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Operationalizing the neighborhood effects of the built environment on travel behavior

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ABSTRACT

Evidence of a connection between the built environment and individual travel behavior is substantiated by multidisciplinary research. In general, compact development patterns exhibiting high concentrations of activity locations and a traditional street design support sustainable travel. However, uncertainty in the magnitude of this connection remains due to how the built environment has been operationalized, usually at a geographic boundary chosen out of convenience. This Portland, Oregon study uses household travel survey data to systematically examine variation in the magnitude of this association when measuring land development pattern, urban design, and transportation system features at various scales. Specifically, this study measures 57 built environment features describing an individual's trip origin and destination at 12 combinations of zonal systems and spatial extents, and assesses their effect on home-based mode choice. First, correlations between individual- and household-level walking behaviors and each combination of indicator and geographic boundary were measured to examine scaling and zoning effects associated with the modifiable areal unit problem (MAUP). These sensitivity test results informed the specification of home-based work and non-work multinomial logit models estimating the effect of sociodemographic, economic, and built environment features on mode choice. Our study findings offer new insight into the MAUP's scaling effect on measuring smart growth indicators and their connection to sustainable travel behavior.

1. Introduction

The transportation-land use connection has an extensive evidence base, with public health research more recently investigating the influence of the built environment on walking or transportation-related physical activity (Saelens and Handy 2008). Early transportation-land use research almost exclusively studied auto-related travel with regional built environment measures; however, the current of practice is to also adopt neighborhood-level indicators to evaluate environmental connections to all transportation modes. A shift largely attributed to the advent of geographic information systems and the pairing of disaggregate land use and household travel diary data (Boarnet 2011). These measurement advancements, coupled with this ascribed multidisciplinary interest, have guided the growth of integrated transportation-land use programs aimed at creating walkable, activity-friendly communities.

Policies and programs that facilitate active transportation or physical activity are generally place-dependent and therefore linked to a person's physical surroundings (Sallis 2009). Yet, conceptualizing the built environment with a set of key indicators reflecting land development pattern, urban design, and the transportation system (Frank and Engelke 2001) remains a complicating factor in quantifying the strength of this stated connection. Although improvements in data integrity and availability support this nontrivial task, many measures remain inadequate for understanding how changes to different built environment dimensions can moderate more sustainable travel behaviors. While reflecting the built environment is an ongoing and challenging endeavor, past studies generally reveal a significant association between the built environment and travel (Ewing and Cervero 2010). However, given the variation in spatial boundaries chosen to operationalize these myriad measures, the extent of any environmental association with mode choice is still somewhat unclear (Clark and Scott 2014).

Inconsistencies in the modeled neighborhood effects of the built environment on travel behavior resulting from measuring a traveler's environmental context with dissimilar spatial boundaries is defined as

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the modifiable areal unit problem (MAUP) (Hess et al. 2001). A methodological issue, arising from representing different measures with varying aggregation levels and zoning systems, which has received inadequate attention in the transportation-land use evidence base (Kwan and Weber 2008). This prospect for scale-related decisions to distort the significance or degree of any theorized interaction also confounds any understanding of how the physical context near each trip end effects an individual's travel behavior.

While recent health-related studies have investigated the impact of the MAUP on connections between walkability indicators and walking behaviors, transportation research has given less attention to the requisite decision of geographic scale selection. Despite a recognition that the likelihood of the MAUP affecting study findings—and therefore creating uncertainty in any modeled relationship—increases with the continued variation in scale and spatial extents (Clark and Scott 2014). In response, a pair of notable studies (Mitra and Buliung 2012; Clark and Scott 2014) started to consider the implications of scale and zoning effects on recognized transportation-land use connections. Extending these efforts, our study seeks to assess the impact of the MAUP in the connection between the built environment and pedestrian travel. Specifically, our study operationalizes an extensive list of built environment measures with a wide range of zonal systems to (a) analyze the connection between travel mode choice and the built environment at varying fixed and sliding scales, and (b) investigate the contribution of the built environment at each trip end for adult travel to work and non-work locations.

2. Literature review

Selecting a spatial scale to represent the built environment is inherent to studies of the transportation-land use connection (Hess et al. 2001). Contextual impacts on travel behavior often stretch continuously across areas, presenting a challenge in dividing its spatial effect into distinct, overlapping, or multilevel analytic units (Openshaw 1983; Kwan 2012). Research has investigated the built environment's impact on travel with measures operationalized with assorted spatial scales (Handy et al. 2002), with few studies experimenting with scale variation (Boarnet 2011). An inattention to scale choice in context measurement may lead to inconsistent study findings and policy implications.

