Accident Analysis and Prevention 106 (2017) 243–253

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Investigating articulated heavy-vehicle crashes in Western Australia using a spatial approach

Ori Gudes[a,*], Richard Varhol[b], Qian (Chayn) Sun[c], Lynn Meuleners[d]

[a] City Futures Research Centre, Built Environment, The University of New South Wales, Sydney, NSW, 2052, Australia
[b] Department of Health Policy and Management, School of Public Health, Faculty of Health Sciences, Curtin University, Perth, WA, 6845, Australia
[c] Department of Spatial Sciences, Faculty of Science and Engineering, Curtin University, Perth WA, 6845, Australia
[d] Curtin Monash Accident Research Centre (C-MARC), Faculty of Health Sciences, Curtin University, Perth, WA, 6845, Australia

ARTICLE INFO

Keywords:
Spatial analysis
Emerging hotspot analysis
Articulated heavy vehicles
Western Australia

ABSTRACT

Background: Recent developments in Western Australia's economy including widespread traffic congestion as well as road safety issues are increasingly becoming prominent. Previous studies relied on traditional statistical methods to investigate patterns and characteristics of motor vehicle crashes. Although useful, statistical analysis alone is incapable of providing a spatial context and is therefore unable to associate existing crash characteristics with a spatial distribution.
Aims: To identify concentrations or "hotspots" of articulated heavy vehicle crashes in WA between the years 2001–2013, by using a spatial analysis approach.
Methods: Spatial modelling and spatio-temporal analytical methods such as Emerging Hotspots were used to identify emerging hotspots on specific roads in Western Australia using the Integrated Road Information System (IRIS).
Results: The results suggest that the majority of articulated heavy vehicles crashes occurred in the vicinity or within the Perth metropolitan area. Based on spatial-temporal trend analyses, our findings highlight some regions that are emerging as areas of interest.
Discussion: This study was one of the first attempts to adopt a spatial analysis approach in studying heavy-vehicle crashes in Western Australia. Applying spatial methodologies to road safety data has the potential of obtaining previously undiscovered insights, which can be extended further, and provide future avenues to research in this field.

1. Introduction

The recent developments in Western Australia's (WA's) resource-based economy has resulted in an increase in traffic congestion, which has significant impacts on road safety and has increasingly garnered widespread attention (Palamara et al., 2013). In WA, there were 6391 heavy-vehicle crashes involving 12,460 casualties officially reported between 1990 and 2003; 69% of these crashes involved casualties other than the occupants of a heavy vehicle (Meuleners et al., 2006). The consistent yearly increase (NTARC, 2015) in WA's heavy-vehicle crashes highlights the need to investigate this from a variety of perspectives to help reduce potentially preventable road fatalities. To that end, a diverse range of road-related information, collected by regional road authorities, has enabled statistical analyses to be conducted using a cross section of analytical methodologies. Although useful in its own right, statistical analysis alone is incapable of providing a spatial context and therefore it is challenging to associate existing crash characteristics with a spatial distribution, e.g. identifying the spatial concentrations of vehicle crashes. Crash rates can be deduced through specific actions carried out at high-volume accident sites. However, it is possible that due to the complexity of the vehicle crashes it may require a more elaborate analysis (Tiwari et al., 2005), which could provide more definitive results to support efficient decision-making.

Recent techniques have been based on the use of Geographic Information Systems (GIS), allowing the generation of maps, models and risk estimates from a spatial perspective. This approach has been used: to explore different spatial and temporal visualisation methods to reveal patterns and significant factors relating to vehicle crashes; to identify hotspots; or as a management system for crash analysis (Cantillo et al., 2016). Adopting a spatial analytical approach to investigate crashes is not new to the field of GIS (Chen, 2012; Plug et al., 2011; Bíl et al., 2013; Prasannakumara et al., 2011). A number of recent

* Corresponding author.
E-mail address: o.gudes@unsw.edu.au (O. Gudes).

http://dx.doi.org/10.1016/j.aap.2017.05.026
Received 15 June 2016; Received in revised form 10 April 2017; Accepted 28 May 2017
Available online 21 June 2017

studies involved GIS in investigating traffic crash patterns in spatial or spatial-temporal dimensions. For instance, Erdogan et al. (2008) provided an overview of vehicular crashes in Turkey by showcasing how GIS systems can aid in taking precautionary steps to prevent traffic crashes on highways through the identification of "hotspots"—where crashes occur most frequently. One of the challenges these authors faced was that traffic crash reports were text-based, rather than having categorical, clearly-defined, well-structured data. This made it difficult to analyse these crash reports. To leverage information in these reports, Erdogan et al. (2008) explained how a system was developed to transform this textual data into a tabular form, from which data was geo-referenced into a highway network. Hotspots were subsequently identified and determined using two different methods: 1) Kernel Density Analysis, and 2) Repeatability Analysis. It was found that the identified hotspots were often associated with road features such as roundabouts, junctions and crossings. Spatial allocation of traffic crashes, together with their associated and accumulated statistical data, were analysed by road authorities to help find solutions within these problematic areas. For instance, the authors were able to use these data to identify crash conditions at the hotspot locations. Some of the variables analysed included driving conditions such as: time of year (summer, winter etc.); time of day (morning, afternoon, evening); day of the week (Monday, Tuesday etc.); causes (such as carelessness, hit from behind, speeding, disobeying traffic signs and lights, improperly overtaking other vehicles); and hotspot type (including crossroads for villages and small cities, hairpin turns, slippery areas during wet seasons and junctions).

