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Evaluating the impact of Mobike on automobile-involved bicycle crashes at the road network level

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ABSTRACT

As a booming system, free-floating bicycle-sharing (denoted as Mobike) attracts a large number of users due to the convenient utilization procedure. However, it brings about a rapid increase of bicycle volume on roadways, resulting in safety problems especially on road segments shared by automobiles and bikes. This study aimed to evaluate impacts of Mobike on automobile-involved bicycle crashes on shared roadways at a macro level, the network level. Relation between traffic volumes and crashes was first established. Then, the travel mode choice before and after supplying Mobike in the market was analyzed, based on which the multi-class multi-modal user equilibrium (MMUE) models were formulated and solved. Two attributes of Mobike, supply quantity and fare, were investigated via various scenarios.

Results suggested the Mobike attracted more walkers than auto-users in travel mode choices, which caused the volume increase of bicycles but few volume decline of automobiles and resulted in more crashes. The supply quantity of Mobike had a negative impact on safety, while the fare had a positive effect. The total supply of Mobike in the market should be regulated by governments to avoid over-supply and reduce bicycle crashes. The fares should be also regulated by including taxes and insurances, which can be used to build up more separated bicycle facilities and cover the Mobike accidents, respectively. The findings of this study provide useful information for governments and urban transportation managers to improve bicycle safety and regulate the Mobike market.

1. Introduction

Bicycles, used for both recreational and commuting trips, are an important travel mode in urban transportation system. Many countries have been encouraging this environment friendly travel mode, such as the United States, Canada, and European countries. However, the safety problem of bicyclists has drawn an increasing amount of attention from transportation professionals in recent years, especially the automobile-involved bicycle crashes. The automobile-involved crashes account for a large proportion of the total bicycle accidents, which usually results in serious injuries to bicyclists. These crashes occur not only in intersections, but also on roadways without separated bicycle facilities (Fournier et al., in press). More accidents may occur with more automobiles and bicycles on the shared roadways.

In China, the amount of automobile-involved bicycle crashes is currently at a high level. The reasons include: (a) the rapid motorization leads to dramatic increase of vehicle quantity in urban roadways, which increases the possibility of bicycle collisions with automobiles; and (b) the booming bicycle sharing system in recent years brings about a new increasing trend of bike utilization. The bicycle sharing here refers to the free-floating bicycle sharing system without stations (Pal and Zhang, 2017). The convenient utilization and return procedure stimulates a large number of bicycle-sharing users. As of May 2017, there are approximately 10 million shared bicycles in the market and more than 100 million users in China (SINA, 2017). Among all the bicycle sharing companies, the Mobike company accounts for about 70% of the total market (MONEY, 2017). Thus, for convenience, we use Mobike to represent the free-floating bicycle sharing system hereinafter.

Like utilizing private bikes, the same safety problem may occur when the Mobike users travel on roadways shared with automobiles (see Fig. 1(a)). Given the factors contributing to crashes unchanged, such as road network attributes, the utilization of Mobike has no impact on automobile-involved bicycle crash rate. However, the demand of Mobike differs from that of private one, which is affected by the supply and fare provided in the market (see Fig. 1(b)). With more supplies and lower fares, the utilization of Mobike will be increased significantly. The enlarged traffic exposure may cause more automobile-involved

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Nomenclature

A	the node-link incidence matrix
$d^{w,n,m}$	the travel demand between O–D pair w by mode m of user class n
$D^{w,n}$	the total demand for O–D pair w of user class n
M^{w}	The supply quantity of Mobike between O–D pair w the input-output vector for traffic demand which has two non-zero
E	components: one has a value 1 in the component corresponding to origin node and the other is -1 for destination
fft	the free flow travel time of link
Cap	the capacity of link
$t_l^m(x)$	the travel time of link l, including impact of Mobike's fare
$x_l^{w,n,m}$	the passenger flow on link l of O–D pair w by mode m of user class n
$\beta^{n,m}$	parameters in the multinomial logit model used in MMUE
θ_n	parameters in the multinomial logit model used in MMUE

(a) (b)

Fig. 1. Typical shared roadways and Mobike, (a) roadways shared by automobiles and bicycles; (b) large supply of Mobike (Baidu, 2017).

bicycle crashes even with the same crash rate.