This sensitivity of empirical results to the definition of spatial units for collecting and quantifying these neighborhood effects is termed the MAUP (Fotheringham and Wong 1991). The MAUP has two components, scale and zoning effects, describing the subjective decisions of boundary delineation in reporting contextual effects. Scale effect is the sensitivity of built environment measures to changes in the size of the geographic unit of analysis (Gehlke and Biehl 1934; Openshaw 1983). Therefore, variation in a stated transportation-land use connection may simply be an artifact of adopting smaller or larger scales to reflect land use. Zoning effects arise from the many ways to configure a spatial boundary at each level of aggregation (Jelinski and Wu 1996). This review, structured by measurement of the built environment with fixed or sliding scales (Guo and Bhat 2007; Gehrke and Clifton 2016), describes studies of the built environment determinants of travel that have explored boundary variation.

2.1. Fixed geographic scales

Describing a built environment aspect within a predefined set of distinct, adjoining boundaries represents the application of a fixed geographic scale. Implementation of a fixed zonal system to operationalize built environment measures is typically due to analytical convenience, data availability, and the attractiveness of prevailing hierarchical structures (Kwan and Weber 2008). Fixed zonal systems include administrative, statistical, and artificial boundaries (Gehrke and Clifton 2016). The use of statistical boundaries (e.g., census units) to outline the local environment is pervasive in travel behavior research because of the availability of socioeconomic data at this boundary (Guo and Bhat 2007) and its approximation of a neighborhood unit (Manaugh and Kreider 2013). However, variation in the spatial scale of contiguous statistical boundaries has led an increased adoption of artificial boundaries (e.g., grid cells) that assess the built environment's neighborhood effect by generating a uniformed, synthetic zoning system (Krizek 2003).

Zhang and Kukadia (2005) used three statistical and five artificial zoning systems to operationalize the built environment around an individual's residence to assess its impact on mode choice. Considering three common measures, the authors noted tractable and stable estimates of home-based travel when operationalizing the built environment with artificial boundaries. In an active travel study, Clark and Scott (2014) compared the adoption of statistical and artificial boundaries to operationalize five development pattern, urban design, and transportation system features of the traveler's residential environment. Corroborating the prior study, the authors suggested the MAUP significantly influenced the relationship between the built environment and active travel. Other studies outside the United States (Duncan et al. 2010; Learnihan et al. 2011; Mitra and Buliung 2012) similarly employed statistical boundaries to understand the impact of their adoption for quantifying the neighborhood effect of the built environment on physical activity. Investigating land use mix, Duncan et al. (2010) measured development patterns at four census scales and found adjusting for scaling effects improved the phenomenon's association with walk trip duration. Learnihan et al. (2011) examined the impact of four walkability indicators near the residence on walking for transport and recreation; whereas, Mitra and Buliung (2012) considered the influence of a greater set of contextual indicators near the home location and destination on school-related active travel. Houston (2014) found evidence of zoning effects by using three artificial boundaries to estimate the effects of five environmental measures at home and non-home locations on moderate and physical activity bouts.

Studies examining the MAUP by adopting fixed scales confirm the existence of scaling and zoning effects. Zoning effects result from the seemingly arbitrary placement of a trip end, which may be near the center or perimeter of the partitioned space, inside the unit of analysis (Oliver et al. 2007; Mitra and Buliung 2012). For this reason and the availability of detailed data reducing the scaling effect (Clark and Scott 2014), recent studies have also generally operationalized the built environment with sliding scales.

2.2. Sliding geographic scales

Measuring an individual's contextual surroundings at a given activity location by using objective distance- or time-related boundaries indicates the adoption of a sliding geographic scale (Guo and Bhat 2007; Gehrke and Clifton 2014). Sliding scales offer an individual-centric operationalization of the neighborhood concept that seeks to explain the built environment aspects most likely to affect travel decisions (Gehrke and Clifton 2016). The creation of areal buffers extending from an activity location, a sliding scale application, permits the formation of overlapping spatial boundaries that enable variation in neighborhood delineations. Yet, the assumption that the environment in this circular-unit representation is equally consequential in all directions to the decision-making process and its insensitivity to the physical access constraints presented by nearby natural and artificial boundaries limits the appeal of areal buffers (Guo and Bhat 2007). Network bands, confining the neighborhood boundary to include only the area that an individual can hypothetically travel to along a street network, reflect a more nuanced way to operationalize the built environment with a sliding geographic scale (Frank et al. 2008).

Applying areal buffers and network bands at four extents, Forsyth et al. (2008) found modest relationships between physical activity and housing, population, employment, and activity density at the home