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Exploring unobserved heterogeneity in bicyclists' red-light running behaviors at different crossing facilities

Yanyong Guo[a,b,c], Zhibin Li[b,c,*], Yao Wu[b,c], Chengcheng Xu[b,c]

[a] Department of Civil Engineering, University of British Columbia, 6250 Applied Science Lane, Vancouver, BC, V6T 1Z4, Canada
[b] Southeast University Road #2, Nanjing, 211189, China
[c] School of Transportation, Southeast University Si Pai Lou #2, Nanjing, 210096, China

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ABSTRACT

Bicyclists running the red light at crossing facilities increase the potential of colliding with motor vehicles. Exploring the contributing factors could improve the prediction of running red-light probability and develop countermeasures to reduce such behaviors. However, individuals could have unobserved heterogeneities in running a red light, which make the accurate prediction more challenging. Traditional models assume that factor parameters are fixed and cannot capture the varying impacts on red-light running behaviors. In this study, we employed the full Bayesian random parameters logistic regression approach to account for the unobserved heterogeneous effects. Two types of crossing facilities were considered which were the signalized intersection crosswalks and the road segment crosswalks. Electric and conventional bikes were distinguished in the modeling. Data were collected from 16 crosswalks in urban area of Nanjing, China. Factors such as individual characteristics, road geometric design, environmental features, and traffic variables were examined. Model comparison indicates that the full Bayesian random parameters logistic regression approach is statistically superior to the standard logistic regression model. More red-light runners are predicted at signalized intersection crosswalks than at road segment crosswalks. Factors affecting red-light running behaviors are gender, age, bike type, road width, presence of raised median, separation width, signal type, green ratio, bike and vehicle volume, and average vehicle speed. Factors associated with the unobserved heterogeneity are gender, bike type, signal type, separation width, and bike volume.

1. Introduction

China has been known as the kingdom of bikes due to the heavy reliance on cycling for mobility. In recent years, there has been a rapid increase in the use of electric bikes in urban areas of the country. From 1998 to 2016, the number of electric bicycles has increased from 58,000 to 466,000,000, which is an average of 64.8% increase per year (National Bureau of Statistics, 2016). Bikes provide travelers with convenient, flexible and affordable mobility and accessibility (Guo et al., 2014). They occupy less road space and because they produce less emissions compared to motorized modes of transport, they are considered environmentally-friendly (Parker, 1999, 2006; Cherry and He, 2010; Hansen and Nielsen, 2014; Guo et al., 2018a,b).

Despite the aforementioned advantages, bikes have also raised many safety issues and concerns (Fishman and Cherry et al., 2016). According to the China Road Traffic Accidents Statistics Report, 3986 bicycle riders were killed in crashes and 11,722 were seriously injured in China in 2011 (CRTASR, 2011). Nearly 4790 electric bike riders were killed in urban areas and 23,830 were injured (CRTASR, 2011). Crashes involving bikes accounted for 83.3% of fatalities and 84.6% of injuries among non-motorized traffic crashes (CRTASR, 2011). Electric bikes are found to be more crash-prone than conventional bicycles. Previous studies have reported that the running the red light at crosswalks is the leading cause for the bike-related crashes (Wang and Nihan, 2004; Yao and Wu, 2012; Du et al., 2013; Johnson et al., 2013; Pai and Jou, 2014; Guo et al., 2014, 2018a,b).

A number of road and traffic factors are known to impact red-light running behaviors. However, there is the unobserved heterogeneity across individuals, which may influence the likelihood of running a red light. For example, traditional models can consider gender as a factor in predicting red-light running behaviors. However, even within the same gender group, due to the impact of height, weight or other physiological and psychological factors, bicyclists have different red-light running likelihoods (Mannering et al., 2016). If such unobserved heterogeneity is ignored, the model will be inaccurate and may result in biased parameter estimation and erroneous inferences and predictions. The

* Corresponding author at: School of Transportation, Southeast University Si Pai Lou #2, Nanjing, 210096, China.
E-mail addresses: yanyong.guo@ubc.ca (Y. Guo), lizhibin@seu.edu.cn (Z. Li), wuyaomaster@126.com (Y. Wu), xuchengcheng@seu.edu.cn (C. Xu).

