumption of the Chicago School's invasion–succession model (Burgess, 1925; Park, 1952) is that neighbourhood change is an inevitable result of residence competition for space, and that neighbourhoods will change as higher income residents in outer rings are invaded and finally replaced by lower income residents from inner rings. The filtering model developed by Hoyt (1939) explains this neighbourhood decline as a function of aging properties and new construction on the periphery of cities. It is the attraction of new neighbourhoods on the periphery, rather than the push from inner cities, that resulted in the outward expansion of urban areas (Pitkin, 2001). Although these models examine the mechanisms of a range of changes in demographic, socioeconomic, and physical conditions of neighbourhoods, they rarely examine the spatial dimension of those changes.

In recent decades contemporary development has challenged those traditional models, which has resulted in flourishing theoretical and empirical research on the significant changes in social and spatial structures in metropolitan areas. First, the transformation of the demographic and economic structure of metropolitan areas has led to a growing heterogeneity in an increasingly decentralized metropolitan America. Distinctive typologies were identified by race, age, or socioeconomic status. Several empirical analyses have confirmed the diversity of contemporary US metropolitan areas, especially in suburbia, providing typologies of samples of suburban municipalities and census-designated places, such as poor cities and suburbs (Kneebone and Berube, 2008), declining suburbs (Jargowsky, 2003; Short et al, 2007; Vicino, 2008), African American and immigrant suburbs (Hanlon et al, 2006), and manufacturing suburbs (Mikelbank, 2004), to name a few. These studies challenge the traditional metropolitan models of urban core and homogeneous suburbs, but focus only on socioeconomic dimensions without considering their spatial dimensions.

Second, specific patterns of socioeconomic compositions and changes are likely to influence the configuration of spatial structure at the metropolitan level. The suburbanization of both populations and employment has led to a more diversified demographic composition as well as a more dispersed and polycentric urban form. As Knox (2008) suggests, socioeconomic realignments have given rise to new urban, suburban, and extraurban landscapes. These new landscapes are characterized by the dispersed spatial structure of 'urban realms' (Lang and Knox, 2009) and the disjointed and decentralized urban landscapes of the 'galactic metropolis' (Lewis, 1983), 'postsuburban' (Phelps et al, 2010), 'edge cities' (Garreau, 1991), 'edgeless cities' (Lang, 2003) of low-density office development, the interspersed landscape of "metroburbia" (Knox, 2008), and 'cosmoburbs' of wealthy suburbs that are also diverse (Lang and LeFurgy, 2007). Those dispersed and polycentric urban forms are characterized by the emergence of employment centres in suburbs (Anas et al, 1998; Coffey and Shearmur, 2001). More recently, a megapolitan spatial model (Nelson and Lang, 2011) was proposed to capture the notion of super, multimetropolitan regions with a strong economic interdependency. This body of literature has examined the spatial expression of contemporary population and employment structure and recognized the overall trend of decentralization and suburbanization. However, patterns of spatial change are less well understood.

Just how have the socioeconomic changes played out across US metropolitan areas? Many empirical analyses have investigated metropolitan socioeconomic patterns (Fan, 2010; Hanlon et al, 2006; Mikelbank, 2011; Nelson and Lang, 2011; Phillips and Lucy, 2001). In addition, socioeconomic decline was one of the major concerns of the Chicago school and also of subsequent studies on neighbourhood decline (Jargowsky, 1997; Massey and Denton, 1998). Meanwhile, several studies have developed within a broader framework for the understanding of neighbourhood upward transition. For example, Van Criekingen and Decroly (2003) have delineated four types of neighbourhood renewal—gentrification, marginal gentrification, neighbourhood upgrading, and incumbent upgrading. Specific forms of upward mobility were also investigated by Owens (2012), whose findings suggest that white suburban neighbourhoods are the main components of neighbourhood ascent, in spite of the increasing upgrade of minority and immigrant neighbourhoods over time.

At the same time, many studies show that racial and income segregation relate to metropolitan form to a certain extent. Racial segregation has declined slowly, while class segregation among minorities has increased over time (Jargowsky, 1996). The affluent and poor are increasingly living in isolated neighbourhoods far away from each other. The structure of class segregation of metropolitan areas in the Northeast and Midwest is more likely to follow the concentric zone model; while metropolitan areas in the South and West are less likely to manifest this form of segregation (Dwyer, 2010). Dwyer also identified the determinants of spatial forms of class segregation: suburbanization, class inequalities, and racial disparities. He pointed out that metropolitan areas that had developed in a period when manufacturing was located downtown were more likely to exhibit a concentric zone pattern, while metropolitan areas dominated by new-economy industries are less likely to do so. His study confirmed that the concentric zone model is still the dominant form of class segregation.

In spite of the significant progress those studies have made in achieving better understanding of neighbourhood change across cities and metropolitan areas, they may either focus on cross-sectional socioeconomic distribution at a certain time without considering changes in distribution, or they may address the changing issues but ignore the spatial patterns of those transformations. In other words, the relationships between concomitant changes in socioeconomic profiles and changing metropolitan spatial structure remains unclear.

Most importantly, how well the classic theories about the social ecologies of the early 20th century explain today's metropolitan structure has received much less attention.

3 Socioeconomic change in the North Carolina Piedmont metropolitan region

The Piedmont metropolitan region, including Charlotte-Gastonia-Rock Hill (CGR), Raleigh-Cary, and Durham-Chapel Hill MSA (metropolitan statistical areas), refers mainly to the hilly plateau between coastal plains and mountains in North Carolina. The fast-growing development in the North Carolina Piedmont region is somewhat typical of the US. For over a hundred years this vast rural area that formerly produced cotton and tobacco has developed textile, processing, and other related industries. The Piedmont has been the most populated region in North Carolina for nearly a century (Meade, 2008) and for decades has been the top metropolitan area, showing continued significant growth, strong competitiveness, a strong economy, and one of the best living areas in the state (Frey, 2005; 2010; Hughes, 1990; Katz, 2010; Meade, 2008; The Brookings Institution, 2000a; Wial and Kulkarni, 2012).

The CGR MSA is anchored by the city of Charlotte. Hanchett (1998) has described how the city's early development involved a "sorting out" along racial and class lines. Initially driven by economics, an original, ante-bellum "salt and pepper" ecology of spatially intermixed African American and white populations gave way to a "patchwork quilt" of racial segregation in the 1880s. A booming textile economy at the turn of the 20th century produced new wealth that quickly found expression in streetcar suburbs that were sharply segregated through restrictive covenants. After the Great Depression, the city's social ecology changed again in response to modernization and the advent of the automobile, developing—like many other North American cities—a sectoral pattern in terms of income and race. By the mid-20th century, the basic layout of modern Charlotte had been formed, with wealthy and upper-middle-class white families dominating the south and southeast of the city, while the north and west sides were dominated by the more modest homes of the city's large African American and working-class white populations.

