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Spatial autocorrelation analysis of cargo trucks on highway crashes in Chile

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ABSTRACT

The growing number of cargo trucks on highway crashes in recent years due to the increase in freight movement in Chile motivates this study to identify the formation of persistent crash clusters on highway *Ruta 5* (R5). Two spatial statistical methods (Moran's I and Getis-Ord Gi*) were used to determine whether crashes on this highway showed spatial clustering over time from a global and local perspective. Globally, recurrent crash clusters are spatially correlated on vertical curves and straight highway sections on northern R5 with different truck types and with the tractor-trailer units during rainy days on southern R5. The local spatial autocorrelation results suggest that the contributing causes related to the loss of control of the vehicle, the fatigue and imprudence of the driver, and crashes involving tractor units with trailer tend to cause persistent rollover crash clusters throughout R5. Overall, clustering of crash attributes with high values (i.e., hot spots) occurring on highway locations with vertical curves and on cloudy days predominated in the northern R5, and the largest number of recurrent hot spots occurred on sunny days along southern R5. A hot spot spatial co-occurrence analysis was further performed to identify the strong relationships between the studied crash attributes, and the crash and injury types as outcomes. The indication of high risk for the clustering of cargo trucks on highways crashes provides a basis for improving highway safety and reduce the associated social and economic costs.

1. Introduction

Cargo trucks on highways (CTH) form a fundamental part of goods transportation and mobilization, and is an important economic component in the United States and the European Union, among others (Islam and Hernandez, 2013; Castillo-Manzano et al., 2016). In the United States, transportation-related goods and services accounted for approximately 10% of the total economy in 2002 (Bureau of Transportation Statistics, BTS, 2004). Similarly, the transportation sector contributed 11.9% of the total economy of Canada in 2008, 7.9% in Mexico also in 2008 (Lopez, 2011), and 3.2% in Colombia in 2011 (Rodriguez, 2013). In Chile, the goods transportation sector represents approximately 4% of total GDP (Ministerio de Transportes y Telecomunicaciones, MTT, 2012). CTH is the main mode of cargo transportation in Chile, accounting for approximately 87% of total annual tons (Instituto Nacional de Estadística, INE, 2014). The majority of land freight traffic occurs along highway *Ruta 5* (R5), which connects the main cities of the country in a north-to-south direction. Between 2010 and 2015, R5 led the annual growth in average vehicular flow by approximately 11% compared to the rest of the nation's highway system, and the flow of cargo vehicles presented an average annual increase of 6.6% on R5 during the same period (Concesionarios de Obras de Infraestructura Pública A.G., COPSA, 2016).

Cargo trucks have distinct operating characteristics, such as high gross weight, long vehicle length, and poor acceleration/deceleration performance that impact crash severity (Chang and Chien, 2013). In the European Union, transportation-vehicle related crashes are the second largest cause of fatal crashes (European Agency for Safety and Health at Work, EU-OSHA, 2010). In 2010, large trucks accounted for 8% of all vehicles involved in fatal crashes in the United States (Pulugurtha and Pasupuleti, 2013). In Taiwan, large trucks were implicated in 9.9% of all fatal crashes in 2005 (Chang and Chien, 2013). Trucks have caused 17.5% of total road crashes and 22% of total deaths in China (Chen and Xie, 2014). In Chile, CTH comprise roughly 6% of the national fleet of vehicles, of which approximately 15% of these vehicles are involved in some type of crash every year (Instituto Nacional de Estadística, INE, 2014). The consequences of these crashes lead to an annual mortality rate of 2%, which is 2.5 times higher than the outcome of crashes involving only light vehicles (Comisión Económica para América Latina y el Caribe, CEPAL, 2010). Among all highways in Chile, R5 has the highest annual average crash rate reaching nearly 30% between 2010 and 2014 with 24% of these crashes involving CTH.

In addition to the fatalities as a major aftermath of truck-involved crashes, these crashes represent significant costs such as loss of

