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Research Paper

A longitudinal study of changes in urban sprawl between 2000 and 2010 in the United States

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HIGHLIGHTS

- Compactness indices paint a plausible picture of sprawl and changes in sprawl in the U.S.
- Generalizing, compactness decreased and sprawl increased between 2000 and 2010.
- The overall compactness index bears a strong relationship to transportation outcomes.
- Two of the four individual compactness factors also bear strong relationships to outcomes.

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ABSTRACT

The debate over metropolitan sprawl and its costs has been ongoing since the early 1970s in the U.S. To inform the debate, this study uses principal component analysis (PCA) and 2010 cross sectional data for large U.S. urbanized areas (UZAs) to operationalize compactness/sprawl in each of four dimensions—development density, land use mix, activity centering, and street accessibility. Higher values represent greater compactness, lower values greater sprawl. The four factors are then combined into an overall compactness/sprawl index.

The study then applies factor score coefficient values for 2010 to the same variables for 2000 to create comparable metrics for 2000. Compactness scores for 2000 are compared to the same scores for 2010 to see which UZAs sprawled the most between censuses, and which sprawled the least or actually became more compact.

Finally, the study validates the compactness index and its component factors against transportation outcomes for 2010, specifically walk mode share, transit mode share, and average drive time on the journey to work. If sprawl has any widely accepted outcome, it is automobile dependence and heavy automobile use. Consistent with this characterization of sprawl, this study finds that the overall compactness index bears a strong relationship to transportation outcomes. Generalizing across the entire universe of large urbanized areas in the U.S., compactness decreased and sprawl increased between the two census years; but only slightly. Several urbanized areas, however, have significantly different rankings in 2000 than 2010.

1. Introduction

Sprawl is principally considered to be an American phenomenon caused by specific technological innovations like the automobile and by government policies like single-use zoning or the mortgage-interest deduction on the federal income tax. Suburbanization, however, is ubiquitous and often takes the form of sprawl in other countries. Hence the U.S. experience may be generalizable. Milan, for example, has lost approximately 600,000 residents to the urban fringes over the last 15 years. Development patterns in Barcelona are comparable, where extensive suburban development is likely responsible for the largest population loss of any European city in the last 25 years.

High rates of automobile ownership, easy availability of peripheral land, and a lack of central planning have made sprawl particularly prevalent in the United States. The debate over metropolitan sprawl and its costs has been ongoing since the early 1970s in the U.S. (Real Estate Research Corporation, 1974)

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and has spilled over into European and Asian counties (Wilson & Chakraborty, 2013). There is still little consensus on the definition of sprawl or its alternatives: compact development, pedestrian-friendly design, transit-oriented development, and the catch-all term "smart growth." There is also little consensus about how sprawl impacts everything from open space preservation, air quality, traffic congestion, housing affordability, and quality of life (Bruegmann, 2006; Burchell et al., 1998, 2002; Duany, Plater-Zyberk, & Speck, 2001; Ewing, 1997; Ewing, Pendall, & Chen, 2002; Gordon & Richardson, 1997; Hayden, 2004; Hirschhorn, 2005; Kahn, 2006; Kunstler, 1993). Even if scholars do not agree on the costs and benefits of sprawl, there is a general agreement that, in order to assess its impacts, we must first have valid and reliable measures of urban sprawl.

A decade ago, Ewing et al. (2002) and Ewing, Pendall, and Chen (2003) developed compactness/sprawl indices for metropolitan areas and counties which have been widely used in health and other research (Cho et al., 2006; Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Ewing & Rong, 2008; Ewing et al., 2003; Fan & Song, 2009; Griffin et al., 2012; Holcombe & Williams, 2012; Joshu et al., 2008; Kahn, 2006; Kelly-Schwartz, Stockard, Doyle, & Schlossberg, 2004; Kim, Subramanian, Gortmaker, & Kawachi, 2006; Kostova, 2011; Lee, Ewing, & Sesso, 2009; McDonald & Trowbridge, 2009; Nguyen, 2010; Plantinga & Bernell, 2007; Schweitzer & Zhou, 2010; Stone, 2008; Stone, Hess, & Frumkin, 2010; Trowbridge & McDonald, 2008; Trowbridge, Gurka, & O'connor, 2009; Zolnik, 2011). While most studies have linked sprawl to negative outcomes, there have been exceptions (see, in particular, Kahn, 2006; Holcombe & Williams, 2012).