Raleigh's sociospatial development followed a similar chronological pattern, but with a different geography. Here the locus of affluent white neighbourhoods was in the north of the city, while poor African American neighbourhoods were concentrated in the south. While Charlotte and Raleigh both presented a clear demarcation between rich white and poor African American populations, with each occupying one end of the city, Durham developed a distinctively different social ecology. African American business thrived in Durham, a unique phenomenon in the early South. The hub of African American businesses was Parrish Street, widely known as 'Black Wall Street', adjacent to the town's tobacco warehouses. The early streetcar suburbs in Durham, in contrast to those in Charlotte and Raleigh, were largely established to serve African American communities such as Trinity Park, Morehead Hills, Club Boulevard, and Needmore (Turner, 2002).

Since the mid-1970s the population of the Piedmont region has grown rapidly (Berube et al, 2006; The Brookings Institution, 2000b). The population of CGR MSA was 829 824 in 1980, and by 2010 it had reached 1758 038. The population of Raleigh-Durham-Cary (RDC) CSA (combined statistical area) reached 1634 847 by 2010 from just over 635 131 in 1980. Central-city Charlotte, for example, topped the American core cities list with a 70% population growth rate (Landis, 2009). Migrants and immigrants, drawn first by manufacturing jobs relocated from the deindustrializing Northeast and then—and in much greater numbers—by the growth of 'new-economy' jobs in banking, advanced business services, digital technologies, and biotechnology, contributed to rapid growth.

One aspect of this growth in the Piedmont has been the changing family structure, including a growth in the numbers of married couples with children, single-person households, and senior households. The Piedmont metro areas also became an immigration gateway in the

1990s, resulting in a marked increase in foreign-born populations, especially Hispanics and Asians (Kasarda and Johnson, 2006; Singer, 2004; Smith and Furuseth, 2004). Meanwhile, racial segregation and its attendant inequalities have persisted within the Piedmont metro areas, despite an overall increase in affluence (The Brookings Institution, 2000b).

Another aspect of this growth has included changing employment structure. As those regions have grown, the spatial locations of some sources of employment have become more decentralized, such as in Charlotte MSA; some may have experienced small changes in the spatial locations of employment, such as in Durham MSA (Kneebone, 2009). With respect to job creation and job sprawl, Weitz and Crawford (2012) used 2001–06 data to show that Raleigh MSA and Charlotte MSA gained in job creation but decreased in job accessibility. In another study, Stoll (2005) showed that Charlotte and Raleigh MSAs experienced relatively higher job sprawl but lower job mismatch for African Americans among 300 metropolitan areas based on year 2000 data.

An important factor in the growth of the Piedmont metros has been the 'Research Triangle' anchored by the University of North Carolina (Chapel Hill), Duke University (Durham), and North Carolina State University (Raleigh). The Triangle has been listed among the nation's top high-tech regions in terms of labour-force quality (Koo, 2005), competence, and population gains since the 1990s (Landis, 2009). Centred on Research Triangle Park, this area has fostered the growth of the region's new economic industries. Just as in other metropolitan regions, these employers have sought new settings well away from congested central-city areas. The result has been the emergence of a 'metroburban' metropolitan form (Knox, 2008), with a polycentric structure that incorporates urban realms and corridors, 'edge cities', 'edgeless cities', 'exurbs', 'micropolitan' centres, and 'boomburbs'. Cary, for example, is a "boomburb" with a total office space market of over 5.5 million ft^2, a retail space market of almost 6 million ft^2, and a flex-space market approaching 1 million ft^2. It is home to many new-economy corporations, scattered throughout the district in small office parks and commercial corridors. They include the SAS Institute (the largest privately held software company in the world and Cary's single largest employer), Geotek Mapping, 3D Learning Solutions (simulation software for the military), Deutsche Bank Global Technologies, R H Donnelley (publisher), Infineon Technologies, Research in Motion (smartphone manufacturer), and Epic Games (video game developer). Cary's new-economy corporations have attracted an influx of employees from across the country. A much-recited witticism among North Carolinians is that the district's name is an acronym, standing for Containment Area for Relocated Yankees. Not all are Yankees, of course, but the great majority are 'relos': affluent middle-class households that have had to relocate as a result of the increasing fluidity and flexibility of corporate location strategies within the new economy.

Meanwhile, both Charlotte and Raleigh have invested heavily in their downtowns. In the 1980s and 1990s Charlotte had one of the healthiest downtown office markets in the United States (Hughes, 1990), and it remains the country's second largest financial centre (after New York City) in terms of the financial assets that it controls (Charlotte Chamber of Commerce). Raleigh, as the state capital, has developed a significant amount of office employment in its downtown area, though it has almost none of the glassy office towers that characterize Charlotte's business district. A transitional mixture of land uses surrounds both city centres. Some older residential districts remain, while others have been razed, a block at a time, to provide daily parking lots or sites for small business. Still others have been redeveloped as condominiums. In both cities older single-family homes and town homes in leafy inner-city districts have attracted 'gentrifiers' in significant numbers.

The Piedmont was historically a rural agricultural region but has now urbanized so much that it is swarming with the largest and fastest-growing cities. Now what characterizes the

Piedmont region, especially the cities of Charlotte, Raleigh, and Durham, are fast-growing, vibrant job centres for financing and hi-tech, top population growth, and racial diversification.

4 Data and methods

The primary source of the data used in this study at the census tract level from 1980 to 2010 is the Longitudinal Tract Data Base (LTDB) prepared by Spatial Structures in the Social Sciences. In order to track neighbourhood changes directly over time, we used the LTDB data that have been standardized to 2010 boundaries. Central cities of 1980 are identified based on the indicator in the Neighbourhood Change Database produced by the Urban Institute and GeoLytics. The boundaries of the 2010 Census used in GIS analysis are from the National Historical Geographic Information System. The central-city boundaries are those of 1980, and therefore some suburban tracts in 1980 might have become central-city tracts in 2010. This will affect the numbers and proportions of clusters in 2010 to a certain extent. However, the focus of this study is the spatial pattern of neighbourhood change, and the boundaries of central cities will not influence the patterns of spatial distribution and transformation.