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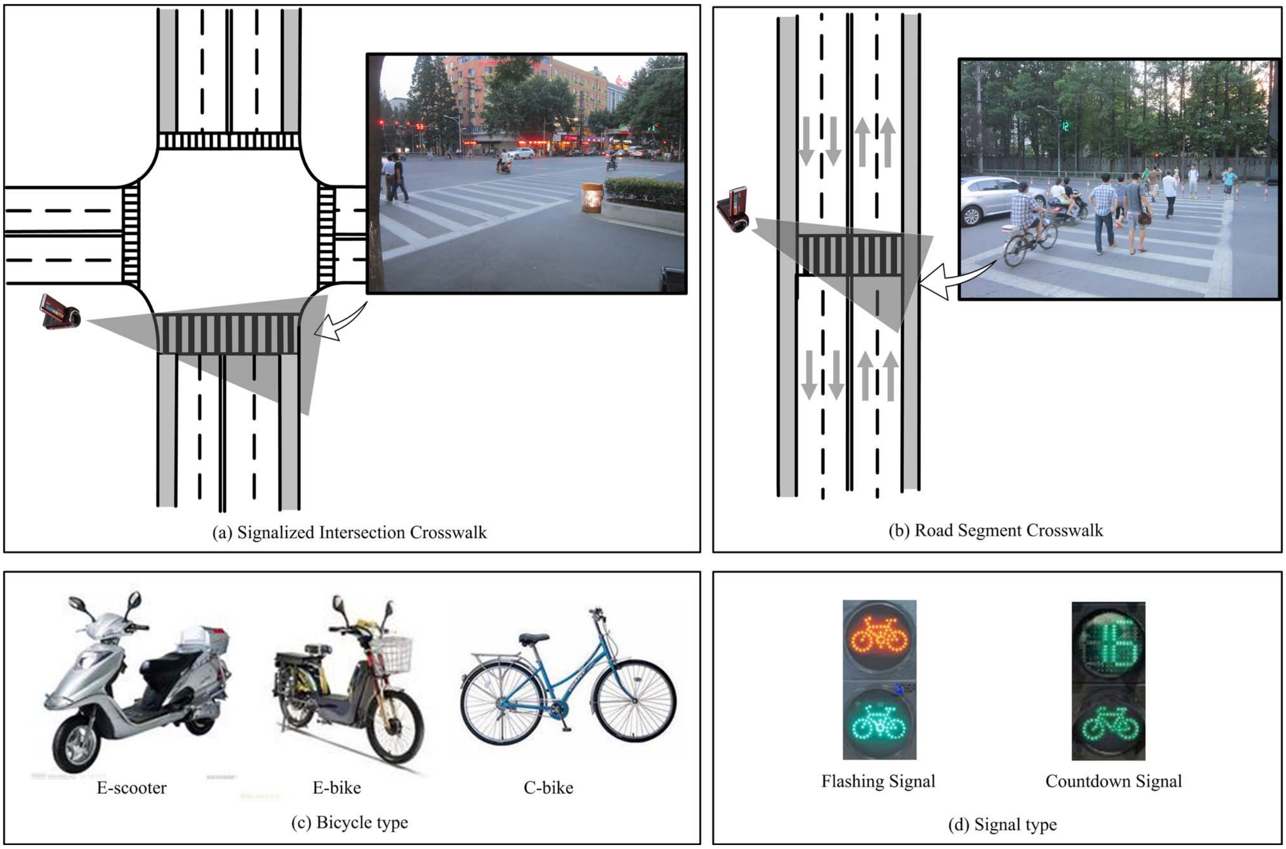

Fig. 1. Bicycle crossing facilities, bicycle type, and signal type. (For interpretation of the references to color in text, the reader is referred to the web version of this article).

only study that considered the individual heterogeneity in red-light running studies was by Pai and Jou (2014). They used the standard mix logit model, the drawback of which is that it requires an assumption to be made for the functional form of the mixing distribution (Behnood and Mannering, 2016). State-of-the-art statistical approach is required to improve the performance and prediction of the model for this type of studies.

The primary objective of this study is to explore the factors affecting bicyclists' red-light running behaviors at signalized bicycle crossing facilities. The full Bayesian random parameters logistic regression was estimated to account for the unobserved heterogeneous effects across the population. Two types of bicycle crossing facilities were considered: the signalized intersection crosswalks and the road segment crosswalks (shown in Fig. 1a and b). Three types of bicycles were examined: the scooter-style electric bicycle (e-scooter), the conventional electric bicycle (e-bike), and the conventional bicycle (c-bike) (shown in Fig. 1c).

2. Literature review

Numerous studies have investigated bicyclists' red-light running behaviors at crosswalks (Ling and Wu, 2004; Bernhoft and Carstensen, 2008; Johnson et al., 2011; Wu et al., 2012; Yao and Wu, 2012; Wang et al., 2012; Zhang and Wu, 2013; Johnson et al., 2013; Du et al., 2013; Pai and Jou, 2014; Guo et al., 2014; Richardson and Caulfield et al., 2015). In those previous studies, a large number of factors were found to be related to red-light running behaviors which were briefly reviewed in this section.

Johnson et al. (2011) conducted a cross-sectional study to determine the rate and associated factors of cyclists' red-light infringement. The results showed that travel direction was a main factor for a red-light violation. Namely, cyclists turning left were found to be 28.3 times more likely to run a red light at intersections as compared to those who travel straight through. It was also found that presence of other road users had a deterrent effect with the odds of infringement. In the subsequent study, Johnson et al. (2013) investigated why cyclists infringe at red lights. The results showed that young (18–29 years) and male cyclists were more likely to run the red light than mid-aged (30–49 years), older (over 50 years) and female cyclists. Crash involved cyclists were found to be more likely to infringe at red lights than those had not previously been involved in crash.

Wu et al. (2012) conducted an observational study was to investigate the rate, associated factors, and behavior characteristics of cyclists' red light running behavior. The results indicated that cyclists were more likely to run red light when they were young (< 30 years), riding alone, when there were fewer riders waiting, when there were riders already crossing on red, and there was fewer crossing traffic.

Yao and Wu (2012) examined risk factors affecting involvement of e-bike riders in collisions and established the relationships between safety attitudes, risk perception, and aberrant riding behaviors. The results suggested that gender and automobile driving experience were associated with at-fault collision involvement. Errors and aggressive aberrant riding were found to be significant factors with at-fault collision. Structural equation model results indicated that safety attitudes and risk perception both significantly affected aberrant riding behaviors.

Pai and Jou (2014) investigated the cyclists' red-light running behaviours by classifying crossing behaviours into three distinct manners, including risk-taking, opportunistic, and law-obeying. The results showed that several factors, such as intersections with short red-light duration, when riders were pupils in uniform, when riders were riding electric bicycles, and when riders were unhelmeted, were significantly increase the likelihood of bicyclists' risky behaviours.

Guo et al. (2014) used a binary logit model to evaluate how various factors affected the cyclists' red-light running rates. The results showed that male cyclists had a high possibility of running red light when fewer people are waiting at the intersection, and when the intersections