Another study (Cela et al., 2013) provided a comprehensive overview of traffic crash data in Serbia. The authors were able to analyse the spatial patterns of crash locations within the network by utilising network methods such as Network K-function and the Network Kernel Density Estimation. The novelty of their work was the application of the Network Kernel Density Estimation, which enabled the authors to identify actual cluster locations of crashes (see also Okabe and Sugihara, 2012). In addition, Cela et al. (2013) found that road crashes were primarily explained by road conditions and time.

A methodological paper authored by Quddus (2013) focused on the relationship between average speed, speed variation, and crash rates using spatial statistical models and GIS. The results showed that speed was not associated with crash rates when controlling for other factors such as traffic volume, road geometry and number of lanes. Speed variation, however, was found to be statistically significant and positively associated with crash rates. In a later publication, which investigated spatial patterns of single-vehicle crashes in WA, Plug et al. (2011) reviewed traffic crashes over a nine-year period (1999–2008) to identify possible reasons for crashes based on location and time in particular hotspot regions. By utilising both spatial and temporal hotspots illustrated by Kernel Density Estimation and star graph methodologies, including a combination of the two, through the use of spatial-temporal approaches, the authors were able to show the changes of accident patterns during certain time periods. The limitation of the study lies in the isolation of the temporal visualisation from spatial distribution by spider graphs.

To date, the extent to which GIS approaches can be used in an attempt to understand articulated heavy-vehicle crashes across WA has not been documented. Moreover, few studies have gone beyond the conventional hotspot analysis to provide not only the spatial, but spatial-temporal patterns. The aim of this study was to identify hotspots of heavy-vehicle crashes that occurred between 2001 and 2013 by location, using a set of spatial statistical visualisation and modelling techniques. In order to achieve the aim of this study, three spatially-related research questions were identified:

- Which State roads have the highest crash rates?
- Where are the high concentrations (hotspots) of articulated heavy-vehicles crashes across State and non-State roads?
- What are the trends in time and space of articulated heavy-vehicle crashes (spatial-temporal patterns)?

2. Methods

In this study, a retrospective analysis of articulated heavy-vehicle road crashes in WA from 2001 to 2013 was undertaken using a GIS approach. Vehicle crash data and related spatial data from various sources were imported into an ArcGIS database for management and analysis. Guided by a Spatial Intelligence Framework, which defines the technical approaches, two steps of data analysis were developed including: 1) million vehicle kilometres travelled (MVKT) measures, and 2) categorising space-time patterns using the Emerging Hotspot Analysis tool (by employing the ArcGIS Pro software by ESRI). The categorised spatial-temporal patterns of heavy-vehicle crash patterns across the metropolitan, regional and remote areas of WA were then analysed, modelled and visualised.

2.1. Data collection

Primary data was obtained from local road authorities. One limitation of the dataset was that there was no information pertaining to the time of year (i.e. season) during which the road volume and crash data was collected over the 10-year time frame. For the purpose of this research it has been assumed that the data collection was undertaken at any time of the year, accounting for all weather periods. Peak traffic periods such as national and State holidays were not treated differently to non-peak times of the year. To account for varying peak periods, traffic volume for both road segments and total road lengths were normalised by the use of the MVKT metric, which focuses on the average volume of traffic within a particular distance, multiplied by each million vehicles travelling. Traffic volume and road information provided to the research team was broken down into 1601 road segments, representing 495 roads in WA. To assess an indicator related to travel exposure, the MVKT was calculated for each segment of the road to identify the volume of both regular and articulated heavy-vehicular traffic (refer to the Appendix A for a sample calculation). Road segments vary in length and therefore tend to skew the results when vehicular traffic is included. In this study, road segments were aggregated to total road distance and the data smoothed or visualised to account for the spatial variation. Road crash data used in this study was obtained from the Integrated Road Information System Crash Database (IRIS), which contains information an all road crashes reported to WA Police and is maintained by Main Roads WA. The IRIS database contains detailed information on the characteristics of the vehicles involved in road crashes, crash circumstances, police reported injury and road information related to the crash location. The dataset represented 2828 articulated road-crash locations on non-State roads and 5136 on State roads from 2001 to 2013. Additional information provided by the IRIS database included location, month, date, day, time, vehicle type, crash severity and type of crash. A separate dataset supplied by Main Roads WA provided information pertaining to traffic volume for both individual road segments (1601) and for 495 State roads within WA. Information from both datasets was utilised to generate normalised crash rates across WA. Next, the accumulated traffic volume data that was provided reflecting WA State roads volume of traffic. Delineation of the total dataset into smaller datasets, based on available traffic volume, is an important distinction, especially in relation to policy recommendations. In WA, the majority of State road funding and maintenance of highways and main roads (with the exception of the Commonwealth's funding contribution towards the National Land Transport road network) is the responsibility of the State Government (*Main Roads Act 1930*; Main Roads Western Australia, 2011). Since the volume of traffic was available for State-road locations, it was possible to account for traffic and calculate the rate of crashes per MKVT on State roads.