In this study those census tracts with populations lower than 200 in each census year have been excluded from the analysis in order to avoid estimations based on a small number of data (Bench, 2003). After excluding these tracts and tracts with missing data, the pooled data in this study included a total of 2874 tracts (632 tracts in 1980, 740 tracts in 1990, 749 tracts in 2000, and 753 tracts in 2010). All variables for each tract were standardized as z-scores relative to all the other tracts in the same census year. The major advantage of our study is that it allows direct comparisons of the relative importance and spatial organization of each major tract type from one census year to another. When analyzing the spatial changes of socioeconomic distribution from 1980 to 2010, only those tracts that have specific typologies in both census years (629 tracts for both 1980 and 2010) were included in the analysis.

In seeking to delineate the sociospatial transformation of these Piedmont metros, we have pooled the standardized tract-level data from 1980 to 2010 for the three MSAs and employed a *k*-means cluster analysis to develop the overall typologies. *K*-means is a method of cluster analysis that partitions N observations into k clusters. In this process each observation belongs to the cluster with the nearest mean. In order to identify the number of clusters that are relatively stable, we relied on a data visualization technique—clustergrams—to guide the choice of the number of clusters. The clustergram is used to examine how the members of these clusters are formed as the number of clusters increases. The width of the line segments indicates the number of observations that are assigned to a cluster.

5 Results

5.1 Changing social ecology: empirical analysis

In this study ten variables related to demographics, socioeconomic status, and housing characteristics were selected based on the literature of neighbourhood typologies (Hanlon, 2009; Kitchen and Williams, 2009; Mikelbank, 2004; 2011; Morenoff and Tienda, 1997). In order to determine just how the spatial patterns of Piedmont metros have changed since 1980, we have drawn on tract-level decennial census data on this standard set of ten socioeconomic variables.

We first divided the pooled data into two to eight clusters using *k*-means algorithms. The three to five group solutions have the relatively larger values based on the Calinski/Harabasz pseudo-F test. Then, a clustergram indicates the relative stability of the five-cluster choices (figure 1). Thus, our analysis will be based on the five-fold classification of census tracts in the Piedmont metros.

Table 1 lists the means of the ten variables for the five clusters. A significant group of tracts were dominated by *middle-class* households—the classic demographic of America's

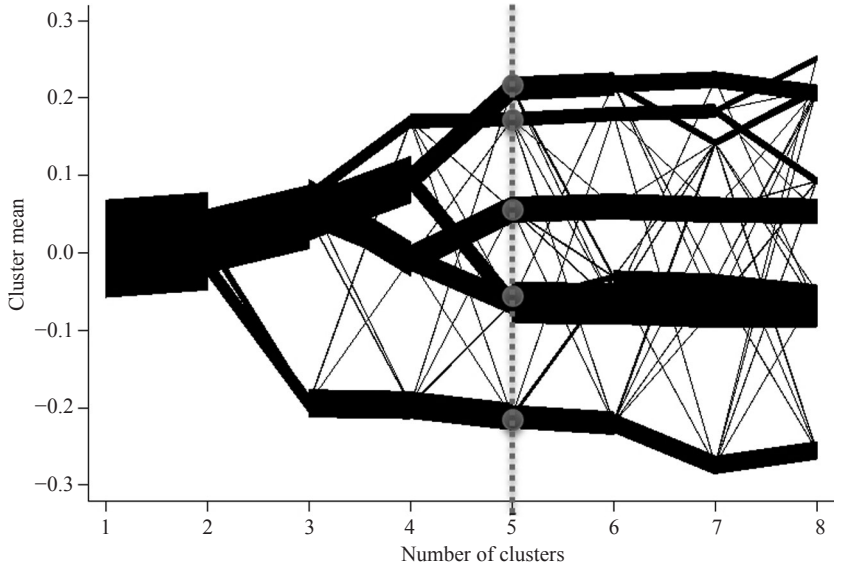

Figure 1. Visualization of clusters.

'sitcom suburbs' (Hayden, 2003): family-oriented, white, and relatively stable homeowning households. In comparison, *lower/aging* tracts had lower homeownership and median household incomes with a relatively higher proportion of seniors. *Black/poor* tracts were characterized by the highest percentages of African American populations and the lowest median household incomes. We described the fourth group of tracts as *upper-income*: households with significantly higher than average median household incomes, as well as the highest proportion of persons with a higher education. *Immigrant/renter* described those tracts with the lowest homeownership and the highest proportions of foreign-born populations. It should be emphasized that these results reflected the dominant general patterns among the pooled tract data for the period 1980–2010.

Table 1. *Z*-score means across clusters.

Variable	Middle-class	Lower/aging	Black/poor	Upper-income	Immigrant/renter
Demographic					
Percentage of persons aged 17 years and under	0.29	0.10	0.51	0.49	−1.09
Percentage of persons aged 60 years and over	0.04	0.73	0.17	−0.40	−0.33
Percentage of persons of black race, not of Hispanic origin	−0.22	−0.14	2.42	−0.69	−0.03
Percentage of foreign born	−0.38	−0.61	−0.24	0.35	1.07
Socioeconomic status					
Percentage of persons with at least a four-year college degree	−0.25	−0.91	−0.93	1.27	0.61
Percentage unemployed	−0.32	0.27	1.77	−0.59	−0.07
Percentage of manufacturing employees (by industry)	−0.17	1.46	−0.20	−0.34	−0.77
Median household income	0.11	−0.62	−1.23	1.53	−0.44
Housing characteristics					
Percentage of owner-occupied housing units	0.58	0.19	−1.11	0.65	−1.24
Percentage of vacant housing units	−0.33	0.10	0.54	−0.14	0.18

5.2 Changing spatial patterns of neighbourhood distribution

This section of the paper revolves around the question of what spatial patterns of neighbourhood distribution may be discerned in the Piedmont region. Given the nature and extent of changes in metropolitan form and social and demographic structure, it is reasonable to expect that the remarkably consistent social ecology of mid-20th century North American cities—zones, sectors, and clusters—has evolved in significant ways. The contemporary urban social fabric might be fragmented at the fine-grained level but integrated at the macrolevel (Marcińczak and Sagan, 2011). Thus, we expected a consistent pattern in the spatial expression of neighbourhood distribution.