While many metrics have been developed since then (Cutsinger, Galster, Wolman, Hanson, & Towns, 2005; Ewing et al., 2002; Frenkel & Ashkenazi, 2008; Galster et al., 2001; Jaeger, Bertiller, Schwick, & Kienast, 2010; Mubareka, Koomen, Estreguil, & Lavalle, 2011; Torrens, 2008), none has captured changes in sprawl over time. In this study we seek to measure changes in sprawl by developing compactness/sprawl indices for 2000 and 2010 based on definitions and procedures in Ewing et al. (2002, 2003), but refined and applied this time to urbanized areas (UZAs) rather than metropolitan areas or counties. Census UZAs were chosen as units of analysis because UZAs are the only census geographies that expand systematically with urban development over time. Counties and metropolitan areas have fixed boundaries and hence tend to appear more compact over time. Census UZAs expand incrementally as rural areas are converted to urban uses and density thresholds are exceeded. If expansion takes the form of low densities, segregated land uses, commercial strips, and poorly connected streets, compactness scores will decrease. Conversely, if expansion occurs with moderate to high densities, integrated land uses, activity centers, and interconnected streets, compactness scores will increase. Likewise, if growth occurs though infill and redevelopment, compactness scores will increase.

1.1. Characteristics of urban sprawl

While sprawl is principally considered to be an American phenomena, global urbanization and rapid population growth have made sprawl an international development form.

The characterizations of sprawl, however, are not similar across the world. The development pattern which is considered low-density in "sprawling" European and Asian cities is significantly denser than sprawling American cities. "In the Western context the term typically evokes images of low density, automobile dependent and largely monotonous residential development along the periphery of an urban area. However, this characterization is less useful in many developing countries where urbanization has different drivers and appears in a different guise, posing yet another challenge for the generalizability of research findings" (Wilson & Chakraborty, 2013). So the unique characteristics of regions must be accounted for when a study seeks to operationalize urban sprawl.

In the Unites States, urban sprawl (also referred to as suburban sprawl) is the de-facto development pattern. Finding good examples of compact development, the antithesis of sprawl, is surprisingly difficult. For just one densely developed county, there are dozens of sprawling counties. For just one Manhattan, yet there are hundreds of Walton and Lapeer counties (sprawling counties located on the periphery major cities).

One of the first attempts to define sprawl related on qualitative assessments (Ewing, 1997). The definition of sprawl that was employed defined sprawl as comprising: (1) leapfrog or scattered development, (2) commercial strip development, (3) expanses of low-density development or (4) expanses of single-use development (as in sprawling bedroom communities).

Additional resolution was provided to these prototypical urban forms as "primary indicators" of sprawl that could be quantitatively measured. The most important indicator, which underlies any definition of sprawl, was poor accessibility.

Poor accessibility can be observed in scattered or leapfrog development, where residents or workers must pass vacant land from one area to another. Poor accessibility can also be observed in strip development, where shoppers must pass by other land uses on their way from one store to the next. Finally, poor accessibility defines low-density, single-use development, where segregation of and large private lots makes everything far apart. Understanding this underlying theme make the link to public policy clear. In sprawling areas, the low accessibility of land uses to one another means that residents and workers have to commute large distances to reach a destination. More often than not, this travel will be done in a private automobile.

1.2. Measuring urban sprawl

Early attempts to measure the urban sprawl were unrefined. Several researchers created measures of sprawl that relied almost solely on density (Anthony, 2004; Fulton, Pendall, Nguyen, & Harrison, 2001; Lang, 2003; Lopez & Hynes, 2003; Pendall & Carruthers, 2003; Pendall, 1999). The most notable feature of early studies (with exceptions noted below) was the failure to define sprawl in all its complexity. Density was the primary indicator of sprawl in the early studies likely because it is easy to measure, and captures one important dimension of sprawl. Density alone however does not fully capture urban sprawl. Another characteristic of the early studies was the high variability in sprawl ratings for different metropolitan areas reported by the studies (Ewing et al., 2003).

The same mistakes made in early quantitative studies of sprawl, neglect of land use interactions and empirical outcomes, have been made in recent studies using satellite imagery (House-Peters, 2011; Huang, Lu, & Sellers, 2007; Martellozzo & Clarke, 2011; Poelmans & Van Rompaey, 2009; Sarvestani, Ibrahim, & Kanaroglou, 2011). Huang et al. (2007), for instance, calculated seven spatial metrics that capture five distinct dimensions of urban form (complexity, centrality, compactness, porosity and density) in order to compare different cities and countries throughout the world. Such methods are useful for comparing one metropolitan or urbanized area with another. However, these methods are limited in their ability to distinguish patterns of high accessibility from patterns of low accessibility because they ignore land use and street patterns.

Many scholars now agree that sprawl is a complex and multidimensional phenomenon (Cutsinger et al., 2005; Ewing et al., 2002; Frenkel & Ashkenazi, 2008; Galster et al., 2001; Jaeger et al., 2010; Mubareka et al., 2011; Torrens, 2008). But this can lead to more