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Potential risk and its influencing factors for separated bicycle paths

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ABSTRACT

In this paper, we propose two potential risk indicators to define and evaluate the safety of bicycle path at the microscopic level. Field bicycle data were collected from three survey sites under different traffic conditions. These two risk indicators based on speed dispersion were proposed and calculated during each 5-min interval. The risk influences of various widths of bicycle path and traffic conditions were analyzed by using one-way ANOVA. We further proposed a generalized linear model (GLM) for modeling and analyzing the relationships between bicycle risks and v/c ratio and percentages of electric bicycles, male cyclists, young cyclists, and loaded cyclists. The stepwise regression models were applied for determination of coefficients. The results show that the influences of gender and age of cyclists on potential risks are not significant. The risks increase with the width of bicycle path and percentage of electric bicycles, while only for wider bicycle path (4-lane case in this study), the risks are associated with whether or not cyclists are loaded. The findings could contribute for analysis and evaluation of the safety for bicycle path.

1. Introduction

The increase in road crashes has been recognized as a major public health problem. A report published by the World Health Organization (WHO) in 2013 stated that around 1.24 million people lost their lives and 50 million were injured in crashes on roads all over the world each year (World Health Organization, 2013). With the increased number of serious injuries and fatalities, the safety problem has become a high-priority issue to traffic engineers (Kuang et al., 2015; Qu et al., 2014a,b). Similar with motorized vehicles, non-motorized vehicle crashes have also increased quickly in recent years. Because of the significant environmental, climate, congestion and public health benefits of cycling (Schepers et al., 2014a), classic bicycle (CB) and electric bicycle (EB) are encouraged by many governments particularly by developing countries such as Vietnam, Malaysia, Indonesia, and China. The rapid development of bicycles has brought many efficiency and safety problems (Du et al., 2013; Jin et al., 2015). Therefore, safety of bicycle traffic is becoming a very important topic.

In recent years, there were many risk indicators developed for modeling and evaluating the safety and crash risk of highway (Jin et al., 2013). Different from motorized vehicles, the behavior of cyclists is more complex and unpredictable, particularly under the heterogeneous bicycle traffic conditions, which will lead to severe risks for bicycle path. Therefore, there is a need for a deeper understanding of the implications of potential risks and their influencing factors for bicycle traffic, and to develop suitable bicycle path planning and management policies to improve the safety of bicycle paths. Toward this end, this paper examines two following research questions: (1) Which risk indicators are suitable for evaluating the safety of heterogeneous bicycle traffic? (2) Do the traffic conditions, width of bicycle path, bicycle types, and characteristics of cyclists affect the risk severity of bicycle traffic?

1.1. Literature review

The safety of bicycle path has been an important research topic. With the rapid increase of bicycles (mainly EBs), the numbers of deaths and injuries from traffic accidents of non-motorized vehicles have continued to increase in China. According to Fig. 1, the numbers of deaths and injuries for EBs are quickly increasing in recent ten years (Traffic Management Bureau Ministry of Public Security in China, 2003–2012). According to the statistics from the