Plotting the spatial distribution of each tract type over the three decades reveals some interesting patterns in segmentation, diversification, and evolution of different socioecological settings in the North Carolina Piedmont region. Tables 2 and 3 summarize the populations and distributions of clusters. Given the overall growth of MSAs over the period, the general trend for most tract types is towards an increase in aggregate populations and tract numbers, but the percentages of tracts vary by tract types. Figure 2 shows the spatial patterns of the five types of neighbourhoods in CGR MSA and RDC CSA in 2010. Generally speaking, immigrant/renter and black/poor tracts were generally located near urban cores. Middle-class socioecologies formed rings in the suburbs of the region. The upper-income neighbourhoods occupied one or several sectors. The lower/aging tracts are located generally in outer suburbs and exurbs. In many cases, immigrant/renter tracts occupy the sectors between black/poor and upper-income neighbourhoods. Using the extended urban region—the North Carolina Piedmont—as the basis for the empirical analysis, a spatial model (Piedmont model) is developed and illustrated in figure 3.

In contrast to our expectations, cities are still organized with ‘zones’, ‘sectors’, and ‘clusters’ as described in the classic urban models. The first point to make here is that the urban social patterns of Piedmont cities still bear some resemblance to the concentric zone model. A broad observation is that the middle-class dominance in suburbs, and the immigrant/renter

Table 2. Populations by cluster.

Year	Total tracts	Middle-class	Lower/aging	Black/poor	Upper-income	Immigrant/renter
1980	632	342 756	313 787	186 017	224 807	233 931
1990	740	532 238	472 646	209 501	292 937	401 728
2000	749	813 804	580 484	220 320	434 422	502 557
2010	753	1 259 841	575 685	301 266	617 502	636 792

Table 3. Distribution of clusters.

Location	Year	Total tracts	Middle-class (%)	Lower/aging (%)	Black/poor (%)	Upper-income (%)	Immigrant/renter (%)
Suburbs	1980	509	38.90	22.00	6.09	21.02	11.98
Suburbs	1990	618	39.00	23.14	4.37	18.77	14.72
Suburbs	2000	627	36.52	24.88	4.31	20.41	13.88
Suburbs	2010	631	37.40	20.44	7.45	19.02	15.69
Cities	1980	123	13.01	5.69	30.08	16.26	34.96
Cities	1990	122	9.02	2.46	32.79	10.66	45.08
Cities	2000	122	8.20	3.28	31.15	9.02	48.36
Cities	2010	122	5.74	4.92	31.97	12.30	45.08

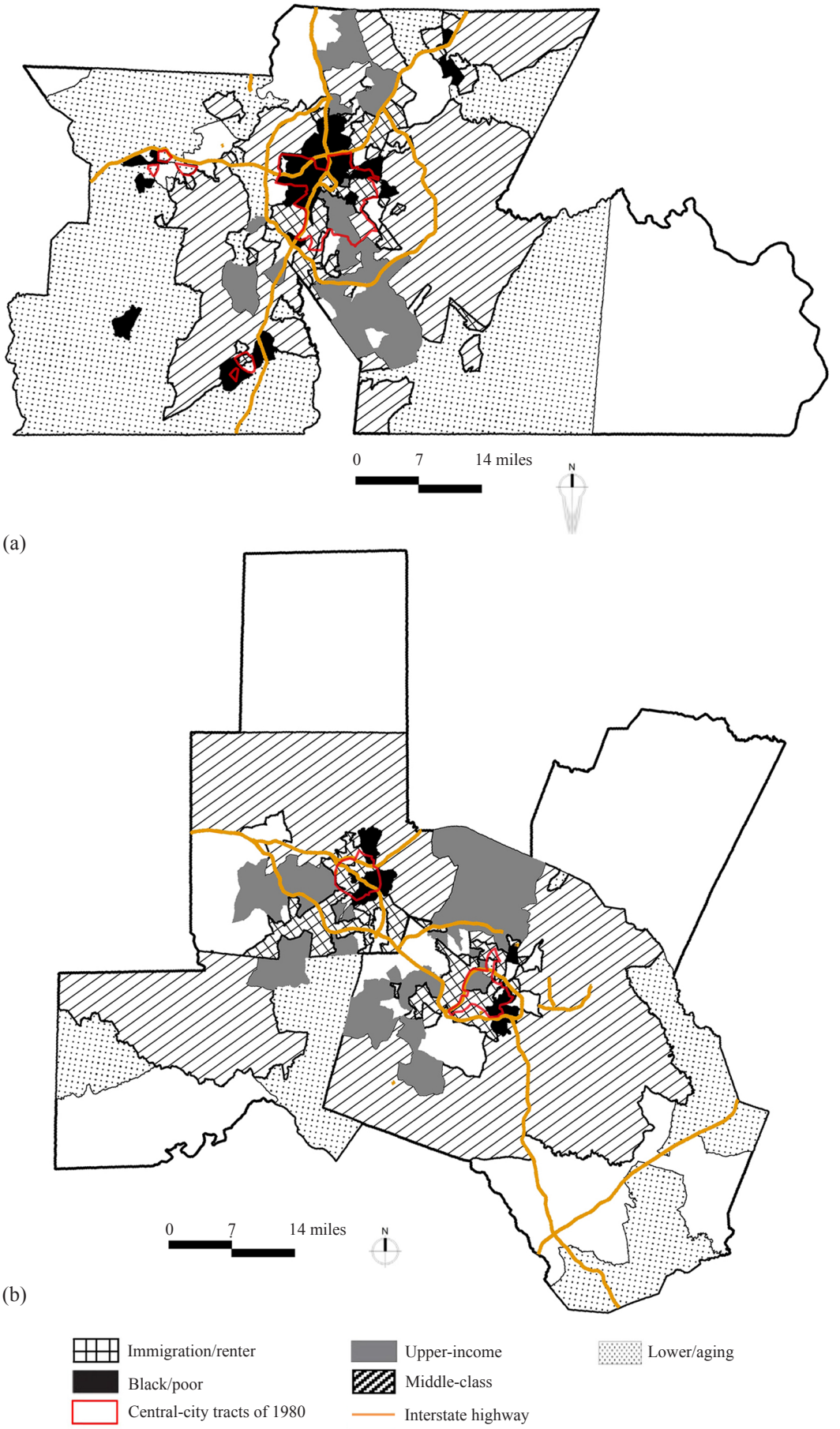

Figure 2. [In colour online.] Spatial pattern of clusters in CGR MSA and RDC CSA in 2010: (a) Charlotte-Gastonia-Rock Hill metropolitan statistical area, and (b) Raleigh-Durham-Cary combined statistical area.