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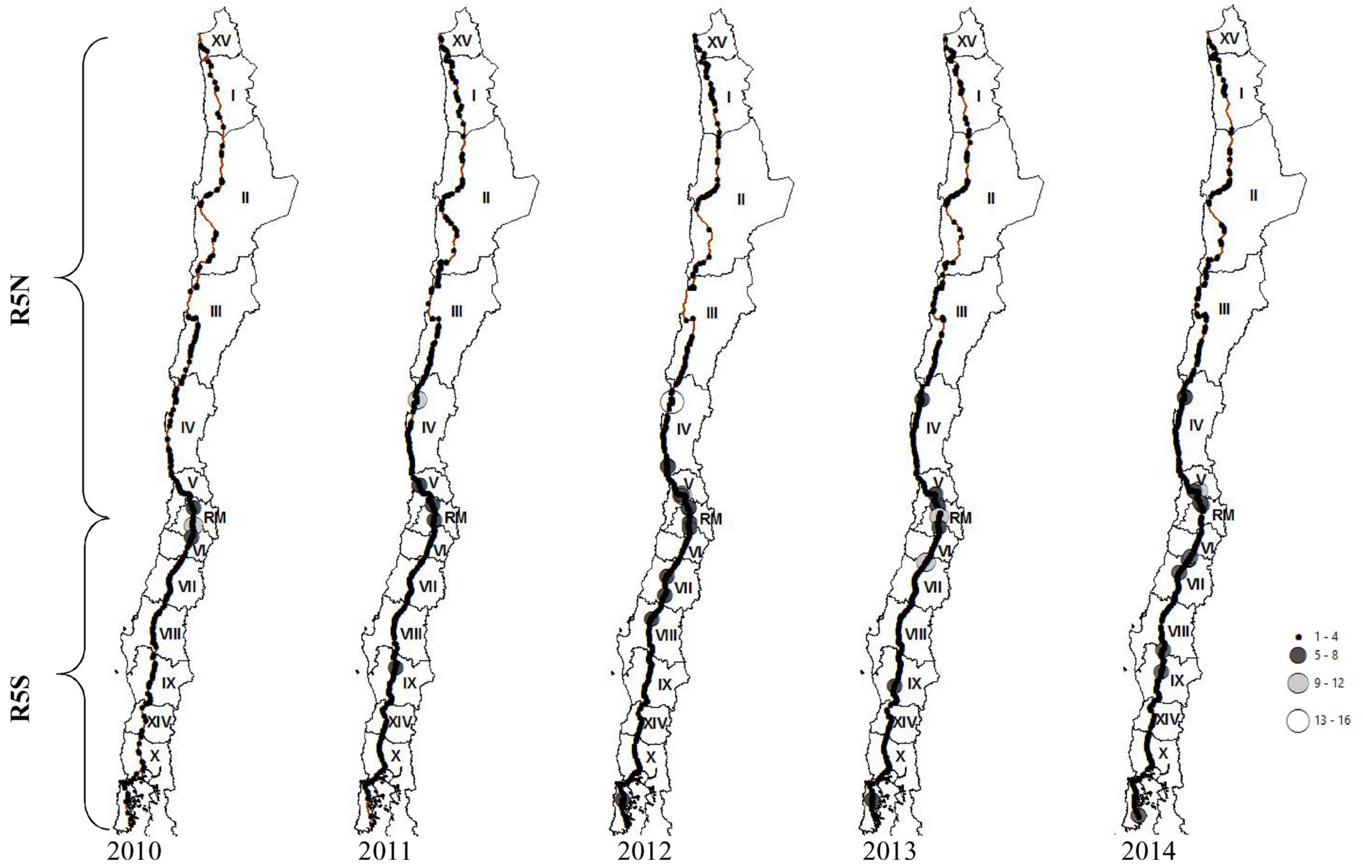

Fig. 1. CTH crashes on R5 during the period of 2010–2014.

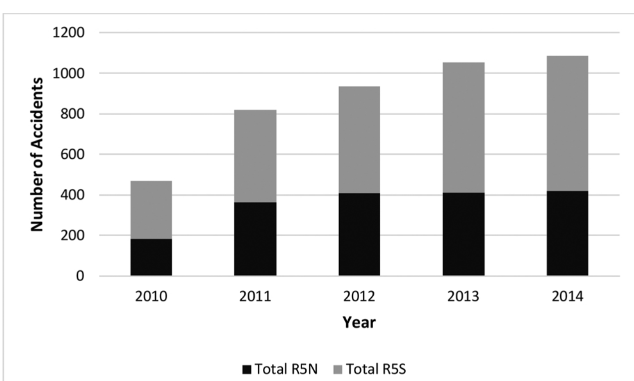

Fig. 2. Number of CTH accidents for R5N and R5S during the 2010–2014 period.

productivity, medical costs, property damage costs, and social costs associated with the deaths or injuries of main income-earners in a family (Zaloshnja and Miller, 2004). Moreover, CTH crashes detain the flow of cargo causing disruptions in the supply chain and yielding costly operational delays. The costs associated with CTH crashes demonstrate the need to increase safety in trucking operations. In Chile, CTH drive the national economy through the daily movement of freight on R5, and it is expected to continue to rise in the future. Due to the relevance of CTH in Chile and the safety concerns they pose, crash statistics must be comprehended and recurrent hazardous locations along R5 must be identified. This study is motivated by the idea that these crash locations on R5 may represent persistent spatial structures (clusters) for certain crash characteristics such as type of crash and contributing cause.

The crash analysis of cargo trucks has been studied in the literature using a variety of econometric approaches such as regression trees, multinominal logit, ordered-probit, and tobit regressions (Castillo-Manzano et al., 2016; Chang and Chien, 2013; Khattak et al., 2003; Khorashadi et al., 2005; Islam and Hernandez, 2013, 2016; Naik et al., 2016; Pahukula et al., 2015; Zhu and Srinivasan, 2011). Other studies have applied spatial statistical methods to analyze patterns of highway crashes that involve this type of vehicles (Chien et al., 2002; Eckley and Curtin, 2013; Harkey, 1999; Pulugurtha and Pasupuleti, 2013; Teoh et al., 2017; Yalcin and Duzgun, 2015). Among different existing spatial statistical methods, spatial autocorrelation analysis has been employed to characterize the degree of spatial associations in different fields such as economy (Kondo, 2015), health (Kao et al., 2017), geology (Sarp and Duzgun, 2015), and environment (Meng, 2016). This type of statistical analysis has also been widely used to identify spatial clusters in traffic safety research. Some studies employ the Moran´s I statistic to distinguish crash clusters with high or low values globally by providing a single value of the spatial autocorrelation. For example, Blazquez and Celis (2013) and Truong and Somenahalli (2011) employed Moran's I to determine the overall clustering of pedestrians crashes in urban areas. Mitra (2009) detected statistically significant clusters of crashes resulting in fatalities or severe injuries also using global Moran's I index. Dezman et al. (2016) evaluated the spatial association between traffic crashes and socioeconomic indicators at the census tract level using global Moran's I.

Other research use the Getis-Ord Gi* statistic to differentiate between crash cluster locations with high or low spatial associations (i.e., hot spots). For instance, the Getis-Ord Gi* statistic was employed by Choudhary et al. (2015) to perform a local spatial autocorrelation of the road crash in India, which yielded improved results when compared to Kernel Density Estimation. Another study by Khan et al. (2008), Getis-Ord Gi* was used to identify significant patterns of weather-related crashes in the State of Wisconsin. Songchitruksa and Zeng (2010) also