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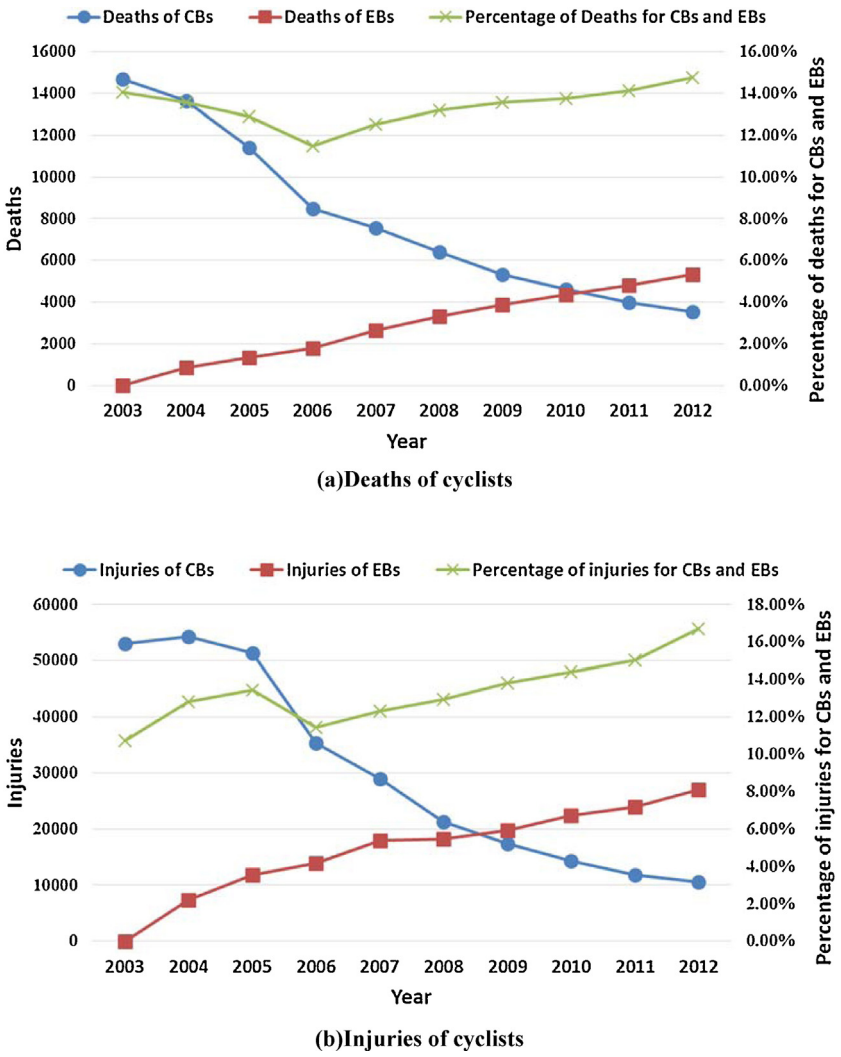

Fig. 1. Deaths and injuries of cyclists in traffic crashes from 2003 to 2012 in China.

Traffic Management Bureau Ministry of Public Security in China (2003–2012), EB-related deaths increased almost six times from 882 in 2004 to 5314 in 2012, while the injuries of EB cyclists increased from 7278 in 2004 to 26,966 in 2012. Compared to EB, CB-related deaths and injuries have a significant decline, which decreased from 14,537 to 661 and from 61,564 to 37,488, respectively, during the same decade. The percentage of deaths and injuries of cyclists in all travel modes has been increasing, which implies that the safety of bicycle traffic is more severe than that of motorized vehicles.

The research on bicycle safety refers to crash pattern (Yan et al., 2011; Bambach et al., 2013; Bai et al., 2013; van der Horst et al., 2014; Shackel and Parkin, 2014), injury severity (Kim et al., 2007; Hu et al., 2014), red-light running behavior (Wu et al., 2012; Zhang and Wu, 2013; Pai and Jou, 2014), and safety evaluation (Madsen et al., 2013; Weber et al., 2014). Publications on the evaluations of the risk and safety for bicycle traffic, particularly related to heterogeneous bicycle traffic, are hardly available. Schepers et al. (2014b) presented a conceptual road safety framework comprising mutually interacting factors for exposure to risk resulting from travel behavior and for risk, and used the framework to link research on cycling safety to land use and infrastructure. Some researchers have proposed the relationship between bicycle volumes and safety, and found that safety per cyclist increases with increasing bicycle volumes (Leden et al., 2000; Robinson, 2005; Schepers et al., 2011). Jacobsen (2003) studied bicycle crashes and found that crashes per cyclist decrease as overall cyclist mode shares increase. The first bicycle safety performance functions (SPFs) were presented and applied to Boulder, Colorado by Nordback et al. (2014). Such functions provide a basis for both future investigations into safety treatment efficacy and for prioritizing intersections to better allocate scarce funds for bicycle safety improvements. Carter et al. (2007) developed a macro-level bicycle intersection safety index (Bike ISI) that would allow engineers, planners, and other practitioners to use known intersection characteristics to prioritize intersection approaches with respect to bicycle safety proactively. Lawson et al. (2013) used some macroscopic factors (including the safety behavior of existing cyclists, the users of other travel modes and their attitude toward cyclists, facilities and network infrastructures applicable to cycling as well as to other modes in all parts of an urban transportation network) to determine perception of safety of cyclists in Dublin City. Vandenbulcke et al. (2014) proposed a spatial Bayesian modeling approach to predict cycling accident risk for an entire network and identify how road infrastructure influences cycling safety in the Brussels-Capital Region (Belgium). Risk factors are limited to infrastructure, traffic and environmental characteristics. Similar studies have been presented by Hamann and Peek-Asa (2013) and Chataway et al. (2014).

From the above references, most previous studies applied macroscopic safety indicators to evaluate bicycle traffic. Little