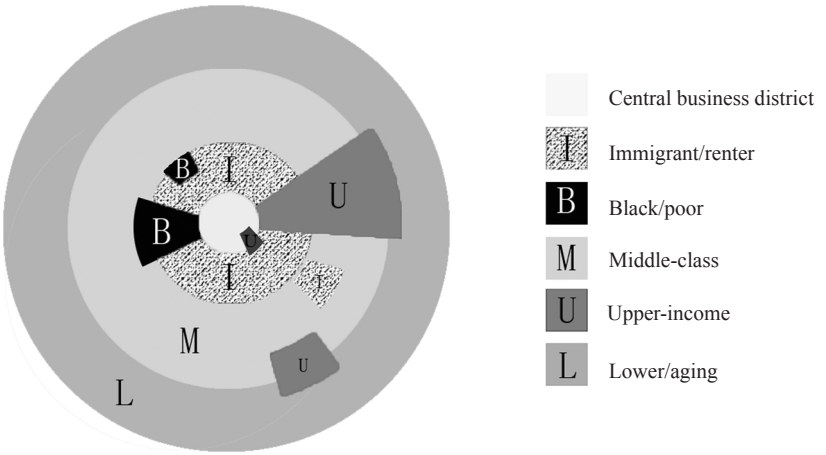

Figure 3. The basic version of the Piedmont model.

and black/poor dominance in city centres have been maintained numerically and spatially throughout these decades. In the Piedmont model neighbourhoods of immigrant/renter and black/poor are generally located in rings near urban cores; with the middle-class in suburban rings.

At a more detailed scale, much of the sociospatial differentiation in the Piedmont region exhibits a sectoral pattern. As in most of metropolitan America, and indeed as established in the early development of the Piedmont metros, most affluent white and low-income African American neighbourhoods occupied one or several sectors; they are not only spatially segregated but located at some distance from each other. Both Charlotte and Raleigh have traditional affluent regions, barely changed except for accretion, that date back to the streetcar era. The exception, as in its own early development, is Durham, where black/poor tracts are in close propinquity to upper-income white tracts. But in recent decades the upper-income tracts are being separated from black-poor tracts. This finding is consistent with Hoyt's sector model to a certain extent, where residential functions tend to grow in wedge-shaped patterns with sectors of low-income households and high-income households. Households with incompatible social, cultural, and economic backgrounds tend to avoid living together (Clark, 2009), which may explain why black/poor and upper-income neighbourhoods rarely exist in the same areas.

In addition to zones and sectors, the Piedmont model also incorporates a clustered pattern for some social groups. For example, many new houses are developed on the edges of cities due to decentralization of retail, people, and jobs. In suburbs and exurbs we see clusters of upper-income neighbourhoods. Due to urban regeneration and gentrification, clusters of upper-income neighbourhoods can also be found in central cities. Some other types of neighbourhoods also show signs of clusters. For instance, most immigrant/renter tracts are located near university areas in the Piedmont region. The North Carolina Piedmont region is home to a large number of colleges and universities (The Brookings Institution, 2000b). These characteristics suggest that these areas have a higher education rate but lower homeownership rate. The finding that universities may attract well-educated immigrants and renters is consistent with certain aspects of the multiple nuclei model of Harris and Ullman.

Another broad observation, then, is that the sociospatial ecology of the Piedmont metros is characterized by a juxtaposition of a relatively stable structure with a growing fragmentation and diversification at a finer grained level. Since the 1980s the Piedmont metros have become substantially postsuburban (Phelps et al, 2010). Despite the dominance of the middle-class in suburbia, the Piedmont region has shown an increasingly diverse and fragmented mosaic.

The spatial patterns have become more diversified due to sociospatial restructuring, but the basic, traditional patterns and relative locations of neighbourhood types have remained largely stable over time. In other words, the Piedmont region has remained largely stable in terms of overall patterns of distribution but has also experienced increasing diversity at the microscale. Thus, sociospatial trajectories in the Piedmont are both an extension of historical trends and a consequence of new forces, such as new streams of migration and immigration, social polarization, and gentrification.

5.3 Changing spatial patterns of neighbourhood transition

In this section we look in more detail at specific trajectories of neighbourhood change from 1980 to 2010 in order to investigate how socioeconomic changes are reflected in urban landscapes. Several further observations emerge. Stability is the single greatest dimension of metropolitan change; while for those neighbourhoods that have changed their attributes, the succession and growth of each type of neighbourhood reveal some interesting patterns. In this study, neighbourhood upgrading and downgrading are identified based on changes in neighbourhood income.

5.3.1 *Neighbourhood succession*

First, we focused on the succession process, defined as the sequences of neighbourhood change where typologies of neighbourhoods come to occupy a territory formerly dominated by another typology. Specifically, we examined the different evolutionary trajectories of ecological change across the Piedmont metro region. Table 4 illustrates the types of neighbourhood succession from 1980 to 2010. Figure 4 illustrates succession patterns of neighbourhood change in CGR MSA and RDC CSA. In looking at the overall succession patterns of the five types of tracts in the entire Piedmont region, we found that succession patterns differ by clusters:

(1) Immigrant/renter and black/poor neighbourhoods: a few immigrant/renter and black/poor neighbourhoods have been upgraded into middle-class or upper-income neighbourhoods, especially in suburbs. Several immigrant/renter neighbourhoods in inner cities that are adjacent to upper-income neighbourhoods have been gentrified into upper-income neighbourhoods, especially in the Charlotte MSA. In addition, transitions between black/poor and immigrant/renter neighbourhoods occurred both in central cities and suburbs of 1980.

(2) Upper-income neighbourhoods: the fringes of sectors of upper-income neighbourhoods, especially those close to inner-ring suburbs, have generally been superseded by middle-class tracts and, to a lesser extent, immigrant/renter tracts. However, those upper-income neighbourhoods located in central cities are relatively stable. In particular, no upper-income neighbourhoods have been superseded by black/poor neighbourhoods in the Piedmont region.

(3) Lower/aging neighbourhoods: most lower/aging sectors in suburban and some in exurban settings have been upgraded into middle-class neighbourhoods. Several lower/aging neighbourhoods in the central-city of Charlotte have changed into black/poor. A few have been upgraded into upper-income neighbourhoods or changed into immigrant/renter neighbourhoods both in central cities and suburbs.

(4) Middle-class neighbourhoods: elsewhere within the background of middle-class suburbia it is possible to discern two broad trajectories of change: deteriorating middle-class tracts and strong and rising middle-class tracts. Generally speaking, middle-class ecologies formed rings in the suburbs of the region; the interior perimeter of these middle-class rings was adjacent to neighbourhoods that were previously middle-class, but have shifted to immigrant/renter and black/poor neighbourhoods; the outer suburban exterior perimeter of the middle-class rings, in particular in CGR MSA, tended to consist of neighbourhoods that were previously middle-class but have emerged as lower/aging tracts. This result confirms the invasion–succession model to a certain extent, where neighbourhoods will change as higher income residents

Table 4. Neighbourhood succession from 1980 to 2010.

