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Socioeconomic characteristics and crash injury exposure: A case study in Florida using two-step floating catchment area method

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ABSTRACT

The objective of this study is to investigate the exposure of different population groups to severe injury crash hotspots using an empirical-Gaussian two-step floating catchment area (EG-2SFCA) method based on roadway network distances and a socioeconomic-based weighting approach. This is performed by developing a special form of a crash-to-population ratio index that incorporates the severe crash hotspots relative to the locations of populations they might impact. While identifying these hotspots, four different age groups are considered: 17 and younger, 18 to 21, 22 to 64 and 65 and older. For each age group, severe crash hotspots are identified based on the roadway network and the number of severely injured crash occupants that belong to the specific age group. Using these age-specific crash hotspots and the EG-2SFCA method, communities that were exposed to elevated crash injury risk (crash injury exposure) have been identified. Furthermore, from a residential perspective, a socioeconomic analysis is conducted in order to develop a socioeconomics-based crash injury exposure measure. This measure assesses the exposure of different socioeconomic groups to the risk of being injured. Results demonstrated by applying this measure in the Tampa Bay region, FL show that different population groups are under varying risk of being injured depending on their residential location. The developed approach has the potential to be a social fairness measure able to be applied by agencies, which could enhance the well-being of communities that are subject to elevated injury risk.

1. Introduction

The Tampa Bay region in Florida, identified as part of District 7 by the Florida Department of Transportation (FDOT), is an important development zone, where significant growth is planned and expected in the future (District 7 Office, 2016). Population growth will lead to more traffic, and therefore related traffic safety problems associated with the roadways such as crashes. As such, the identification of crash hotspots (high crash risk locations) becomes a critical issue for the populations living near locations where severe injury crashes (involving injuries and/or fatalities) are clustered. Understanding the variable exposure of different socioeconomic groups to these severe injury clusters can help us manage this growth, and develop better transportation plans and policies. Therefore, there is a need to evaluate crash injury exposure, especially those associated with fatalities and severe injuries, accounting for the socioeconomics of the population and available transportation network in the region.

Many previous studies have focused on problems associated with roadway crashes. Among those, several studies looked at the relationships between crash frequency and people's age and demographics given a geo-specific location of the crash involvement (Abdel-Aty, Chen, & Radwan, 1999; Boyce & Geller, 2002; Krahe & Fenske, 2002). These studies confirm that driving behavior can be substantially different between age groups. This behavior is also relevant with respect to different geospatial considerations. Geospatial models have also been used to analyze and visually assess spatial roadway crash data. For example, spatial characteristics and the distribution of crashes on roadway networks have been examined via various methods such as hotspot detection analysis

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and regression models (Dai, 2012; Gundogdu, 2010; Ulak, Ozguven, Spainhour, & Vanli, 2017). Additionally, crashes will have an affect not only on the drivers but also on vehicle occupants. Moreover, Blatt and Furman (1998), Ulak et al. (2017) affirm a common notion that people are usually involved in crashes on roadways where they travel the most. This also implies that people might be involved in more crashes on roadways closer to their homes where they access easily (Burdett, Starkey, & Charlton, 2017). Clearly roadways closer to a given residence would be more likely to be used for trip purposes by the people living in that residence.

Transportation accessibility has also been frequently studied in the literature. Numerous studies focus on defining and measuring people's accessibility to various facilities such as supermarkets (Widener, Farber, Neutens, & Horner, 2015), libraries (Horner, Duncan, Wood, Valdez-Torres, & Stansbury, 2015), nursing facilities (Saliba, Buchanan, & Kington, 2004), multimodal facilities, and regular or special needs shelters. Recently, researchers have also investigated freight accessibility and logistic employment in the U.S. (Van den Heuvel et al., 2014), and accessibility to freight terminals (Cartenì, 2014; Thomas, Hermia, Vanelslander, & Verhetsel, 2003). There also several pioneering studies that focused on a variety of mathematical models. These methods consists of the gravity model (Joseph & Bantock, 1982), regional availability model (Khan, 1992), kernel density models (Guagliardo, 2004), and floating catchment methods (Luo & Wang, 2003; Radke & Mu, 2000). In the literature, accessibility is defined as the volume and proximity of services provided to the population of interest or the services that are available to a certain region or population given the prevailing transportation system. In this paper, a "crash injury exposure" measure is developed, which measures how a region or neighborhood is more or less exposed to crash related injuries compared to others. For this purpose, a measure of accessibility is translated into one that captures crash injury exposure (or 'accessibility', but in a negative connotation since it is about proximity to crash hotspots).

