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Multi-level hot zone identification for pedestrian safety

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ABSTRACT

According to the National Highway Traffic Safety Administration (NHTSA), while fatalities from traffic crashes have decreased, the proportion of pedestrian fatalities has steadily increased from 11% to 14% over the past decade. This study aims at identifying two zonal levels factors. The first is to identify hot zones at which pedestrian crashes occurs, while the second are zones where crash-involved pedestrians came from. Bayesian Poisson lognormal simultaneous equation spatial error model (BPLSESEM) was estimated and revealed significant factors for the two target variables. Then, PSIs (potential for safety improvements) were computed using the model. Subsequently, a novel hot zone identification method was suggested to combine both hot zones from where vulnerable pedestrians originated with hot zones where many pedestrian crashes occur. For the former zones, targeted safety education and awareness campaigns can be provided as countermeasures whereas area-wide engineering treatments and enforcement may be effective safety treatments for the latter ones. Thus, it is expected that practitioners are able to suggest appropriate safety treatments for pedestrian crashes using the method and results from this study.

1. Introduction

According to the National Highway Traffic Safety Administration (NHTSA), both fatalities and fatality rates from road traffic crashes in the United States have steadily declined from 2006 to 2011. Conversely, fatalities resulting from traffic crashes slightly increased in 2012 (NHTSA, 2013). Totally 33,561 lives were lost due to road traffic crashes in 2012. Among these fatalities, the proportion of pedestrian has steadily increased from 11% to 14% over the past decade (NHTSA, 2014). It shows the reason why we must keep focusing on the pedestrian crash issues. There are two perspectives to analyze traffic safety. The first perspective, microscopic safety analysis focuses on specific roadway entities including segments, intersections, corridors and so forth. The microscopic safety analysis aims to find out factors affecting traffic safety risk from geometric design and/or traffic characteristics of the roadway entities, and suggest specific engineering solutions to alleviate this risk. On the other hand, macroscopic safety analysis concentrates on zonal-level traffic safety with zonal characteristics. The macroscopic safety analysis can provide a broad spectrum perspective, and it suggests policy-based countermeasures including enactments of traffic rules, police enforcements, education/safety campaigns, and area-wide engineering treatments. In this study, the multi-level pedestrian safety was explored at the macroscopic level with the objective of providing guidance to policy decision makers to effectively improve pedestrian safety.

Pedestrian crashes have been considered a serious issue and many researchers have conducted pedestrian crash analysis at the macroscopic level (LaScala et al., 2000; Ng et al., 2002; Loukaitou-Sideris et al., 2007; Wier et al., 2009; Cottrill and Thakuriah, 2010; Ukkusuri et al., 2011; Siddiqui et al., 2012; Siddiqui and Abdel-Aty, 2012; Wang and Kockelman, 2013; Abdel-Aty et al., 2013; Lee et al., 2013). LaScala et al. (2000) examined pedestrian injury rates across 149 census tracts in the city of San Francisco. The authors found that the pedestrian injury rates were associated with traffic flow, population density, age composition of the local population, unemployment, gender and education. Ng et al. (2002) revealed that the number of cinema seats, commercial area, flatted factory area, market stall, and MTR catchment area were positively related to the pedestrian crashes. Meanwhile, the greenbelt area, specialized factory area, and school places had negative relationships with pedestrian crashes in Hong Kong.

Loukaitou-Sideris et al. (2007) explored the pedestrian collisions based on census tracts in the city of Los Angeles. They found out that pedestrian collisions are more likely to occur in

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neighborhoods with high population and employment density, high traffic volumes, and a large concentration of commercial/ retail and multifamily residential land uses. Moreover, zones with high concentration of Latino population had a higher chance to have more pedestrian crashes per capita. Wier et al. (2009) investigated pedestrian crashes using 176 census tracts of San Francisco. The authors showed that the traffic volume, arterials without transit, the proportion of land area zoned for commercial and residential uses, employee and resident populations, and the proportion of people living in poverty, were found significant and positively affecting pedestrian crashes. In contrast, total land area (mi^2) and the proportion of population aged 65 or over had negative signs in the pedestrian crash model.