Succession	Types of neighbourhood change [a]	Total tracts	Suburbs	Cities	Suburbs (%)	Cities (%)
Middle-class	11	122	120	2	98.36	1.64
	12	18	17	1	94.44	5.56
	13	20	12	8	60.00	40.00
	14	30	30	0	100	0
	15	23	18	5	78.26	21.74
Lower/aging	21	35	35	0	100	0
	22	69	66	3	95.65	4.35
	23	6	6	0	100	0
	24	2	1	1	50.00	50.00
	25	7	4	3	57.14	42.86
Black/poor	31	5	5	0	100	0
	32	2	2	0	100	0
	33	47	18	29	38.30	61.70
	34	4	4	0	100	0
	35	10	2	8	20.00	80.00
Upper-income	41	38	33	5	86.84	13.16
	42	3	1	2	33.33	66.67
	43	0	0	0		
	44	57	45	12	78.95	21.05
	45	29	28	1	96.55	3.45
Immigrant/renter	51	10	10	0	100	0
	52	3	3	0	100	0
	53	5	3	2	60.00	40.00
	54	16	14	2	87.50	12.50
	55	68	30	38	44.12	55.88

[a] Each two-digit number represents a neighbourhood type in each census year from 1980 to 2010. 1 = middle-class; 2 = lower/aging; 3 = black/poor; 4 = upper-income; 5 = immigrant/renter.

in outer rings are invaded and finally replaced by lower income residents from inner rings. Finally, certain sectors of the middle-class rings have changed into upper-income tracts, a phenomenon mainly found in tracts of 1980s suburbs.

5.3.2 *Neighbourhood growth*

In addition to these patterns of ecological succession, it was possible to identify another aspect of metropolitan change by looking at patterns of ecological transformation: the growth of a neighbourhood typology through occupation of a territory that was formerly dominated by other typologies. Table 5 shows the types of neighbourhood growth from 1980 to 2010. Figure 5 illustrates such patterns in the Piedmont region. This growth process can be categorized into four patterns: clustering, sectoral growth, border accretion, and greenfield expansion. The ecological changes of each typology of tracts in the Piedmont region follow one or a mix of the four patterns.

(1) *Clustering*: the immigrant/renter tracts that are a distinctive feature of the 2010 maps generally emerged from neighbourhood social ecologies that were previously dominated by white populations or, in a few small patches, by black/poor populations. By 2010 these newly

Figure 4. [In colour online.] Succession patterns of the five typologies of tracts in the Piedmont region: (a) middle-class; (b) upper-income; (c) black/poor; (d) lower/aging; (e) immigrant/renter.

Table 5. Neighbourhood growth from 1980 to 2010.

	Types of neighbourhood change [a]	Total tracts	Suburbs	Cities	Suburbs (%)	Cities (%)
Middle-class	11	122	120	2	98.36	1.64
	21	35	35	0	100	0
	31	5	5	0	100	0
	41	38	33	5	86.84	13.16
	51	10	10	0	100	0
Lower/aging	12	18	17	1	94.44	5.56
	22	69	66	3	95.65	4.35
	32	2	2	0	100	0
	42	3	1	2	33.33	66.67
	52	3	3	0	100	0
Black/poor	13	20	12	8	60.00	40.00
	23	6	6	0	100	0
	33	47	18	29	38.30	61.70
	43	0	0	0		
	53	5	3	2	60.00	40.00
Upper-income	14	30	30	0	100	0
	24	2	1	1	50.00	50.00
	34	4	4	0	100	0
	44	57	45	12	78.95	21.05
	54	16	14	2	87.50	12.50
Immigrant/renter	15	23	18	5	78.26	21.74
	25	7	4	3	57.14	42.86
	35	10	2	8	20.00	80.00
	45	29	28	1	96.55	3.45
	55	68	30	38	44.12	55.88

[a] Each two-digit number represents a neighbourhood type in each census year from 1980 to 2010. 1 = middle-class; 2 = lower/aging; 3 = black/poor; 4 = upper-income; 5 = immigrant/renter.

emerged immigrant/renter tracts had generally developed a cluster pattern within the central cities as well as in the suburbs.

(2) *Border accretion*: most new black/poor areas emerged from middle-class tracts on the border of stable black/poor districts. Many new upper-income areas have evolved from formerly middle-class tracts on the suburban border of stable upper-income tracts.

(3) *Sectoral growth*: the expansion of upper-income ecologies has tended to occur along the outer border of the original upper-income tracts, but many of them are due to the transformation of outlying middle-class and lower/aging districts through upscale new developments in sectoral patterns.

(4) *Greenfield expansion*: most new middle-class districts have evolved from formerly lower/aging tracts, or, to a lesser extent, upper-income tracts in underdeveloped suburban areas. Several middle-class tracts have evolved from immigrant/renter and black/poor suburban tracts. In addition, tracts that became lower/aging also exhibited a pattern of greenfield expansion. Most of these areas transitioned from former middle-class tracts in outer suburbs, and several from the other types of tracts.

Figure 5. [In colour online.] Growth patterns of the five typologies of tracts in the Piedmont region: (a) middle-class; (b) upper-income; (c) Black/poor; (d) lower/aging; (e) immigrant/renter.

6 Conclusions

In the Piedmont region, as in other US metropolitan regions, external forces such as structural economic change, secular changes in social organization and demographic structure, as well as immigration, have clearly had a significant influence in shaping trajectories of ecological change. The Piedmont region has morphed rapidly into polycentric metropolitan regions with traditional city centers and suburban employment centres, and has become an exemplar of contemporary Sunbelt suburbanization. Thus, we hope that our investigation of the dominant metropolitan areas of the North Carolina Piedmont region—Charlotte-Gastonia-Rock Hill, Raleigh-Cary, and Durham-Chapel Hill—will make a contribution to understanding social ecological changes in metropolitan areas in the US.

Given the joint action of postwar external forces and historical concentration of poverty and racial minorities, the Piedmont has evolved rapidly into segmented, diversified, and polarized socioecological settings and a more pronounced polycentric metropolitan form. Across the Piedmont metro region, relatively stable spatial patterns of historical trends at the macroscale have been shown to be juxtaposed with growing fragmentation and diversification at a finer grained level. Segregation as reflected in longstanding structural inequalities may be the reason that the Piedmont region stays largely stable over time; while new dynamics of socioeconomic change and the emerging new-economy industries is likely the reason that this region is growing into more segmented and fragmented patterns.