Among the existing methods, the two step floating catchment area method (2SFCA) is very promising in terms of applicability to "crash vs. population" studies. The pioneering 2SFCA studies were conducted by Luo and Wang (2003) and Radke and Mu (2000). Over the last years, several studies have developed methodological improvements to the traditional 2SFCA approach. For example, residential segregation in spatial access to healthcare facilities was investigated in the in metropolitan Detroit area using the catchment method integrating a Gaussian function to continuously discount access within the catchment areas (Dai, 2010). Another study proposed to incorporate a kernel function as part of the 2SFCA method in order to capture the variation in each catchment area for accessibility to food stores in the southwest Mississippi (Dai & Wang, 2011). On the other hand, 3SFCA (three-step floating catchment area method) was proposed to account for a reasonable model of healthcare supply-demand in the Austin-San Antonio area (Wan, Zou, & Sternberg, 2012). The aim was to reduce the overestimation of healthcare demand problem and address potential competition among suppliers. A modified 2FSCA method has been published to account for public transport opportunities using continuous decay functions with a case study in Wales (Langford, Fry, & Higgs, 2012). An early application of variable catchment areas proposed a smoother and continuous distance decay function in Victoria, Australia (McGrail, 2012). The Gaussian function was also used to account for the continuous distance decay, with a focus on the accessibility to vaccine sites for rabies in Sao Paolo (Polo, Acosta, & Dias, 2013). Language barriers and ability of physicians to accept new patients were also evaluated with this approach in Ontario, Canada (Bell, Wilson, Bissonnette, & Shah, 2013). In 2015, a variable catchment method (VFCA) was proposed to conceptualize the accessibility to parks in multi-modal cities using the attractiveness of a park as a measure with a case study in Mecklenburg County of North Carolina (Dony, Delmelle, & Delmelle, 2015). In another study, Luo (2014) introduced the Huff model into the catchment method in order to resolve the effect of distance impedance and supply capacity on spatial accessibility, which was enhanced by Lin et al. (2016). Clearly there are a wide range of applications and extensions to the 2SFCA model, as it can be modified to adapt to a range of scenarios.

Literature suggests that the 2SFCA method generally applies to situations where there are supply-demand interactions such as patients' seeking primary care services. In our study, however, the 2SFCA was applied taking a different approach. To elaborate, the hotspots used in the study, on the one hand, are considered as a hazard that threatens the public health, which is analogous to the "supply" in traditional 2SFCA studies. Population, on the other hand, simply represents the "demand". Therefore, as long as a population group has access to this "supply" (i.e. crash hotspots), that group is exposed to 'danger', and hence has a risk of being injured. Therefore, the 2SFCA approach is utilized to assess this "crash hotspots-population" interaction, and this type of use of 2SFCA method is novel in transportation planning and transportation geography fields. Note that these hotspots could potentially be replaced with any other hazard that threatens public health such as crime, pollutants, or any other technological hazard hotspots (Malleson & Andresen, 2015). The modified model is applied in the Tampa Bay region of FL.

More broadly, the purpose of this study is to investigate the proximity of residents living in neighborhoods to severity-weighted crash hotspots (regardless of the prevailing traffic conditions) rather than identifying roadway sections posing a high relative crash risk or having unexpectedly high numbers of crashes with respect to their overall traffic volume. It is important to emphasize that this is not a crash frequency or crash rate study, in which adopting traffic volume-normalized crash frequencies would be clearly more favorable. Additionally, the study does not focus on the number of trips generated from one point to another, or stated more broadly, the origin or destination of particular trips. In that sense, this study defines "crash injury exposure" as the exposure of the population groups in census units (thanks to the catchment method employed) to the presence of severe crash hotspots that are identified based on severely injured occupants involved in accidents. The socioeconomic-based crash injury exposure measure leads to a weighted "fairness measure" controlling for socioeconomic groups depending on their residential location and, finally the total number of people in each of these groups.

2. Methodology

Three main steps are identified as part of the approach: (a) roadway network-based crash hotspot identification for specific age groups, (b) application of the empirical Gaussian two step floating catchment area method (EG-2SFCA), and (c) evaluation of socioeconomic-based crash injury exposure measure (SECIE). Crash injury exposure is measured by the roadway network distance between the crash hotspot locations and the geometric centroids of the U.S. Census blocks. These values are aggregated to higher spatial scales and used to find a weighed metric for U.S. Census tracts and counties using the socioeconomic data associated with the census block groups. Socioeconomic data are based on the American Community Surveys (ACS) data component and is attached to each block group (ACS, 2010), which is obtained from the Florida Geographical Data Library. Variables related to ethnicity, education level, and the poverty level are collected. In order to visually illustrate the results, crash injury exposure maps are created in