Journal of Transport Geography 66 (2018) 125–134

Contents lists available at ScienceDirect

Journal of Transport Geography

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

Urban development patterns and exposure to hazardous and protective traffic environments

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ARTICLE INFO

Keywords:
Transportation
City planning
Health disparities
Infrastructure
Traffic

ABSTRACT

Estimates of the proportion of the U.S. population living close to high-traffic roads range from four to 19%. These proportions are higher for minority and low-income populations. Although the relationships among traffic exposure, race, and socioeconomic status have been consistent and reproducible, they are spatially heterogeneous and there has been limited investigation into the patterns heterogeneity. Using a spatially-explicit global regression and an exploratory geographically weighted regression (GWR), we examined variation in residential exposure to traffic at regional and neighborhood scales. Race/ethnicity, income, and college attainment are our variables of interest. Consistent with prior studies, we found that minority and lower socioeconomic status are systematically linked to higher exposure to traffic. Furthermore, the GWR approach has the potential to uncover patterns of disparities at a more localized level. However, a richer set of land use variables needs to be evaluated within this framework.

1. Introduction

Research from public health, sociology, geography, and urban planning has called for a deeper examination into how development patterns in metropolitan regions influence health disparities (de Briggs, 2005; Morenoff and Lynch, 2004; Osypuk and Acevedo-Garcia, 2010; Wilson et al., 2008). For example, residential segregation and environmental racism are among the underlying causes of health disparities, and these phenomena can operate through zoning codes, housing markets, and decisions about siting hazardous land uses (e.g., toxic waste facilities and freight centers) (Bullard, 1990; Sampson, 2013; Sanchez et al., 2004; Williams and Collins, 2001; Wilson et al., 2008). In this study, we examined exposure to traffic as another type of built-environment mechanism related to health disparities by race/ethnicity and socioeconomic status.

One motivation for focusing on exposure to traffic generally, as opposed to a specific environmental outcome such as air pollution or noise, is the recognition that exposure to high traffic volumes affects public health in manifold ways. High traffic volumes, in combination with roadway design and land use patterns, generate exposures to air pollution, noise, traffic stress, and safety hazards. In turn, these exposures can lead to adverse health outcomes such as respiratory disease, cardiovascular disease, low birth weight, injury, and depression (Anderson et al., 2012; Babisch, 2014; Gee and Takeuchi, 2004; Morency et al., 2012; Sapkota et al., 2010; Song et al., 2007). In addition, high traffic volumes are a known barrier to walking, bicycling, and access to transit, as well as a contributor to community severance and diminished social capital (Anciaes et al., 2016; Appleyard and Lintell, 1972; Loukaitou-Sideris, 2006). Thus, traffic is a consequential feature in the relationship between public health and the built environment, even in a future scenario where cleaner fuels and vehicles could mitigate air pollution and greenhouse gas emissions.

A second motivation for focusing on exposure to traffic is this metric's salience in transportation planning and regulation. The U.S. Department of Transportation and the Centers for Disease Control and Prevention use proximity to major roadways as a stand-alone public health indicator, not only as a predictor of a specific public health outcome, as it is commonly used in the research context (USDOT (U.S. Department of Transportation), 2017; Maantay et al., 2010). The threshold for being considered a major roadway is 125,000 average annual daily traffic (AADT) movements, because this is the threshold at which federal air quality regulation requires a quantitative hot spot analysis (EPA (Environmental Protection Agency), 2006). However, evidence from public health and urban planning indicates that traffic has adverse effects on public health and social cohesion at much lower traffic volumes and for a variety of issues beyond air quality (Anciaes

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https://doi.org/10.1016/j.jtrangeo.2017.11.014
Received 21 November 2016; Received in revised form 17 November 2017; Accepted 19 November 2017
0966-6923/

et al., 2016; McAndrews et al., 2017; USDOT (U.S. Department of Transportation), 2017). We adopt this traffic-focused orientation, despite its limitations, because it is a policy-relevant point of entry for dialogue about public health, transportation, and equity.

A third motivation is the recognition that exposure to high traffic volumes is not equally distributed across populations. Estimates of the proportion of the U.S. population living close to high-traffic roads range from four to 19%, depending on the definition of road type and assumptions about what defines "close". These proportions are higher for minority, foreign-born, and low-income households (Boehmer et al., 2013; Gunier et al., 2003; Houston et al., 2004; Rowangould, 2013; Tian et al., 2013). In California, for example, children of color are three times as likely as white children to live close to high traffic volumes, and minority and low-income neighborhoods have twice the traffic density of the regional average (Gunier et al., 2003; Houston et al., 2004). Consonant with the traffic-focused policy framework, prior research has calculated exposure with a binary measure of proximity to a high-traffic road (i.e., close or not close, although studies may also use multiple distance categories, e.g., 100, 300, or 500 m away from a high traffic road; (Boehmer et al., 2013; Houston et al., 2004; Rowangould, 2013; Tian et al., 2013).

