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The relationship between urban street networks and the number of transport fatalities at the city level

Mehdi Moeinaddini *, Zohreh Asadi-Shekari, Muhammad Zaly Shah

Department of Urban and Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

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ABSTRACT

There are factors that impact traffic safety and the number of accident-related fatalities, such as street users, environment, road design and vehicle characteristics, but there have been limited studies that examine the relationship between street network factors and traffic-related crashes and fatalities at the city level. Therefore, this paper focused on this relationship by introducing urban street network variables, such as blocks per area, nodes per selected areas and length of roads and motorways, as independent variables and the number of fatalities as the dependent variable. This study used Open Street Maps (OSM) and International Association of Public Transport (UITP) data from 20 cities around the world. The number of blocks per area and nodes per selected areas resulted from modifying and analyzing OSM maps in ArcGIS software. The strength of the relationship in this study was found using generalized linear modeling (GLM). The findings of this research indicated that increases in fatalities are correlated with an increasing number of blocks per area, number of nodes per selected areas and length of the motorways.

1. Introduction

Annually, road traffic crashes cause over 1.2 million deaths and more than 50 million severe injuries worldwide (WHO, 2009). The number of traffic crashes has increased in recent decades, especially in developing countries, and statistics show that approximately 70 percent of traffic-related deaths occur in these countries (Augustus, 2012). For example, between 1975 and 1998, the number of road traffic deaths per capita increased over 200% in Colombia and Botswana and by 44% in Malaysia (Kopits, 2004). This issue is different in high-income countries. Over the same period, traffic fatalities per person decreased by amounts ranging from 25% to 50% in most European countries and by 60% in Canada and Hong Kong (Kopits, 2004). The Fatality Risk (Deaths/100,000 Persons) is estimated to be 7.8 in 2020 in high-income countries, and this rate may be between 14.9 and 31 in other regions (Kopits, 2004). Therefore, concerns about traffic safety are very serious in developing countries and still exist in developed countries.

Ample studies have been devoted to evaluating the effects of specific safety factors, such as speed limits (Eluru et al., 2008; Abdel-Aty et al., 2007; McCarthy, 2001; Snyder, 1989), helmet laws (Lapparent, 2005; Sass and Zimmerman, 2000), seat belt laws (Evans, 1986; Wagenaar et al., 1988) and alcohol control policies (Mann et al., 2001; Ruhm, 1996; Whetten-Goldstein et al., 2000; Dee, 1999; Wilkinson, 1987), on traffic fatalities based on within-country data. Alcohol consumption, location of crash, speed, street conditions (lighting), time of day and day of the week, hit-and-run crashes, pedestrians and driver age are also some important factors that influence pedestrian fatalities in the US (Shankar, 2003).

Permpoonwiwat and Kotrajaras (2012) concluded that policy (government budget for road safety), personal and socio-economic (health and safety, economic growth, income and education), demographic (vehicle kilometers traveled, age and gender), and geographic (population density) factors influenced the fatality rates for motor vehicle accidents in Thailand in 2006–2009. In India, increased enforcement of road traffic rules can decrease road traffic crash fatalities (Grimm and Treibich, 2012).

Generally, accidents involve damage to vehicles and potential loss of human life, in addition to causing travel costs as a result of delays in traffic (Hadayeghi, 2002). The causes of motor vehicle crashes are multi-faceted and involve the interaction of a number of pre-crash variables that include humans, vehicles and road conditions (Augustus, 2012). Because there is no single variable that will reduce road crashes and fatalities, employing engineering, enforcement and education with a focus on both motorized and non-motorized users is a comprehensive approach.

The purpose of this paper was to:

1. Review the literature concerning macro-level collision prediction models.
2. Estimate the relationship between urban street networks and the number of transport fatalities across different cities.

* Corresponding author. Tel.: +60 129410543.
E-mail address: mmehdi2@live.utm.my (M. Moeinaddini).

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3. Demonstrate the use of macro-level models in a city level planning process.

Only a few efforts have been undertaken to quantify and assess traffic safety impacts in the planning process at the city level (De Leur and Sayed, 2001). Collision prediction models at the community-based macro-level would improve the road safety analyses that are used by engineers and planners (Hadayeghi et al., 2003; Guevara et al., 2004). Some studies have developed macro-level collision prediction models to provide empirical tools for engineers and planners to conduct proactive road safety planning (Hadayeghi et al., 2003; Guevara et al., 2004; Hadayeghi et al., 2010a). In one of the early studies on urban form factors and traffic safety, Augustus (2012) proposed a model that used the length of roads (in km), the presence of a road safety corps (special traffic police in Nigeria) and population as independent variables and the number of road traffic accidents as the dependent variable in Lagos from 1970 to 2001. Although this model suggests considering two urban design factors, these indicators are not strong enough to illustrate urban street patterns on a macro-level scale at the city level.

Rifaat et al. (2011) proposed the effect of street patterns on the severity of crashes involving vulnerable road users. In this study, street patterns were classified into four categories: grid-iron, warped parallel, loops and lollipops, and mixed patterns (refer to Fig. 1). This classification divided the city into different precincts. The results of this research showed that, compared to other street patterns, the loops and lollipops design increased the probability of an injury but reduced the probability of fatalities and property damage-only incidents in the event of a crash. However, it should be considered that the areas of these precincts may affect the results regardless of street patterns.

