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Spatial investigation of aging-involved crashes: A GIS-based case study in Northwest Florida

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ABSTRACT

This study attempts to understand the unique nature of crashes involving aging drivers, unlike many previous crash-focused traffic safety studies mostly focusing on the general population. The utmost importance is given to answering the following question: How do the crashes involving aging drivers vary compared to crashes involving other age groups? To achieve this objective, a three-step spatial analysis was conducted using geographic information systems (GIS) with a case study application on three urban counties in the Northwest Florida region, based on crash data obtained from the Florida Department of Transportation (FDOT). First, crash clusters were investigated using a kernel density estimation (KDE) approach. Second, a crash density ratio difference (DRD) measure was proposed for comparing maxima-normalized crash densities for two different age groups. Third, a population factor (PF) was developed in order to investigate effect of spatial dependency by incorporating the effect of both number and percent of 65+ populations in a region. This spatial analysis was followed by a logistic regression-based approach in order to identify the statistically significant factors that can help investigate the distinct patterns of crashes involving aging drivers. Results of this study indicate that crashes involving aging drivers differ from other age group crashes both spatially and temporally. Further, the DRD and PF factors are useful metrics to identify and investigate important regions of study. The GIS-based knowledge gained from this research can contribute to the development of more reliable aging-focused safety plans and models.

1. Introduction

Traffic crashes have vital, social and economic consequences for many developed and developing regions that heavily depend on a safe and reliable traffic network. According to the Federal Highway Administration of the U.S. Department of Transportation (NHTSA, 2014), in the U.S., roadway crashes are one of the leading cause of death and injury, and the total societal cost of roadway crashes is more than $230 billion annually. Therefore, studies on traffic crashes are of critical importance to reduce the drastic effects of those crashes on the society. Over the last 25 years, many researchers have recognized the necessity of delving into the nature of the traffic crashes. This necessity arises from the fact that developing methodologies to reduce crashes are vital to provide the public with safe and reliable transportation. From a transportation safety perspective, this problem becomes even more challenging and complex when older drivers are considered, since research has shown that they are more vulnerable to roadway crashes than other age groups (Abdel-Aty et al., 1998; Alam and Spainhour, 2014). Physical and cognitive limitations, slower reflexes, deteriorated visions, and other health conditions due to aging contribute to the escalation of this crash risk for aging drivers (Hellinga and Macgregor, 1999; Merat et al., 2005; Sandler et al., 2015). A thorough review of the literature shows that there is still a gap in terms of investigating the spatial properties of crashes involving aging drivers as well as investigating the significant factors that specifically affect the occurrence of these crashes. Note that by “crashes involving aging drivers,” we mean the crashes involving at least one driver 65 years and older, whether the driver is at-fault or not.

Given the limitations of existing traffic crash studies focused on the aging drivers, this paper develops a GIS-based spatial analysis methodology with the following objectives: (a) to identify the clustering behavior of crashes on a given roadway network, and (b) to discover the geospatial differences between aging drivers and other age groups based on the comparison of high risk crash locations. For this purpose, we first proposed a “density ratio difference” (DRD) approach. Next, spatial dependence of the crashes involving aging drivers was investigated in the form of the effect of spatial distribution of aging populations on the crash occurrences. We investigated this spatial dependency by developing a novel metric called “population factor” (PF). To the authors' knowledge, these have not been done before in the traffic safety/engineering field, which represent the main contributions of this paper. This spatial analysis methodology is applied on three urban counties

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in the Northwest Florida region, namely Leon, Bay and Escambia counties. These counties are documented to have high crash rates with respect to their aging population by the Safe Mobility for Life Coalition in Florida (Sandler et al., 2015). The spatial analysis followed by a statistical analysis to identify the significant factors influencing the crashes involving aging drivers spatially and temporally using a logistic regression-based approach. Aging population living in the vicinity of high crash risk locations are also included as a factor in this analysis. The proposed methodology can enable transportation officials to analyze the significant factors that influence the crashes involving aging drivers, along with the prevalence of occurrence locations of these crashes on the roadway network. This can help decision makers understand the unique nature of crashes involving aging drivers, and differentiate the spatial properties and contributing factors from other age group-involved crashes.

2. Literature review

2.1. Effects of aging on crash involvement

Several researchers have investigated the effects of aging on crashes and traffic safety (Please see Bayam et al. (2005) for an exhaustive review of these studies). A study by Abdel-Aty et al. (1998) showed that driver age was significantly correlated with crash-related factors such as average daily traffic and roadway characteristics. In this study, relative crash frequencies were used instead of actual total crash numbers since the total number of crashes varied with respect to the number of drivers in each age group. The relative crash frequency measure performed better than the actual crash numbers while comparing crashes of different age groups.