These previous findings of differential exposure to traffic have been consistent and reproducible, but the specific patterns of differential exposure vary by the scale of analysis and the region. For example, low-income and minority households are, compared to the national average, more likely to live near high-volume roadways. However, at a local scale, there are counties "where no disparities are present, or where disparities work in the opposite direction" (Rowangould, 2013:18). Health geographers have studied related questions of environmental equity, focusing on noise, air pollution and toxic releases (Anciaes, 2014; Brainard et al., 2004; Havard et al., 2009; Mennis and Jordan, 2005). The contribution of the health geography literature is its application of robust, spatially-explicit epidemiological models to investigate the specific spatial distribution of inequity.

We adopted a similar analytical strategy and applied it to the question of traffic exposure itself. In this analysis, we asked two related research questions. First, we asked whether minority race/ethnicity and lower socioeconomic status (poverty and no college degree) associate with higher traffic exposure when adjusting for spatial dependency. We extend previous research on exposure to traffic by representing exposure as a continuous variable, thus avoiding errors due to categorization (such as categorizing a road as "high traffic" based on an arbitrary threshold).

Second, we used geographically weighted regression (GWR), which is an exploratory method, to assess spatial nonstationarity in the relationship between traffic exposure and socioeconomic status. In doing so, we ask whether differential exposure displayed neighborhood- or region-level patterns that would suggest omitted effects, including those related to land use and policy, for future investigation. Although we did not include land use or policy variables in the statistical modeling, the geographic patterns revealed by GWR are critical toward identifying for future investigation relevant policy factors that can influence disparities in exposure, such as the siting of affordable housing developments and the location of redevelopment districts.

2. Data and methods

2.1. Study area

We examine exposure to traffic and population characteristics (race/ethnicity, poverty, no college degree) in the Denver metropolitan region. The Denver metropolitan region is a high-growth urban area in the western region of the United States, and it exhibits land development and traffic pressures similar to those found in other "Sun Belt" metropolitan regions.

In response to development pressures, local governments in the Denver metropolitan region have coordinated investment in transit projects. In 1999, voters approved tax increases to fund 40 miles of light rail along Interstate 25 (I-25), the region's busiest traffic corridor, in addition to an expansion of the interstate itself. In 2004, voters again supported a tax increase to expand the light rail system regionally. Local governments paired this transit investment with supportive land use policy, including zones for transit-oriented development (TOD). The TOD zones not only included new zoning and regulations around transit stops, but they also provided additional funding for affordable housing within the zones. These TOD policies are congruent with national guidelines about sustainable transportation set forth by the Environmental Protection Agency, the Department of Housing and Urban Development and the Department of Transportation (EPA (Environmental Protection Agency), 2013).

TOD zones are one of many land use control instruments outlined in the Denver Regional Council of Government's (DRCOG's) MetroVision plans, including an urban growth boundary for the region and the designation of "Regional and Neighborhood Centers", where zoning allows for greater density than would otherwise be available to developers. Together, these instruments have the goal of managing urban growth by simultaneously decreasing demand for automobile infrastructure (by improving public transportation) and decreasing the amount of land available for greenfield development (by promoting dense development and limiting sprawl). Thus, the Denver metropolitan region provides an example of local governments coordinating and implementing strategies inspired by the smart growth movement. Smart growth, a term for sustainable development that emerged from statewide growth management initiatives, has been adopted by planning, policy, development, and environmental interest groups to describe policies and practices that facilitate development while protecting environmental resources (Godschalk, 2004).

The Denver metropolitan region also includes Boulder County, which has some of the strictest growth management regulations in the nation. Boulder County residents approved the first green space preservation tax in the nation in 1967, and the County has been continually acquiring open space to prevent greenfield urban development since. In this study, we attempt to interpret patterns of traffic exposure in the Denver metropolitan region within the context of the region's unique growth management strategies. Fig. 1 shows the Denver Metro region.

2.2. Data sources

To represent traffic, we used 2010 AADT estimates for each road segment in the 10-county Denver metropolitan region. The DRCOG generates these estimates with an activity-based regional travel model. The activity-based model uses over 10,000 in-depth travel journals, in addition to land use, demographic, socioeconomic, and traffic count data, to estimate the travel demand of households to job and activity centers according to their household characteristics. DRCOG serves as the Denver metropolitan region's federally mandated Metropolitan Planning Organization, and forecasting travel patterns for the region is one of its core functions.

We gathered socioeconomic and demographic data for the region from the U.S. Census American Community Survey (ACS) five-year census *block group* and census *block* estimates for 2006–2010, a data set hosted by the IPUMS NHGIS Minnesota Population Center (Manson et al., 2017). Block groups comprise census blocks; census blocks are the smallest geographic unit for which the U.S. Census collects data. Historically, the block designation reflected city blocks, as well as physical paths of census takers who systematically canvassed all housing units within an area (Census Bureau, 1994). Though the U.S. Census collects demographic information at the block level, it does not collect the socioeconomic information necessary for our study (poverty and no college degree) at the block level, and therefore we use block groups instead. According to the U.S. Census, block groups combine