Furthermore, Cottrill and Thakuriah (2010) analyzed the pedestrian crashes in deprived areas with many low-income and minority populations. The authors corrected the under-reporting problem using a Poisson model, and found that the exposure including the suitability of the area for walking and transit accessibility, crime rates, transit availability, income, and presence of children to be significant for pedestrian crashes. Ukkusuri et al. (2011) used census tracts of New York City and discovered several socioeconomic and environmental factors for the frequency of pedestrian crashes using the NB (Negative Binomial) with random parameters model. Siddiqui et al. (2012) found that the roadway length with 35 mph, intersections, dwelling units, population density, the percentage of households with 0 or 1 vehicle, long term parking cost, and total employment had positive relationship with the number of pedestrian crashes, whereas income reduced pedestrian crashes, from their Bayesian Poisson-lognormal model with a spatial error component. Moreover, Siddiqui and Abdel-Aty (2012) estimated pedestrian crash models for zonal interior and boundary crashes, separately. The authors defined a boundary crash if the crash was located within 100 feet from the boundary line, and otherwise the crash was defined as an interior crash. The authors assumed that interior crashes are influenced solely by the characteristics of the zone within which they are spatially located. On the hand, boundary crashes are hypothesized that they are affected by not only the crash zone but also neighboring zones. They pointed out that the models could capture several unique explanatory variables explicitly related to interior and boundary crashes. For instance, total roadway length with 35 mph speed limit and long term parking cost were not significant in the interior pedestrian crash model but they were significant in the boundary model. It was also found that hotel units were positively associated with interior crashes whereas it had a negative sign in the boundary crash model.

Recently, Wang and Kockelman (2013) studied the relationship between pedestrian crash frequency and land use, network and demographic attributes at the census tract level. They revealed that the higher shares of residences near transit stops are associated with pedestrian crash risks. In addition, the provision of sidewalk is

Table 1
Descriptive statistics of the prepared data.

Category	Variable	Mean	Stdev	Min	Max
Target	Pedestrian crashes per crash location ZIP	17.411	22.849	0	227
	Crash-involved pedestrians per residence ZIP	23.779	26.843	0	224
Demographic	Population	19126.5	14561.8	0	72257
	Proportion of children (5–14 years)	0.112	0.037	0.000	0.222
	Proportion of adolescents (15–19 years)	0.065	0.054	0.000	0.974
	Proportion of young people (20–24 years)	0.063	0.049	0.000	0.643
	Proportion of elderly people (65–74 years)	0.189	0.116	0.000	1.000
	Proportion of very elderly people (75 years or older)	0.085	0.063	0.000	0.788
Socioeconomic	Proportion of workers in the tertiary sector	0.780	0.138	0.000	1.000
	Proportion of households without available vehicle	0.027	0.034	0.000	0.462
	Proportion of unemployed people	0.102	0.053	0.000	0.545
	Proportion of households below poverty level	0.169	0.189	0.000	1.000
	Median household income (in $1,000)	50.023	18.796	9.979	250.000
	Whether median year of structure built is before 1984 (yes = 1, no = 0)	0.507	0.500	0.000	1.000
Commute	Proportion of commuters using public transportation	0.017	0.046	0.000	1.000
	Proportion of commuter using non-motorized modes	0.026	0.052	0.000	1.000
	Proportion of commuters by walking	0.019	0.036	0.000	0.444
	Proportion of people working at home	0.054	0.070	0.000	1.000
	Proportion of workers whose commute time is 15 min or shorter	0.263	0.143	0.000	1.000
	Proportion of workers whose commute time is 45 min or longer	0.157	0.108	0.000	1.000
Roadway/traffic	VMT	391498	334027	0	2426838
	Proportion of trucks	0.080	0.051	0.000	0.405
	Proportion of low-speed roads (speed limit: 35 mph or lower)	0.227	0.253	0.000	1.000
	Proportion of medium-speed roads (speed limit: 40–45 mph)	0.402	0.268	0.000	1.000
	Proportion of high-speed roads (speed limit: 55 mph or higher)	0.350	0.311	0.000	1.000
	Proportion of roads with poor pavement condition	0.003	0.016	0.000	0.220
	Number of traffic signals per miles	0.542	0.801	0.000	8.903
	Number of intersections per miles	10.732	29.699	0.000	908.265
Facility/attraction	Number of rail and bus stations per mi^2	0.058	0.774	0.000	19.766
	Number of retail stores (grocery, home improvement, pharmacy, etc.) per mi^2	4.936	9.448	0.000	165.540
	Number of restaurants per mi^2	4.270	11.830	0.000	284.136
	Number of banks per mi^2	0.840	4.297	0.000	128.479
	Number of hotels, motels, and guest houses per mi^2	0.791	3.061	0.000	54.2714
	Number of K–12 schools per mi^2	0.610	1.078	0.000	20.342
	Number of gas stations per mi^2	0.553	0.726	0.000	4.726
	Number of parks and recreation areas per mi^2	0.375	0.777	0.000	6.510
	Number of department stores and shopping malls per mi^2	0.325	0.738	0.000	9.883
	Number of tourist attractions per mi^2	0.310	0.950	0.000	19.766
	Number of colleges and universities per mi^2	0.072	0.362	0.000	7.412
	Number of marinas/ferry terminals per mi^2	0.066	0.256	0.000	4.536
	Number of hospitals per mi^2	0.046	0.176	0.000	3.506