Journal of Transport Geography 62 (2017) 136–147

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

A geographically weighted regression approach to investigating the spatially varied built-environment effects on community opportunity

Chih-Hao Wang[a,*], Na Chen[b]

[a] Department of Geography and City and Regional Planning, California State University, Fresno, Fresno, CA 93740, USA
[b] City and Regional Planning, The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Keywords:
Spatial statistics
GWR
Land-use and transportation planning
Community opportunity
Social equity

ABSTRACT

Geographically weighted regression (GWR) has been increasingly used to better understand the spatially varied relationships between socioeconomic outcomes and policy investments. In this study, a community opportunity index (COI) is computed for Columbus, Ohio, using a set of socioeconomic factors. An ordinary regression and GWR model are estimated to account for the global and local effects of land uses and capital investments respectively, while controlling for socio-demographical characteristics. The global results indicate that the community opportunity increases as the distance from the city center increases, while The Ohio State University (OSU) has higher positive spillover-effect on near communities than on distant ones. However, the local results appear a local spatially inverse relationship in the areas adjacent to the international airport (CMH), indicating the existence of negative externalities. With the advantage of visualizing spatial variations, the GWR results suggest that the most effective location for allocating future developments is in eastern Columbus, where shows a clustering of higher COI premiums of a percentage change in residential and commercial uses. A variety of spatial variations is found among different capital-investment effects. Therefore, local characteristics require consideration when allocating additional public facilities. Finally, the GWR results reveal the existence of spatial mismatch that socially disadvantaged groups (e.g. black population, other minorities, single-parent families, and zero-vehicle households) tend to reside in vulnerable communities. These local results provide a new perspective on land-use and transportation planning to help shape a fair community opportunity framework for the future.

1. Introduction

Geographical mapping of community opportunity can help examine social inequity, using a spatially aggregated index comprised of a set of socioeconomic factors. This idea is based on the concept of “neighborhood effects” that where people live influences their socioeconomic outcomes (Acevedo-Garcia et al., 2004; Jencks and Mayer, 1990). Using GIS, a community opportunity index can be computed by combining a set of un-weighted standardized neighborhood factors. The term “community opportunity” in the present study refers to the physical and socioeconomic outcomes of a residential community. This approach has been applied for visualizing the spatial opportunity and deprivation in many America's cities (Powell, 2007; Reece and Gambhir, 2008). However, the geographical mapping approach does not explicate how the community opportunity is influenced by social and institutional mechanisms. Particularly, the physical setting of land uses and capital investments (i.e. the built environment) was often overlooked in the past research (Sampson et al., 2002). In addition, it is necessary to apply a spatial statistical approach to better understand the spatial variations of the built-environment effects (Du and Mulley, 2012; Mulley, 2014). Geographically weighted regression (GWR) has increasingly attracted attention on studying such spatially varied relationships over a geographical area (Brunsdon et al., 1996; Paez, 2006; Tu, 2011). Through understanding the local built-environment effects, land-use and transportation planning can help shape a fair community development framework to remedy spatial disparities.

In this study, a community opportunity index (COI) was computed and mapped for Columbus, Ohio. Census tracts were selected as the geographic units. An ordinary regression model was estimated to account for the global built-environment effects, while controlling for socio-demographical factors. A GWR model was also estimated to investigate the spatial variations of the built-environment effects. The explanatory variables were characterized into four groups, including metropolitan-location effects, land uses, capital investments, and socio-demographical characteristics. This study will add to the existing literature by examining the local built-environment effects on community opportunity. In the future, the spatially varied relationships can be used to develop an optimization-modeling framework that would facilitate

* Corresponding author at: Department of Geography and City and Regional Planning, California State University, Fresno, 2555 E San Ramon M/S SB69, Fresno, CA 93740, USA.
E-mail addresses: cwang@csufresno.edu (C.-H. Wang), chen.2572@osu.edu (N. Chen).

http://dx.doi.org/10.1016/j.jtrangeo.2017.05.011
Received 4 December 2016; Received in revised form 5 May 2017; Accepted 28 May 2017
Available online 14 June 2017
0966-6923/

the allocation of future land uses and capital investments, either to maximize the total COI scores, or to minimize COI differences among the 284 census tracts.

The remainder of the paper is organized as follows. Section 2 consists in a literature review. The modeling methodology is presented in Section 3. The data are described in Section 4. The modeling results and their analysis are presented in Section 5. Section 6 discusses how GWR can be used to provide local information for planners. Section 7 presents conclusions and outlines areas for future research.

2. Background

2.1. Community opportunity

The discussion of community opportunity is based on the concept of "neighborhood effects", which originates from a longstanding argument in sociology that where an individual lives matters (Acevedo-Garcia et al., 2004; Jencks and Mayer, 1990). Early applications of neighborhood effects in urban planning studies focused on comparing spatial variations among America's cities. For instance, Hill et al. (1998) defined the term "central city" as the image of America's cities that large municipalities are disproportionately poor and distressed, in terms of their socioeconomic outcomes. In their study, "central city" refers to the discussions on the functions of America's large cities, including the functions done within these cities and the disproportionately concentrated outcomes, such as a central core with poor neighborhoods surrounded by wealthier suburbs. Using cluster and discriminant analyses, they reported that there was wide variation among large cities in the country.

