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The effects of roadway and built environment characteristics on pedestrian fatality risk: A national assessment at the neighborhood scale

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ABSTRACT

Characteristics of the transportation system and built environment contribute to pedestrian fatality risks, including vehicular traffic and land-use characteristics associated with higher pedestrian activity. We combined data from FHWA, NHTSA, EPA, and the Census Bureau and performed regression modeling to explore associations between transportation system and built environment characteristics and pedestrian fatalities between 2012 and 2016 at the Census tract scale across the United States. In urban tracts, we found especially strong associations between traffic on non-access-controlled principal arterial and minor arterial roadways and pedestrian fatalities (0.91 and 0.68 additional annual pedestrian fatalities per 100,000 persons per 10,000 VMT/mi^2 increase in traffic density, respectively). In both urban and rural tracts, we also found strong associations between employment density in the retail sector and pedestrian fatalities. Finally, we compared our model to the High Injury Network in Los Angeles, CA. Nearly half (43%) of observed fatalities were identified by both methods, while some fatalities were identified by only one (19% by our model and 23% by the High Injury Network). This work shows that traffic on certain roadway facility types and employment in certain sectors have especially strong associations with pedestrian fatality risk. More broadly, we illustrate how leveraging cross-disciplinary data in novel ways can support prospective, risk-based assessments of pedestrian fatality risks and support integrated and systemic approaches to transportation safety.

1. Introduction

Over the last several decades, traffic fatalities in the United States (US) decreased substantially. However, reductions in traffic fatalities have not been shared equally across transportation modes. Between 2006 and 2014, yearly motor vehicle occupant fatalities decreased by 27% while yearly pedestrian fatalities increased by 3%. Recently, traffic fatalities have risen sharply—from 32,744 in 2014 to 37,461 in 2016—and pedestrian fatalities have accounted for 23% of this increase. (National Center for Statistics and Analysis, 2017a). Pedestrian fatalities now account for 16% of all traffic fatalities in the US, the highest percentage on record (National Center for Statistics and Analysis, 2017b).

A range of policies, including infrastructure-based safety improvements, seat belt laws, and vehicle safety design standards, have prompted historic reductions in motor vehicle occupant deaths (Bunn et al., 2003; Cohen and Einav, 2003). Today, states and metropolitan planning organizations (MPOs) are preparing to set non-motorized safety performance targets as required under the Moving Ahead for Progress in the 21st Century Act (2012). Further, state and local transportation agencies in the US are increasingly integrating pedestrian safety into routine practice (Lyons et al., 2014; Singleton and Clifton, 2017). However, transportation agencies often retroactively designate high-risk areas to prioritize countermeasures—for example, identifying high-risk corridors based on past fatalities (Johansson, 2009). Because pedestrian fatalities are relatively rare events influenced by many factors, retrospective approaches may not sufficiently characterize pedestrian fatality risk. Further, changes in the built environment and transportation system may modify pedestrian fatality risk in ways that could not be anticipated by a retrospective approach. Thus, characterizing associations between pedestrian fatality risk and transportation system, built environment, and sociodemographic

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characteristics may help transportation agencies adopt more forward-thinking approaches to reducing pedestrian fatalities.

Previous studies have sought to characterize pedestrian fatality risk factors at a variety of spatial scales. At the facility scale, specific roadway design elements, such as the presence of sidewalks and crosswalks, have been shown to reduce pedestrian risks (Conway et al., 2013; Das and Sun, 2015; Sarwar et al., 2017). Neighborhood-scale factors, including traffic density, sociodemographic factors, population density, and land use have demonstrated associations with pedestrian risks (Abdel-Aty et al., 2013; Amoh-Gyimah et al., 2016; Cottrill and Thakuriah, 2010; Ukkusuri et al., 2011). Finally, regional characteristics, such as percent of the population walking to work, have also been associated with pedestrian fatalities (Behnood and Mannering, 2016; Jacobsen, 2003). However, the scalability and generalizability of previous studies are often limited. Facility-level studies may use modeled or observed pedestrian and vehicle volumes for specific facilities—data that are unavailable at larger scales. Neighborhood-scale studies often use measures of exposure that are more widely available but less precise, such as population walking to work, and may lack detailed transportation system and/or built environment characteristics. Regional-scale studies do not consider small-scale built environment variations that shape pedestrian behavior, producing findings that are meaningful in the aggregate but have limited usefulness to practitioners seeking to reduce risk in specific contexts. Finally, it can be difficult to discern the individual of effects of transportation, built environment, and sociodemographic factors on pedestrian fatality risk because lower-income neighborhoods often have lower-quality pedestrian environments (Singh et al., 2010). While previous work identified many factors associated with pedestrian fatalities, the limited scalability and generalizability of previous studies restrict their applicability in real-world decision-making contexts.

