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The link between built environment, pedestrian activity and pedestrian–vehicle collision occurrence at signalized intersections

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ABSTRACT

This paper studies the influence of built environment (BE) – including land use types, road network connectivity, transit supply and demographic characteristics – on pedestrian activity and pedestrian–vehicle collision occurrence. For this purpose, a two-equation modeling framework is proposed to investigate the effect of built environment on both pedestrian activity and vehicle–pedestrian collision frequency at signalized intersections. Using accident data of ambulance services in the City of Montreal, the applicability of our framework is illustrated. Different model settings were attempted as part of a model sensitivity analysis. Among other results, it was found that the BE in the proximity of an intersection has a powerful association with pedestrian activity but a small direct effect on pedestrian–vehicle collision frequency. This suggests that the impact of BE is mainly mediated through pedestrian activity. In other words, strategies that encourage densification, mix of land uses and increase in transit supply will increase pedestrian activity and may indirectly, with no supplementary safety strategies, increase the total number of injured pedestrians. In accordance with previous research, the number of motor vehicles entering a particular intersection is the main determinant of collision frequency. Our results show that a 30% reduction in the traffic volume would reduce the total number of injured pedestrians by 35% and the average risk of pedestrian collision by 50% at the intersections under analysis. Major arterials are found to have a double negative effect on pedestrian safety. They are positively linked to traffic but negatively associated with pedestrian activity. The proposed framework is useful for the identification of effective pedestrian safety actions, the prediction of pedestrian volumes and the appropriate safety design of new urban developments that encourage walking.

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1. Introduction

Non-motorized transportation (NMT) such as walking is essential for the development of sustainable transportation systems, whether for short trips, access and egress to/from motorized modes (especially transit) or recreation. As recognized in the literature, NMT can offer substantial benefits in countries like the United States and Canada by reducing automobile traffic, reducing energy consumption and emissions, and improving health and fitness (Dora, 1999; Woodcock et al., 2007; Krizek, 2007). Furthermore, an increase in the provision and use of public transit is likely to increase walking and thus the number of pedestrians (Vuchic, 1999; Besser and Dannenberg, 2005; Woodcock et al., 2007).

In spite of the importance and benefits of walking, road facilities in urban areas are still a significant source of harm to pedestrians. Every year, a large number of pedestrians are killed or seriously injured in crashes involving motor vehicles. In the United States, nearly 4800 pedestrians died (representing approximately 11% of the total road fatalities) while about 70,000 suffered non-fatal injuries each year from 2003 to 2006, most of them being injured in urban settings (NHTSA, 2008). In Canada, 400 pedestrians per year were killed, comprising approximately 13% of total road user fatalities, in the period 2002–2006. In addition, around 6000 per year were seriously injured in this period (Transport Canada, 2007). To address this problem, local government and urban transportation agencies, not only in Canada but also in other countries around the world, have identified the safety and mobility of pedestrians as high priorities. To this end, investments are constantly allocated through different safety improvement programs.

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The development of cost-effective safety improvement programs requires modeling tools to guide decision makers. In the past decade, although considerable research effort has been directed towards addressing road safety issues of motorized modes, relatively little has been directed towards NMT. Significant knowledge and methodology gaps still remain. First, there is a lack of empirical studies that have simultaneously investigated the complex relationships between built environment (BE), pedestrian activity and accident occurrence at the micro-level, in particular at the level of urban intersections.[1] To our knowledge, these relationships have been separately investigated in previous studies, yet none have looked at all of them together. Previous research has mainly focused on the relationship between vehicle–pedestrian collision frequency and traffic and pedestrian volumes (Garder, 2004; Harwood et al., 2008; Lyon and Persaud, 2003; Elvik, 2009). Second, the relationship between BE and pedestrian safety has been investigated primarily at the area-wide level (Lascala et al., 2000; Priyantha et al., 2006; Graham and Glaister, 2003; Sebert Kuhlmann et al., 2009; Wier et al., 2009). Few studies have investigated the relationship between BE and pedestrian activity at intersections (Pulugurtha and Repake, 2008; Schneider et al., 2009). Although these two recent studies have investigated the link between pedestrian activity and BE, they have involved a relatively small sample of intersections. Third, most studies concern US urban areas. Transferability of US evidence to the Canadian context may not be adequate given socio-cultural, urban form and mobility pattern differences (Pucher and Buehler, 2006).

Accordingly, the aim of this paper is two-fold:

(1) To propose a modeling approach to investigate the relationship between the built environment and both pedestrian activity and collision frequency at signalized intersections.
(2) To develop models to identify the main factors associated with both pedestrian activity and collision frequency. The predictive capacity of the developed models is also evaluated as part of this objective.

The paper is structured in several sections. Section 2 offers a literature review on pedestrian safety with particular focus on safety analysis at intersections. Section 3 presents a conceptual framework and model formulation to analyse the interaction between built environment, pedestrian exposure and accident occurrence. As an application environment, a sample of intersections in the City of Montreal is used. Section 4 describes the empirical data used in this research. Section 5 presents the results of the pedestrian activity and collision frequency models; public policy implications and model validation are also part of this section. Finally, Section 6 includes the final conclusions and directions for future work.

2. Literature review

In recent years, a large number of studies have been published addressing different issues related to the development of collision prediction models (Miaou et al., 2003; Miranda-Moreno et al., 2005; Persaud and Lyon, 2007). Relative to the amount of research devoted to motor vehicle-only collisions, few studies have dealt with pedestrian collision occurrence at signalized intersections. Among these studies, we can refer to Brüde and Larsson (1993), Lyon and Persaud (2003), Shankar et al. (2003), Lee and Abdel-Aty (2005) and Harwood et al. (2008). In this literature, one can observe that past studies on vehicle–pedestrian collision occurrence at intersections have mostly looked at the effect of traffic and pedestrian flows on collision frequency, with few studies incorporating BE and geometric design characteristics in their analyses (Lee and Abdel-Aty, 2005; Harwood et al., 2008). The effect of BE on accident occurrence has been mostly studied at the area-wide (e.g., census tract) level (Graham and Glaister, 2003; Wier et al., 2009). In particular, some area-wide studies have been restricted to the study of child safety (Joly et al., 1991; Lascala et al., 2004; Clifton and Kreamer-Fults, 2007). Some others concentrated on alcohol related collisions and their relationships to BE (Lascala et al., 2001). Moreover, previous works have studied the link between BE and pedestrian collision frequency without specifying whether BE influences pedestrian safety by directly affecting pedestrian activity, pedestrian accident frequency or both. In area-level studies, attributes such as population density, land use mix and/or commute travel patterns are often included in multivariate models, but, most often, they are treated as any other contributing factor of pedestrian collisions instead of attributes related to pedestrian activity.

To explain the number of pedestrian collisions, pedestrian volume, referred to here as pedestrian activity, is a key element. In the literature, several possible definitions of pedestrian activity can be found depending on the data available and the unit of analysis. In general, measurements of pedestrian activity can be classified as either site-specific (e.g., intersections) or area-wide (e.g., census tract).[2] For urban intersections, pedestrian exposure can be determined using (1) raw pedestrian volumes observed during one or more periods of time (e.g., morning peak, noon, and/or afternoon) or (2) pedestrian volumes estimated according to prediction methods such as Space Syntax or BE models. Some estimation methods and alternative measures of pedestrian exposure have been suggested in the literature (Jonah and Engel, 1983; Greene-Roesel et al., 2007; Lasarre et al., 2007; Pulugurtha and Repake, 2008; Schneider et al., 2009).

Despite the fact that pedestrian volumes are an essential element in road safety analysis; few transportation agencies collect pedestrian data from a large number of sites on a regular basis. Among other reasons, this is due to the fact that site-specific pedestrian count studies are expensive and time-consuming.[3] To address this issue, a simple and efficient method would be to develop predictive built-environment models based on a sample of intersections in an urban area (Pulugurtha and Repake, 2008; Schneider et al., 2009). The goal of this paper is to estimate pedestrian activity based on built-environment attributes in the proximity of an intersection or a crosswalk. However, very little empirical evidence exists in the literature following this approach. One of the few studies is the recent work done by Pulugurtha and Repake (2008), which develops a model to measure pedestrian activity using data collected for a sample of signalized intersections (176 intersections) in the city of Charlotte, NC. Based on a standard regression analysis, they found that population, total employment, urban residential area, and the number of transit stops are statisti-

[1] A high proportion of vehicle-pedestrian collisions take place at intersections. In Montreal, they represent about 63% of the total pedestrian-vehicle collisions. As defined later, BE is represented by land use, demographic characteristics, transit facilities and road network facilities in the proximity of an intersection.

[2] At the area-wide level (e.g. census tract, neighbourhood, municipality, etc.), several measures have been proposed, such as observed pedestrian volumes at a sample of sites, and estimated pedestrian volumes based on travel surveys or network analysis models, for instance. An extensive literature review of previous studies is provided by Greene-Roesel et al. (2007).

[3] Alternative methods have also been proposed to collect pedestrian activity data at the site-specific level (e.g. signalized intersections or pedestrian crossings). A common method is to obtain pedestrian volumes from manual counts taken directly in the field for one or several rush hours. With new automatic data collection methods (pedestrian sensors or video camaras), expansion factors can be defined to obtain daily flows (Schneider et al., 2009). A review of these alternative counting strategies and pedestrian detection technologies has been carried out by Greene-Roesel et al. (2007).

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