Injury, Int. J. Care Injured 48 (2017) 637–647

Contents lists available at ScienceDirect

Injury

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

Exploring spatial autocorrelation of traffic crashes based on severity

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ARTICLE INFO

Keywords:
Vehicle-related crash
Spatiotemporal clustering
Severity
Spatial statistics

ABSTRACT

As a developing country, Iran has one of the highest crash-related deaths, with a typical rate of 15.6 cases in every 100 thousand people. This paper is aimed to find the potential temporal and spatial patterns of road crashes aggregated at traffic analysis zonal (TAZ) level in urban environments. Localization pattern and hotspot distribution were examined using geo-information approach to find out the impact of spatial/temporal dimensions on the emergence of such patterns. The spatial clustering of crashes and hotspots were assessed using spatial autocorrelation methods such as the Moran's I and Getis-Ord Gi* index. Comap was used for comparing clusters in three attributes: the time of occurrence, severity, and location. The analysis of the annually crash frequencies aggregated in 156 TAZ in Shiraz; from 2010 to 2014, Iran showed that both Moran's I method and Getis-Ord Gi* statistics produced significant clustering of crash patterns. While crashes emerged a clustered pattern, comparison of the spatio-temporal separations showed an accidental spread in distinct categories. The local governmental agencies can use the outcomes to adopt more effective strategies for traffic safety planning and management.

Introduction

Traffic crashes usually increase as the population grows; in other words, fast urban growth and transport infrastructure improvement in developing countries are associated with more dependence on cars. In its turn, this issue results in a large number of road traffic deaths/injuries [1–3]. Traffic have significant impacts on the vehicular traffic flow, since they induce safety concerns and cause traffic delays [4].

Around 1200 thousand people all over the world are killed in vehicle-related crashes annually; between 20 and 50 million become disabled or wounded [5]. These damages are equal to 2.1% of the world's death rate and 2.6% of disability-adjusted life years (DALYs) lost. In this way, poor and middle-income nations annually share about 85% of the deaths and 90% of the DALYs lost due to the traffic crashes [6]. As a developing country, Iran has one of the highest crash-related death rates, with a typical rate of 15.6 cases in every 100 thousand people [7]. Investigations show that 25% of casualties in Iran is due to of unnatural deaths caused by traffic crashes [8]. Human failure is reported as the cause in more than 70% of crashes [9]. Greater reliance on cars and a better quality of life for the Iranian people are linked with the higher crash frequency occurred on the roads and their consecutive impacts [10]. This is estimated to cost more than 7% of the gross national product (GNP). Undesirable social and economic impacts of crashes impose large costs on the society [11].

While numerous studies have investigated spatiotemporal patterns of traffic crashes at different levels, and at area levels such as TAZ [12,13], and the road network with Kernel Density Estimation (KDE) [14–16] and Network KDE [17–19], little efforts have been so far taken for analyzing traffic crashes based on their severity. The novelty of this paper is its focus on different crash types rather than the aggregated crash number.

This paper concentrates on traffic crash patterns at TAZ level in Shiraz, the capital of Fars province, southwest of Iran. The study objectives are: (a) to pattern analyzing and cluster mapping of crashes for identifying hotspots respected to time in Shiraz, and (b) comparing the identified hotspots regarding to the crash type and its severity level.

The rest of the paper is as follows: Section – Literature Review, reviews some background studies; Section – Materials and Methods, introduces the materials and methods applied in this study; Section – Result, presents the main outcomes got from the spatio-temporal analysis of hotspots; and finally, the last section gives a discussion on the findings and draws some conclusions.

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http://dx.doi.org/10.1016/j.injury.2017.01.032
0020-1383/© 2017 Published by Elsevier Ltd.

Literature review

Transportation planners/managers are willing to detect risky zone in their attempts to enhance the road safety level by undertaking risk reduction programs [20,21]. The recognition of risky areas called "*safety black zones*" is the initial step in traffic safety analysis [22,23]. This stage could detect the priorities of investigation localities as the earliest action of the road safety management activities [24].

The spatiotemporal pattern of vehicular crashes and identification of hotspots have progressively been investigated in several researches. Analyzing spatial patterns of motorcycle crashes on Honolulu, Hawaii in 1990, Levine et al., found that most crashes occurred in vicinity of working sites instead of residential areas [25]. In fact, commercial and business areas are positively related with more fatal and injury crashes [26]. In contrast, Kim and Yamashita, discovered that the residential districts were more risky areas, especially during the peak hours [27]. Moreover, Levine et al., found that most deadly or severe injury crashes attributed to late night foolish driving occurred in remote suburban or rural areas instead of urban zones [25]. Scheiner and Holz-Rau studied the connection between the spatial distribution of road crashes and the place of residence in two case studies from Germany (North Rhine-Westphalia and Lower Saxony) [28]. They that the risk of being killed or seriously injured in a road accident is significantly lower for the residences of high-density cores than for the suburban and rural inhabitants.