Several studies verify that the driving behavior of aging drivers is substantially different than that of other age group drivers (Abdel-Aty et al., 1999a; Boyce and Geller, 2002; Krahe and Fenske, 2002). For example, reckless and aggressive driving was found to be uncommon in older drivers (Jang, 2006; Krahe and Fenske, 2002; Rong et al., 2011). This finding implies that aging drivers tend to avoid risky situations, and adopt a risk-averse driving behavior. Aging drivers were also found to avoid driving at night, during adverse weather, on slippery roadways, during peak hours, long distances, highly congested roadways, and roadways with high speed limits (Baker et al., 2003; Bayam et al., 2005; Collia et al., 2003). Furthermore, Mori and Mizohata (1995) showed that aging drivers drove slowly and preferred large gaps in the traffic. Due to these cautious and risk-averse driving behaviors, aging drivers are often regarded as safer drivers than younger drivers in terms of speeding, speed variation, focusing on roadway, signal usage, and keeping distance gaps (Boyce and Geller, 2002). Furthermore, healthy aging drivers are found to be better or at least at the same level with younger drivers in terms of driving skills (Carr et al., 2016). However, even though aging drivers are experienced, cautious, and risk-averse, challenges such as deterioration in health, reflexes, vision and cognitive skills impose a substantial crash risk on aging drivers.

Aging drivers were also found to have different crash involvement characteristics than drivers from other age groups. For example, aging drivers were found more prone to be involved in a crash while turning left or right, changing lanes, merging into traffic, and approaching intersections than drivers of other age groups (McGwin and Brown, 1999). Similarly, failing to yield the right of way, disregarding unseen objects, unintentionally neglecting stop signs and signals were influential on the crashes involving aging drivers (Abdel-Aty et al., 1999a; McGwin and Brown, 1999). However, some factors such as tiredness (fatigue), adverse weather conditions, speeding, road curvatures, and driving at night were identified as non-influential factors for crashes involving aging drivers in the literature (McGwin and Brown, 1999). Moreover, aging drivers were also less likely to be involved in crashes due to alcohol-drug abuse (Abdel-Aty and Abdelwahab, 2000) than other age groups. Note that these factors are not less influential because aging drivers are more resistant to fatigue, night and/or bad weather conditions, nor they are more agile than drivers from other age groups. The reason is that they tend to drive more attentively than other drivers in those conditions, or they simply avoid driving under these adverse conditions. In sum, unique characteristics of driving behavior and crashes involving aging drivers compel devising specific measures addressing their specific problems and ensuring their safety (Bédard et al., 2002).

2.2. Geospatial crash analysis

There are several studies that consider the use of geostatistical and geospatial methods in order to analyze spatial data such as roadway crashes, and to illustrate them visually on maps. Methods such as Ripley's K-function, Getis's G-statistics or Moran's-I are widely used to investigate whether crashes are randomly distributed or not (Steenberghen et al., 2010). Ripley's K-function can test whether spatially distributed points form statistically significant clusters or not whereas Local Indicators of Spatial Association (LISA) methods like Getis's G-statistics or Moran's-I can disclose specific locations of the statistically significant clusters of points (Getis and Ord, 1992). However, these methods either do not illustrate crash clusters (e.g., Ripley's K-function), or present only specific cluster locations in space (e.g., Getis's G-statistics and Moran's-I) rather than showing the clustering behavior on the roadway network. Kernel density estimation (KDE), on the other hand, is capable of highlighting the clustering behavior of the crashes visually on a roadway network, which is of interest in this study. This ability is important in order to investigate the density of spatial distribution of crashes instead of only identifying the cluster locations or determining the existence of statistically significant clusters. Moreover, a comparison of the local spatial autocorrelation with the kernel methods provided by Flahaut et al. (2003) show that these two methods produce similar results in terms of locations of crash clusters.

KDE has been a widely used method to create density surfaces using spatially distributed point data (Brunsdon, 1995). The KDE method has been used to identify 'hot spots' (i.e. locations with an unusually high occurrence of a particular phenomenon), across a range of disciplines. One such example is identifying crime-related clusters by geographical proximity or hot spots in boroughs or cities (Chainey et al., 2008). Similarly, GIS can be used to analyze roadway crashes in order to identify high risk locations, hotspots and/or clusters (NHTSA, 2015). Indeed, this approach has been implemented for the geo-spatial crash analysis successfully (Erdogan et al., 2008; Kilamanua et al., 2011; Mohaymany et al., 2013). Recently, researchers have also been focusing on the effects of spatial dependence and spatial heterogeneity on the crash occurrences since spatial factors are also very important determinants of crashes (Delmelle et al., 2011; Effati et al., 2015). For instance, Effati et al. (2015) showed that crash severity was highly influenced by the urban development and geographic elevation along a highway corridor.

Two types of KDE approaches can be applied to cluster analysis. Planar (Euclidean) KDE uses the straight-line, "as the crow flies," distance between two incidents to measure proximity. For instance, a planar KDE-based cluster analysis was developed by Sabel et al. (2005) for the spatial evaluation of roadway crashes using GIS. The authors combined the spatial data for average traffic flows with the crash locations, and identified significant crash clusters. Similarly, most of the existing studies use the planar distance-based KDE approach. Because vehicles must follow road networks, relying on planar KDE may cause the following problems: (a) Overestimation: Some roadways that do not possess high risk are shown to be risky, (b) Underestimation: Since multiple roadways are shown as critical locations rather than the actual roadways that have high crash risk, agencies may not show the extra attention needed for the actual high risk locations (Yamada and Thill, 2004). Therefore, a network distance-based KDE approach was developed especially for estimating spatial density of data points distributed along networks (Okabe and Sugihara, 2012; Okabe et al., 2009; Steenberghen et al., 2010; Xie and Yan, 2013). This approach solves