Mobike should be encouraged in many countries as an environment friendly part of transportation system. Nevertheless, due to the deficiency of good bicycling environment, it is necessary to quantitatively evaluate impacts of Mobike on automobile-involved bicycle crashes for safer utilization. As a newly-developing system, the historical crash data of Mobike are usually unavailable in most cities. Thus, given the current crash rate unchanged on roadways, how to evaluate safety effects of Mobike at a macro level is worthy of being analyzed. This study tried to investigate the impacts at a macroscopic level, i.e. the road network level. More specifically, this paper aimed to answer the following questions: (a) how Mobike affects travel mode choice and automobile-involved bicycle crashes; (b) how the supply and fare affect Mobike's effects on the crashes; and (c) what countermeasures may be useful to improve bicycle safety in the future. The rest of this paper is organized as follows. Section 2 discusses the literature review about bicycle crashes and optimization. Section 3 describes the methodology of this study. Impacts of supply and fare of Mobike are investigated in Section 4. Section 5 discusses the corresponding countermeasures. Section 6 is a summarization of this paper.

2. Literature review

Three models related to this study have been reviewed. The first one is the empirical model, which uses the historical data to analyze factors contributing to crashes. The second one is spatial model, which investigates the spatial relation and built environment of bicycling with crashes at a macro level. The third one, optimization model, is used to analyze mode choice and traffic assignment.

2.1. Empirical model

Pai (2011) proposed a mixed multinomial logit model using empirical data to predict the likelihood of three non-junction bicycle crashes: overtaking, rear-end, and door crashes. The study suggested that bicycles' traversing manoeuvers were associated with overtaking and rear-end collisions. Beck et al. (2016) analyzed bicycle crash characteristics using injury details and patient outcomes. They found that 69% of crashes occurred on road and combined of single cyclist-only events and multi-vehicle crashes. Fournier et al. (in press) applied a combination of mixed methods to perform an investigation of bicycle crash rates and exposure to different volumes, which overcame the limitation of availability and variability of bicycle count data. To determine factors contributing to bicycle injuries, Robartes and Chen (2017) examined bicyclist, automobile driver, vehicle, environment and roadway characteristics using an ordered probit model. One most notable finding was that automobile driver intoxication increased the probability of cyclist fatality six fold and doubled the risk of severe injuries. Prati et al. (2017) utilized two data mining techniques, CHAID decision tree and Bayesian network analysis, to investigate factors predicting bicycle crash severity in Italy. The results shown the road type, crash type, age of cyclist and type of opponent vehicle were most important predictors.

2.2. Spatial model

Loo and Tsui (2010) conducted the first spatial analysis of bicycle crashes in Hong Kong, investigated circumstances resulting in crashes, and applied an epidemiological study on injury patterns of cyclist casualties. The results of their study indicated the bicycle safety problem had an apparent spatial dimension, based on which the suggestion was proposed to carefully plan new facilities and policies to ensure cyclists' safety. Siddiqui et al. (2012) used a Bayesian spatial framework to model bicycle crashes for investigations of spatial correlation effects. They suggested that the spatial correlation should be taken into consideration when modeling bicycle crashes at the macro-level. Chen and Shen (2016) utilized a generalized ordered logit model and additive model to evaluate built environment effects on cyclist injury severity in automobile-involved bicycle crashes. Suggestions were proposed to promote bicycle safety based on their findings, including increase land use mixture and development density in cities, lower posted speed limits on roadways shared by autos and bicycles, and improve street lighting. Amoh-Gyimah et al. (2016) presented a cross-comparison of various estimation methods for bicycle crash modeling and investigated factors at the macro planning level. Their study indicated the factors such as vehicle kilometers traveled (VKT), population and percentage of commuters cycling to work had a significantly positive correlation with the bicycle crashes. The mixed land use was also found to have the positive association with crashes.