Investigation of neighbourhood distribution revealed something similar to the spatial patterns of the Chicago School and the typical patterns of Murdie's factorial ecology models. Framed by core cities whose social ecology still bears some resemblance to the textbook factorial ecology model of North American cities, the social ecology of Piedmont has demonstrated that, in certain cases, urban phenomena do match those of classic models. It reminds us to reevaluate the contemporary importance of traditional theories. However, it may also question the Los Angeles School's fundamental claim that Los Angeles should be considered the paradigmatic postmodern American city. Urban development in the Piedmont region suggests that similar processes might shape spatial patterns in the way that they have in other parts of the US, such as Los Angeles. However, just as Hanchett (1998) has pointed out, the particular historical context and racial background in the Piedmont will more likely give this process a distinctive Southern flavor.

Further, examination of the changing patterns of metropolitan transformation revealed factors that have generally been ignored by any School. By investigating the structural dimensions of metropolitan change—succession and growth patterns over the past three decades—our study showed some interesting patterns. Despite the variations in patterns of ecological succession among the five types of tracts, a commonality exists. Overall, there are several neighbourhood ascent occurring in central cities and inner-ring suburbs; however, urban-side tracts (near city centres or inner-ring suburbs) are more likely to have experienced a downward socioeconomic transition, while suburb-side tracts tended to experience an upward socioeconomic transformation. It is consistent to the invasion–succession model that neighbourhoods will change as higher income residents in outer rings are invaded and finally replaced by lower income residents from inner rings. This may also reflect certain aspects of central-city and inner-ring suburban decline and the prevailing process of suburbanization. Meanwhile, this study also identified four types of patterns resulting from ecological growth: clustering, border accretion, sectoral growth, and greenfield expansion. This implies the selective operation of a variety of sociospatial processes, including segregation/congregation, filtering, invasion/succession, redevelopment and gentrification, and greenfield development.

Without comparing the changing spatial patterns of neighbourhood distribution and transformation in other metropolitan areas, it is difficult to generalize these patterns to other

regions in the US. This study uses only the North Carolina Piedmont region as the basis for empirical analysis. The literature on urban spatial form shows differences between the East and the West in the US (Lang et al, 1995; 1997) and a clear split in the eastern and western halves of the Sunbelt (Lang, 2003; The Brookings Institution, 2000b). The North Carolina Piedmont urban complex is a clear exemplar of the southeastern form, which shares a rough spatial equivalent in regions such as Nashville and Atlanta. Yet this form is different from that in the southwestern parts, and even from say relatively nearby South Florida. Due to the limited generalizable nature of the findings within this paper, future research is needed to compare the patterns we found across regions, such as Western (or Midwest and Northeast) US metropolitan complexes of comparable urban scale and population. By discovering what similarities or differences may exist, we can discover whether and to what extent the Chicago School theories about the social ecologies of the early 20th century explain today's metropolitan structure.

The results of this study are important for urban planners and policy makers to recognize the relationships among neighbourhood change and social spatial transformation. It also offers planners a rare opportunity to better understand the spatial/temporal patterns of neighbourhood changes in order either to ameliorate urban problems efficiently or implement urban policies in communities and metropolitan areas more effectively.

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References

Alonso W, 1964 *Location and Land Use: Toward a General Theory of Land Rent* (Harvard University Press, Cambridge, MA)

Anas A, Arnott R, Small K A, 1998, "Urban spatial structure" *Journal of Economic Literature* **36** 1426–1464

Bench K, 2003, "Comparing quality measures: the American Community Survey's three-year averages and Census 2000's Long Form Sample estimate", Planning, Research, and Evaluation Division, American Community Survey

Berube A, Katz B, Lang R E, 2006 *Redefining Urban and suburban America: Evidence from Census 2000* (The Brookings Institution, Washington, DC)

Bourdieu P, 1985, "The social space and the genesis of groups" *Theory and Society* **14** 723–744

Burgess E W, 1925, "The growth of the city: an introduction to a research project", in *The City Reader* Eds R LeGates, F Stouts (Routledge, New York) pp 153–161

Charlotte Chamber of Commerce, "Leading financial center", http://charlottechamber.com/business-profile/leading-financial-center/

Clark W A V, 2009, "Changing residential preferences across income, education, and age: findings from the multi-city study of urban inequality" *Urban Affairs Review* **44** 334–355

Coffey W J, Shearmur R G, 2001, "The identification of employment centers in Canadian metropolitan areas: the example of Montreal, 1996" *The Canadian Geographer* **45** 371–386

Davies W K D, 1984 *Factorial Ecology* (Gower, Aldershot, Hants)

Dwyer R E, 2010, "Poverty, prosperity, and place: the shape of class segregation in the age of extremes" *Social Problems* **57** 114–137

Fan Y, 2010, "Reexamining contemporary urbanism in the United States: convenient mix of the old and new" *Environment and Planning A* **42** 2897–2913

Frey W H, 2005, "Metro America in the new century: metropolitan and central city demographic shifts since 2000", in *Living Cities Census Series* (The Brookings Institution, Washington, DC) pp 1–28

Frey W H, 2010, "A demographic lull at Census time", Metropolitan Policy Program, The Brookings Institution, Washington, DC