Sampson et al. (2002) examined social-interactional and institutional mechanisms to account for such spatial variation within a city. By reviewing "over 40 relevant studies", they concluded that there are four valid neighborhood mechanisms, including social ties, collective efficacy, institutional resources, and routine activities. Social ties, driven by social capital, refer to social relations and interactions between neighbors (Sampson et al., 2002). The concept of social capital, a resource through social relationships, reflects the connections between people and organizations, including internal and external networks, local mobilization of resources, and willingness to consider alternative ways of reaching goals (Emery and Flora, 2006; Flora et al., 1997). Collective efficacy can be seen as the mutual trust and shared willingness to intervene for the public good (Sampson et al., 1997). An individual is unlikely to intervene in a neighborhood context if the rules are not clear and neighbors fear one another (Sampson et al., 1997). Institutional resources refer to the quality, quantity, and diversity of capital investments in the community, such as libraries, schools, and hospitals (Sampson et al., 2002). Routine activities measure the types of land use at the neighborhood level, such as commercial, industrial, and residential units (Peterson et al., 2000; Sampson et al., 2002; Scribner et al., 1998; Smith et al., 2000).

Additionally, the term "neighborhood effects" is a broad concept with different meanings in disciplines other than urban planning. In social epidemiology and health, for instance, a "neighborhood effect" is defined as the independent causal effect of residential community on any number of health and/or social outcomes (Arcaya et al., 2016; Oakes, 2004; Perchoux et al., 2016). Many studies in health were based on the assumption that individual health is influenced by both individual characteristics and the contexts to which individuals belong (Arcaya et al., 2016; Dundas et al., 2014; Kestens et al., 2016; Perchoux et al., 2016). Among these studies, multilevel modeling appeared to be a widely-used approach to address neighborhood effects at different spatial scales on individual health (Arcaya et al., 2016; Ellaway et al., 2012; Oakes, 2004; Oakes et al., 2015). However, Oakes et al. (2015) reported inconsistences among the findings of such health studies, particularly using data from experimental designs. More importantly, they also asserted that there could be a bidirectional interaction between individuals and their neighborhood.

The focus of this review is on the modeling interface between community opportunity and built environment. Readers interested in social aspects of "neighborhood effects" might usefully consult Hill et al. (1998), Sampson et al. (2002), Oakes (2004), and Oakes et al. (2015). Given the previous discussion, a possible research framework for this study, which examines how land-use allocation and capital investments influence community opportunity, is supported. The basic assumption is that built environment would influence individuals' behavior and therefore facilitate or deter their social and economic activities (Gilliland et al., 2006). In addition, the physical setting of land use and public facilities shape the built-environment of a community, through a series of planning decisions based on local conventions, economic efficiency and social equity considerations, and lobbying (Sampson et al., 2002; Witten et al., 2003). Thus, the findings would allow planners to better understand the relationships between built environment and community opportunity, for promoting a fair community development for the future. The review of past studies on building community opportunity index is presented in Section 2.2, while spatial statistical modeling is discussed in Section 2.3 to support the proposed research framework.

2.2. Geographical mapping of community opportunity

Conceptually, community opportunity can be measured by a broad set of economic and social outcomes (Stimson et al., 2001). Hill et al. (1998) developed a method to test the null hypothesis of homogeneity among large America's cities, using a set of socioeconomic variables. Stimson et al. (2001) applied the same method to identify the community opportunity and vulnerability for large cities in Australia. Variables used in their studies included household income, unemployment rate, income growth, poverty, housing, and population change. Sampson et al. (2002) also pointed out that there is a need to incorporate physical conditions (e.g. vacant houses and neighborhood quality) in such analyses. In addition to the comparisons among cities, some studies focused on the spatial variation within a city. In particular, geographical mapping of the socioeconomic outcomes of a community was widely used to visualize the neighborhood context, including sustainable employment, high-quality education, healthy and safe neighborhood, affordable housing, and equal accessibility. The mapping results can help address how the neighborhood environment influences individuals' future opportunity (Galster and Killen, 1995; Rosenbaum et al., 2002) and provide a possibility for planners to better allocate public facilities and services (Powell, 2007; Reece and Schultheis, 2008).

To fulfill this purpose, a GIS-based approach was used to illustrate community opportunity (Pearce et al., 2006; Wridt, 2010). Particularly in public health, various GIS-based methods were used to measure community resource accessibility, such as the access to local libraries, schools, parks, grocery stores, and pharmacies (Gilliland et al., 2006; Law et al., 2011; Páez et al., 2012; Pearce et al., 2006; Witten et al., 2011). Moreover, variables used for composing community opportunity in recent studies extend from typical socioeconomic factors to other aspects, such as education, child-wellbeing, and mobility and accessibility (Pearce et al., 2006; Reece and Gambhir, 2008; Robert, 1999; Witten et al., 2003). Using GIS, a sum of a set of un-weighted standardized factors (i.e., *Z*-scores) has been applied to visualize community opportunity for many cities, such as Austin, Chicago, Baltimore, Cleveland, New York City, Detroit, Houston, Atlanta, Los Angeles, and Washington DC (Powell, 2007; Reece and Gambhir, 2008). The results were also used in policy advocacy, community organizing, coalition building, and service delivering (Reece and Schultheis, 2008).