Marshall and Garrick (2011) focused on how some aspects of overall community design might affect road safety at city level. The aim in this research was to identify how the characteristics of the street network, such as street network density, street connectivity and street network patterns, can have an impact on road safety outcomes. This study concluded that road safety outcomes are affected by street network characteristics. They proposed a spatial analysis of crash data in 24 medium-sized California cities. Noland (2003) also found that increases in the total lane miles, the average number of lanes on collector roads, and the percent of collectors with lanes 12 feet or wider was correlated with an increase in total fatalities in the US.

Some researchers have developed empirical road safety planning tools and macro-level collision prediction models at neighborhood level (e.g., Hadayeghi et al., 2003; Lovegrove, 2007; Lovegrove and Sayed, 2006a). Hadayeghi et al. (2010b) and Hadayeghi (2009) considered different types of data, including street networks, land use, traffic demands, socioeconomic and demographic characteristics, dwelling units, and employment, in the city of Toronto to reduce the number of collisions and, consequently, improve safety. Hadayeghi (2002) proposed that the number of households, major road kilometers, vehicle kilometers traveled, intersection density, posted speed and volume/speed ratio can impact accident occurrence. He proposed models for predicting the number of accidents per zone in the city of Toronto.

Wei and Lovegrove (in press) proposed an empirical tool based on four groups of data as independent variables including exposure, socio-demographics, transportation demand management and road network in evaluating the safety of cyclists. These variables are not usually considered at the micro level (Khondakar et al., 2010). Detailed descriptions of these four groups are given

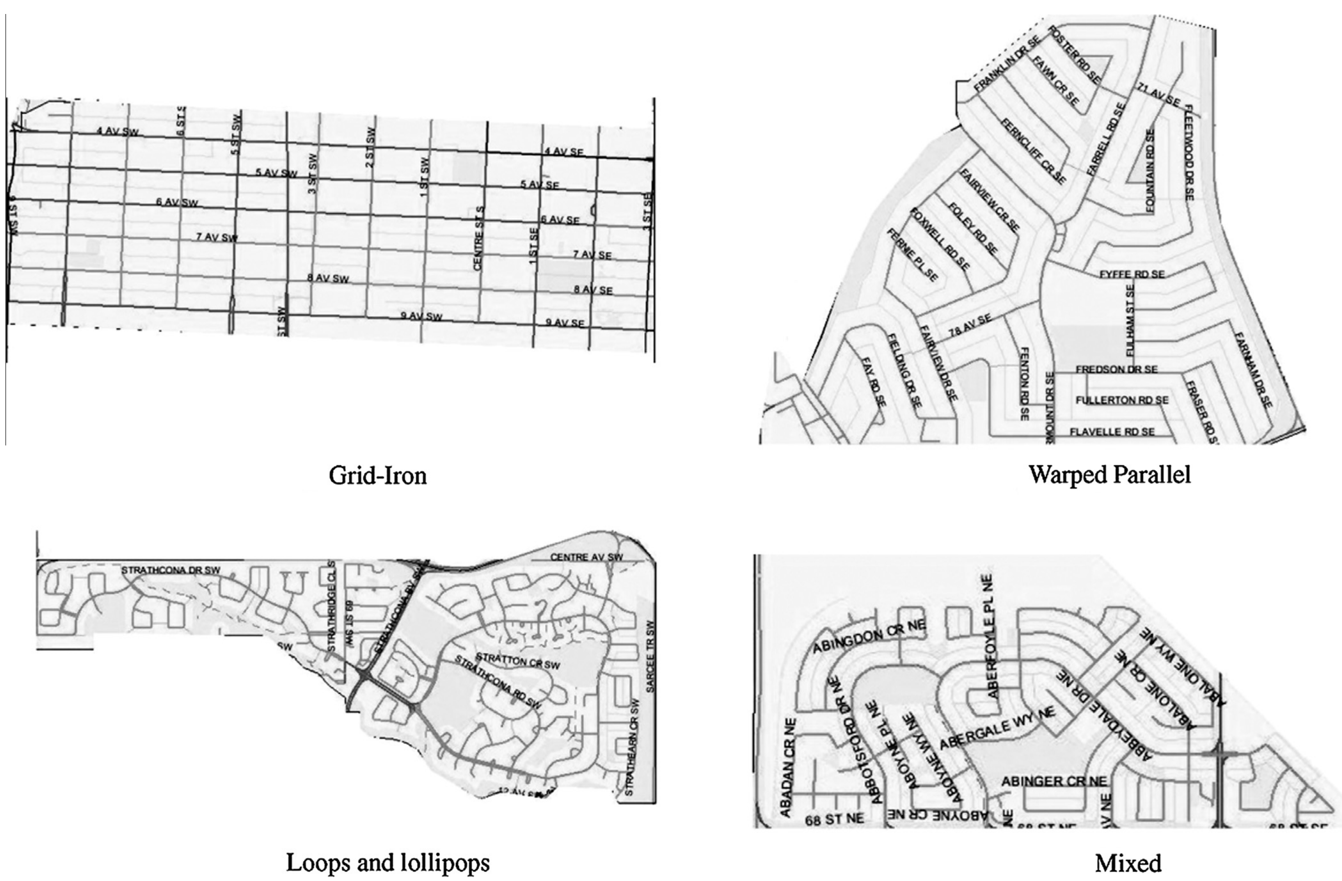

Fig. 1. Examples of street patterns (Rifaat et al., 2011).