To address the need for a generalizable pedestrian fatality risk model, we combined elements of facility-level studies (fine-scaled transportation system data) and area-wide studies (built environment data) with geo-coded pedestrian fatality records from the Fatality Analysis Reporting System (FARS) to characterize Census tract scale pedestrian fatality risk across the US. We then applied our model to in Los Angeles, CA and compared our estimates to the city's High Injury Network (HIN). To our knowledge, this is the first study to combine high-resolution traffic, employment, and built environment data with sociodemographic information to characterize neighborhood-level pedestrian fatality risks at the national scale in the US. This work could inform the development of risk-based decision-support tools to help proactively identify high-risk neighborhoods for pedestrians and support estimates of how changes in the built environment and transportation system could shape pedestrian fatality risk.

2. Materials and methods

2.1. Urban/rural tract designation

Because different factors may affect pedestrian fatality risk in urban and rural contexts, we stratified tracts into urban (n = 50,027) and rural (n = 22,711) categories. An urban tract was defined as having > 50% of its area within Census urbanized areas or having a population density greater than 1000 persons/mi^2 (Census Bureau Urban Area Criteria for the 2010 Census, 2011Census Bureau Urban Area Criteria for the 2010 Census, 2011).

2.2. Data sources

We obtained geo-coded pedestrian fatality records, transportation system and built environment characteristics, and sociodemographic data for all Census tracts in the US (Table 1).

2.2.1. Pedestrian fatalities

The FARS database contains records of all traffic fatalities that occur in the US (National Highway Traffic Safety Administration, 2017). We extracted geo-coded pedestrian fatalities that occurred between 2012 and 2016 from FARS (n = 25,615; n = 374 records not included due to missing geo-coordinates) and assigned records to the Census tract in which they occurred.

2.2.2. Transportation system

The Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) contains roadway characteristic information for all public roadways in the US and is updated yearly (Federal Highway Administration, 2016a). Roadway segments in the HPMS are broken into seven functional classifications (FC) based on function and design characteristics: FC1) interstates, FC2) other freeways and expressways, FC3) other principal arterials, FC4) minor arterials, FC5) major collectors, FC6) minor collectors, and FC7) local roads. FC1 and FC2 roadways have full access control while FC3 through FC7 roadways have partial or no access control (Federal Highway Administration, 2013a). States are required to report annual average daily traffic (AADT) to FHWA using uniform methods for all FC1–5 and urban FC6 roadways; however, states may report AADT on rural FC6, rural FC7, and urban FC7 roadways using their own methods (Federal Highway Administration, 2016b). Due to potential variation in AADT reporting between states, rural FC6, rural FC7, and urban FC7 roadways were excluded.

We used HPMS AADT data to calculate average traffic density for all Census tracts in the US by functional classification for each year between 2012 and 2016. To do so, we first multiplied AADT by segment length to estimate average daily vehicle-miles travelled (VMT) for all HPMS segments. Next, we assigned VMT to the Census tract(s) in which road segments are located. Roadways often form the boundaries of tracts, presenting two difficulties in accurately assigning VMT to tracts. First, HPMS line segments that form tract boundaries may be located entirely within one tract or zigzag between adjacent tracts, potentially resulting in arbitrary assignment of VMT to tracts. Second, traffic on a roadway that forms the boundary between two tracts likely contributes to pedestrian fatality risk in both adjacent tracts. To more accurately assign VMT to tracts, we first generated 50 foot buffers around each HPMS segment and calculated VMT density *(VMT/mi^2)* within each buffer b for each roadway functional class, $VMT_{b,FC}$. We then calculated the intersecting area between each buffer b and each tract t, $A_{b,t}$ and assigned the value of $VMT_{b,FC}$ to each area $A_{b,t}$ within buffer b. Tract-level VMT density by functional classification was then calculated by $VMT_{b,FC}$ for n $A_{b,t}$ within each tract:

$$VMT_{t,FC} = \frac{\sum_{i=1}^{n} A_{b,t} \times VMT_{b,FC}}{A_t} \tag{1}$$

Where $VMT_{t,FC}$ is VMT density in tract t for functional classification FC and A_t is the land area of tract t. Finally, we combined FC1 and FC2 into a single category (interstates, freeways, and expressways) because these functional classifications share full access control.

2.2.3. Population walking behaviors

Data measuring walking at the national scale are sparse. Reported walking to work is available in the American Community Survey (ACS) (Census Bureau, 2016a). However, walking prevalence is under-reported in the ACS relative to other surveys that also measure non-commute walking (Whitfield et al., 2015). Individuals who commute to work via public transit also walk more than the general population (Freeland et al., 2013; Mansfield and MacDonald Gibson, 2016). To capture walking prevalence, walking and public transit commuting were obtained from the ACS for each year between 2012 and 2016. Additionally, we obtained built environment measures with demonstrated associations with walking as proxies for non-commute walking: