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Investigating the gender differences on bicycle-vehicle conflicts at urban intersections using an ordered logit methodology

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ABSTRACT

In the literature, a crash-based modeling approach has long been used to evaluate the factors that contribute to cyclist injury risk at intersections. However, this approach has been criticized as crashes are required to occur before contributing factors can be identified and countermeasures can be implemented. Moreover, human factors related to dangerous behaviors are difficult to evaluate using crash-based methods. As an alternative, surrogate safety measures have been developed to address the issue of reliance on crash data. Despite recent developments, few methodologies and little empirical evidence exist on bicycle-vehicle interactions at intersections using video-based data and statistical analyses to identify associated factors. This study investigates bicycle-vehicle conflict severity and evaluates the impact of different factors, including gender, on cyclist risk at urban intersections with cycle tracks. A segmented ordered logit model is used to evaluate post-encroachment time between cyclists and vehicles. Video data was collected at seven intersections in Montreal, Canada. Road user trajectories were automatically extracted, classified, and filtered using a computer vision software to yield 1514 interactions. The discrete choice variable was generated by dividing post-encroachment time into normal interactions, conflicts, and dangerous conflicts. Independent variables reflecting attributes of the cyclist, vehicle, and environment were extracted either automatically or manually. Results indicated that an ordered model is appropriate for analyzing traffic conflicts and identifying key factors. Furthermore, exogenous segmentation was beneficial in comparing different segments of the population within a single model. Male cyclists, with all else being equal, were less likely than female cyclists to be involved in conflicts and dangerous conflicts at the studied intersections. Bicycle and vehicle speed, along with the time of the conflict relative to the red light phase, were other significant factors in conflict severity. These results will contribute to and further the understanding of gender differences in cycling within North America.

1. Introduction

Road safety is a substantial concern for transportation professionals due to the high economic and social cost of traffic crashes (Abdel-Aty, 2003). In 2012, traffic crashes resulted in 2077 fatalities and over 165,000 injuries in Canada, where cyclists and pedestrians account for approximately 18% of both fatalities and injuries annually (Transport Canada, 2014). While the safety of motorists has commanded much attention, the protection of vulnerable road users has become common only recently (Kockelman and Kweon, 2002). In North America, cyclists are twelve times more likely to be killed than motor vehicle drivers (Moore et al., 2011; Strauss et al., 2014), and 269 cyclist fatalities occurred in Canada between 2008 and 2012 (Transport Canada, 2014).

Recent growth in bicycle activity and infrastructure improvement have increased awareness of bicycle safety issues in North America. In this context, the complex nature of cyclist-vehicle inter-

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actions must be understood by examining factors that contribute to cyclist safety (Klop and Khattak, 2007; Moore et al., 2011). One method for evaluating these factors is traffic crash modelling. Crash models evaluate collision frequency using count regression models, or injury severity using different techniques such as ordered logit, discrete choice regression models, and tree-based or neural network techniques. Many studies have considered the different statistical methods available. A recent summary of literature on crash frequency and severity modelling is provided by Mannering and Bhat (2014). Additional summaries were compiled by Miranda-Moreno (2006), Lord and Mannering (2010), and Savolainen et al. (2011). Traditional safety models calibrated with crash data are reactive, requiring crashes to occur before causes can be identified and countermeasures can be implemented. Additionally, crash-based methods require long observation periods, particularly when cyclists are involved. Given the low rate of crash occurrence for non-motorized users, many years of accident data are required to conduct a safety analysis. Finally, the study of dangerous behaviors and other human factors can often not be investigated.

As an alternative or complementary approach, surrogate safety techniques analyze interactions and conflicts rather than crashes. Conflicts are events that are physically and predictably related to traffic crashes, and are placed immediately below collisions in Hydén's model (Hydén, 1987), presented in Fig. 1. As the pyramid model suggests, traffic interactions are inherently ordered through their proximity to a potential collision, or severity, as measured by various indicators. Modelling interactions rather than collisions provides several benefits. Interactions occur much more frequently than collisions and statistically sufficient data can be collected in a shorter time period. The use of interactions and conflicts is proactive, rather than reactive, surrogate measures are insensitive to crash underreporting (Kockelman and Kweon, 2002), and human factors can be incorporated in the analysis. However, despite the benefits offered by a proactive surrogate approach, dangerous cyclist behaviour in vehicle-bicycle interactions, and their associated factors, have rarely been studied using video analysis, surrogate measures of safety, and regression models.

Existing efforts in injury severity modelling primarily concern motor vehicle occupants in single or multiple vehicle crashes. Multiple modeling techniques have been proposed to investigate the relationship between injury severity levels and associated factors. Mannering and Bhat (2014) provide a comprehensive literature review on the methods used in severity analysis in general, and Eluru et al. (2008) provides a summary of literature concerning analysis of cyclist injuries. Much empirical evidence has been reported in the literature identifying the key factors influencing injury severity, including characteristics of the roadway, environment, and road user, for passengers, drivers, and pedestrians. Moore et al. (2011) utilized a multinomial logit and mixed logit to model cyclist injury severity at intersections and non-intersection locations using seven years of crash data from Ohio. The study stated "the injury mechanisms are substantially different [...] at intersection and non-intersection locations". Klop and Khattak (2007) studied bicycle crash severity on rural roads in North Carolina using an ordered probit model and four years of crash data. Visibility and weather conditions were found to most significantly increase collision severity. Eluru et al. (2008) utilized data from the 2004 US national database to estimate a mixed generalized ordered response logit (MGORL) model of cyclist injury severity. The MGORL generalizes more standard ordered models, providing additional flexibility across observations. Cyclist age and vehicle speed were correlated with injury severity. In the existing literature, gender is often a contributory factor to injury severity.

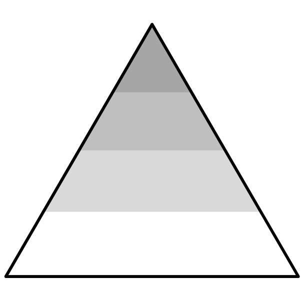

Fig. 1. Safety pyramid based on Hydén's classic model (Hydén, 1987).

The relationship between biological gender and cyclist safety is a particular issue that remains to be investigated using microscopic conflict data. More specifically, it is not that gender itself is necessarily a deciding factor, but rather it is associated with unobserved differences in behaviour, physiology, and experience (which themselves are gender-related) that can be captured using video data. Important behavioral differences have been identified for both pedestrians and motorists of different genders at intersections (Holland and Hill, 2007; Santamarina-Rubio et al., 2014; Tom and Granie, 2011), yet very little is known about this for cyclists. For now, studies on gender differences among cyclists have focussed largely on variation in behaviour or preference. Johnson et al. (2011) studied red-light compliance of cyclists in Australia and found that male cyclists were more frequently non-compliant than females. Bernhoft and Carstensen (2008) used a survey approach, finding male cyclists in Denmark tended to act less cautiously, but also felt safer than their female counterparts. Similarly, French studies show that male cyclists tended to overestimate their ability more so than females whereas females tend to overestimate their carefulness more than males (Felonneau et al., 2013) and that cyclist risk-taking behaviour seems to be gender specific even at an early age (Granié, 2011). Gender differences and their associated risks may help to explain the disparity in ridership currently experienced in cities (Garrard et al., 2012), as well as the implementation of the appropriate designs and facilities.

However, while gender differences are evident in terms of behaviour, behavioural differences do not necessarily create disparity in risk, and recent research has only shown minor differences in actual crash risk for males and females (Kaplan et al., 2014; Martinez-Ruiz et al., 2014). Kaplan et al. (2014) evaluated injury severity using a generalized ordered logit model on Danish crash data collected over a 5-year period, and found no correlation between gender and injury risk. Martinez-Ruiz et al. (2014) used 17 years of crash data from Spain to calculate the crash rate ratio by gender for different ages. Without adjusting for cycling exposure, males were more likely to be involved in a collision than females. When controlling for exposure, crash rates were approximately equal for males and females with age being a stronger determinant of crash risk. Despite parity in risk, in most countries, females still cycle less than males, particularly in English speaking countries that are less bicycle-friendly, including Canada, the U.K., Australia, and the U.S. (Garrard et al., 2012). Route conditions and vehicle interactions greatly influence individuals' likelihood to cycle (Winters et al., 2011) and female cyclists, much more than males, prefer to use routes with maximum separation from motorized traffic (Garrard et al., 2008) and signalized crossings (Bernhoft and Carstensen, 2008), whereas males prefer the fastest routes (Bernhoft and Carstensen, 2008). Studies in the city of Montreal show that routes with separated cycle tracks attract higher cyclist volumes than those without (Strauss and Miranda-Moreno, 2013) and that streets with cycle tracks have a lower injury risk (Lusk et al., 2011). As female cyclists seem to favour sites with cycle tracks (Garrard et al., 2008) a possible explanation for this lack of difference in the risk of accidents could be found in the behavior of male and female cyclists on roads with cycle tracks.