The study by Wang and Abdel-Aty on the longitudinal crash data and intersection clusters for about 500 signalized intersections along corridors in Florida showed that there was a significant correlation between crash incidence in 2000 and 2002 [29]. A similar study undertaken by Huang et al., used a Bayesian spatial model in Florida for explaining the regional differences in crash occurrence risk after controlling for variables of travel distance and population density [30]. The results confirmed that regions with larger traffic volume, population and activity density were associated with a higher crash records. Higher truck traffic volume is correlated with more severe crashes, and the time spent on the journey to work is negatively associated with all kinds of crash risks. The study of spatial pattern of traffic crashes in Baltimore showed a high density in the central area and neighboring districts, as well as a distribution along the major arterial roads and intersections [31].

Li et al., conducted a GIS-based Bayesian analysis to discover the spatio-temporal pattern of motor vehicle crashes occurred in Harris County, Texas; and they found stability in high-risk segments using the data of four years [32]. Using data from a rural region in Pennsylvania and spatial correlation in road crash analysis, Aguero-Valverde and Jovanis, contributed to the method of crash studies [33]. The spatial correlation model showed to have higher conformity (R-square index) to the data than the Poisson lognormal model. Spatial correlation could also be able to decrease the bias accompanying the model misspecification [34]. Dai, determined crash clusters and some injury risk determinants in pedestrian–vehicle accidents by GIS on the urban districts of Atlanta metropolitan area [34]. The analysis found that high-activity corridors in suburban areas, where wide highways cross residential roads, considerably increased injury risks in crashes in comparison with other locations.

Using spatial autocorrelation functions in GIS, Erdogan et al., identified the crash hotspots in Afyonkarahisar, Turkey [35]. The study, in addition, showed the seasonal correlation among crashes mainly in crossroad of the villages and small towns. August and December were found to be the two most risky months of the year. Moreover, Fridays and weekends appeared to have higher number of crashes happened on a daily analysis. . Conventional quantitative methods and Gi* were integrated in a study of crash hotspots in Konya, Turkey. Hotspots were considered as those areas having either the largest 5% crash frequency or significant Gi* value. The analysis found that using two comparative approaches can enhance the precision of hotspot identification [36].

In other study, Blazquez and Celis, attempted to investigate the temporal pattern of kid's crash data from 2000 to 2008 by applying kernel density function in Santiago, Chile [37]. To this end, they used Moran's I index test for identifying the likely spatial autocorrelation on crash incidence during the day. Having used GIS to detect crash hotspots, Mitra, made an attempt to find out the intersection-level variables affecting the concentration of deadly injury crashes using a spatial regression model [38]. The research discovered that the role of spatial dependency is considerably significant when analyzing vehicle-related crash occurrence. Such spatial dependency was helpful for identifying statistically important clusters of crashes involving fatalities or severe/slight injuries.

The relationship between the crash frequency and socio-demographic characteristics of urban residents has been extensively investigated through the application of spatial autocorrelation techniques [39,40]. Safety concern is more serious for more underprivileged social groups and more deprived geographic areas. The areas with lower income level and job opportunity have higher crash rates relatively compared to the wealthy areas [30]. Explanatory variables such as highway length, road network density, and number of different types of vehicles are shown to be influential in crash level at a macro-scale comparison [41]. Numerous studies have found that crash incidence level is affected by roadway type; hence, arterial roads experience higher crash occurrence [42]. What matters are the spatial effects amongst adjacent samples over time or space that make traffic crash exploration complex [43].

It is believed that this matter often disturbs the independency assumption of statistical models. It is probable to have the correlation between one variable at a location and a dissimilar variable at the adjacent positions. Higher similarity shown through spatial arbitrariness suggests spatially-similar clusters in the two variables, whereas more dissimilarity indicates that the two variables are negatively associated [44]. In other words, traffic crash analyses should simultaneously consider the intervention of space and time in order to identify hotspots properly [12,14,24,45,46].

Materials and methods

Case study area

Shiraz, the capital of Fars province – as the case area for this study – is located in south of Iran and has a population of about 1′750′000 based on the report from the Iranian Statistical Centre [47]. The city covers an area of 17′889 ha with population density of 82 people per hectare. Shiraz faces with traffic problems especially with the intra-urban traffic crashes due to considerably increasing motor vehicle ownership and private car users. One of the significant sources of the intra-urban traffic crash growth is the increasing level of vehicle ownership and usage [15] and decrease in the trend of using other modes such as public transport and non-motorized transport by residents.

Furthermore, in Shiraz, urban development has poorly accommodated the requirements of vulnerable road users. Often motorized transport has been supplied, while choices of public transport and non-motorized modes have been rarely paid attention to. Thus, the rapid rate of the urban and population