Garreau J, 1991 *Edge City: Life on the New Frontier* (Anchor, New York)
Hanchett T W, 1998 *Sorting out the New South City: Race, Class and Urban Development in Charlotte, 1875–1975* (The University of North Carolina Press, Chapel Hill, NC)
Hanlon B, 2009, "A typology of inner-ring suburbs: class, race, and ethnicity in U.S. suburbia" *City and Community* **8** 221–246
Hanlon B, Vicino T, Short J R, 2006, "The new metropolitan reality in the US: rethinking the traditional model" *Urban Studies* **43** 2129–2143
Harris C D, Ullman E L, 1945, "The nature of cities" *The Annals of the American Academy of Political and Social Science* **242** 7–17
Hayden D, 2003 *Building Suburbia : Green Fields and Urban Growth, 1820–2000* (Pantheon Books, New York)
Hoyt H, 1939, "The structure and growth of residential neighborhoods in American cities", Federal Housing Administration, Washington, DC
Hughes J, 1990, "City review: North Carolina" *National Real Estate Investor* **32** 131–134
Jargowsky P A, 1996, "Take the money and run: economic segregation in US metropolitan areas" *American Sociological Review* **61** 984–998
Jargowsky P A, 1997 *Poverty and Place: Ghettos, Barrios, and the American City* (Russell Sage Foundation, New York)
Jargowsky P A, 2003, "Stunning progress, hidden problems: the dramatic decline of concentrated poverty in the 1990s", Metropolitan Policy Program, The Brookings Institution, Washington, DC
Kasarda J D, Johnson J H, 2006 *The Economic Impact of the Hispanic Population on the State of North Carolina* (Frank Hawkins Kenan Institute of Private Enterprise, Chapel Hill, NC)
Katz B, 2010, "State of metropolitan America : on the front lines of demographic transformation", Metropolitan Policy Program, The Brookings Institution, Washington, DC
Kearsley G W, 1983, "Teaching urban geography: the Burgess model" *New Zealand Journal of Geography* **75** 10–13
Kitchen P, Williams A, 2009, "Measuring neighborhood social change in Saskatoon, Canada: a geographic analysis" *Urban Geography* **30** 261–288
Kneebone E, 2009, "Job sprawl revisited: the changing geography of metropolitan employment", Metropolitan Policy Program, The Brookings Institution, Washington, DC
Kneebone E, Berube A, 2008, "Reversal of fortune: a new look at concentrated poverty in the 2000s", The Brookings Institution, Washington, DC
Knox P L, 1982 *Urban Social Geography: An Introduction* (Longman, London)
Knox P L, 2008 *Metroburbia USA* (Rutgers University Press, New Brunswick, NJ)
Koo J, 2005, "How to analyze the regional economy with occupation data" *Economic Development Quarterly* **19** 356–372
Landis J, 2009, "The changing shape of metropolitan America" *The Annals of the American Academy of Political and Social Science* **626** 154–191
Lang R E, 2003 *Edgeless Cities: Exploring the Elusive Metropolis* (Brookings Institution Press, Washington, DC)
Lang R E, Knox P L, 2009, "The new metropolis: rethinking megalopolis" *Regional Studies* **43** 789–802
Lang R E, LeFurgy J B, 2007 *Boomburbs: The Rise of America's Accidental Cities* (Brookings Institution Press, Washington, DC)
Lang R E, Popper D E, Popper F J, 1995, "Progress of the nation: the settlement history of the enduring American frontier" *The Western Historical Quarterly* **26** 289–307
Lang R E, Popper D E, Popper F J, 1997, "Is there still a frontier? The 1890 US census and the modern American West" *Journal of Rural Studies* **13** 377–386
Lewis P F, 1983, "The galactic metropolis", in *Beyond the Urban Fringe* Eds R Platt, G Macinko (University of Minnesota Press, Minneapolis. MN) pp 23–49
Marcińczak S, Sagan I, 2011, "The socio-spatial restructuring of Łódź, Poland" *Urban Studies* **48** 1789–1809
Marcuse P, 1989, "'Dual city': a muddy metaphor for a quartered city" *International Journal of Urban and Regional Research* **13** 697–708

Massey D, Denton N, 1998 *American Apartheid: Segregation and the Making of the Underclass* (Harvard University Press, Cambridge, MA)
Meade M, 2008, "The population of the Carolinas", in *A Geography of the Carolinas* Eds D G Bennett, J C Patton (Parkway, Boone, NC) pp 161–186
Mikelbank B A, 2004, "A typology of U.S. suburban places" *Housing Policy Debate* **15** 935–964
Mikelbank B A, 2011, "Neighborhood déjà vu: classification in metropolitan Cleveland, 1970–2000" *Urban Geography* **32** 317–333
Morenoff J D, Tienda M, 1997, "Underclass neighborhoods in temporal and ecological perspective" *Annals of the American Academy of Political and Social Science* **551** 59–72
Murdie R, 1969 *Factorial Ecology of Metropolitan Toronto, 1951–1961: An Essay on the social Geography of the City* (University of Chicago Press, Chicago, IL)
Nelson A C, Lang R E, 2011 *Megapolitan America: A New Vision for Understanding America's Metropolitan Geography* (APA Planners Press, Chicago, IL)
Owens A, 2012, "Neighborhoods on the rise: a typology of neighborhoods experiencing socioeconomic ascent" *City and Community* **11** 345–369
Park R A, 1952 *Human Communities* (Free Press, Glencoe, IL)
Phelps N A, Wood A M, Valler D C, 2010, "A postsuburban world? An outline of a research agenda" *Environment and Planning A* **42** 366–383
Phillips D L, Lucy W H, 2001, "Suburbs and the Census: patterns of growth and decline", Center on Urban and Metropolitan Policy, The Brookings Institution, Washington, DC
Pitkin B, 2001, "Theories of neighborhood change: implications for community development policy and practice", (UCLA Advanced Policy Institute)
Shevky E, Bell W, 1955 *Social Area Analysis: Theory, Illustrative Applications and Computational Procedure* (Stanford University Press, Stanford, CA)
Short J R, Hanlon B, Vicino T J, 2007, "The decline of inner suburbs: the new suburban Gothic in the United States" *Geography Compass* **1** 641–656
Singer A, 2004, "The rise of new immigrant gateways", The Brookings Institution, Washington, DC
Smith H A, Furuseth O J, 2004, "Housing, Hispanics and transitioning geographies in Charlotte, North Carolina" *Southeastern Geographer* **44** 216–235
Stoll M A, 2005, "Job sprawl and the spatial mismatch between blacks and jobs", Metropolitan Policy Program, The Brookings Institution, Washington, DC
The Brookings Institution, 2000a, "Moving beyond sprawl: the challenge for metropolitan Atlanta", The Brookings Institution, Washington, DC
The Brookings Institution, 2000b, "Adding it up: growth trends and policies in North Carolina", Center on Urban and Metropolitan Policy, The Brookings Institution, Washington, DC
Turner W R, 2002, "Development of streetcar systems in North Carolina", http://www.cmhpf.org/development of streetcar systems.htm
Van Criekingen M, Decroly J-M, 2003, "Revisiting the diversity of gentrification: neighborhood renewal processes in Brussels and Montreal" *Urban Studies* **40** 2451–2668
Vicino T J, 2008 *Transforming Race and Class in Suburbia: Decline in Metropolitan Baltimore* (Palgrave Macmillan, New York)
Weitz J, Crawford T, 2012, "Where the jobs are going: job sprawl in U.S. metropolitan regions, 2001–2006" *Journal of the American Planning Association* **78** 53–69
Wial H, Kulkarni S, 2012, "MetroMonitor: tracking economic recession and recovery in America's 100 largest metropolitan areas", The Brookings Institution, Washington, DC