Transportation Research Part A 101 (2017) 203–217

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Estimating level of service of mid-block bicycle lanes considering mixed traffic flow

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ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form 25 July 2016
Accepted 28 April 2017

Keywords:
E-bike
E-scooter
Bicycle
Bicycle lane
Level of service

ABSTRACT

The primary objective of the study was to identify the factors that influenced the comfort perception of e-bike, e-scooter and bicycle riders in mid-block bicycle lanes on urban streets and to estimate the bicycle level of service (BLOS) of a mid-block bicycle lane with mixed two-wheeled traffic. Data were collected at thirty locations on thirty different streets in Nanjing area in China. Pearson's Chi-square tests were conducted to make comparisons of the comfort perception among different cyclist groups. The factors that significantly affected the comfort perception of the cyclists included the age of the cyclists, the type of two-wheeled vehicles, the volume of two-wheeled vehicles, the width of mid-block bicycle lanes, the proportions of e-bikes and e-scooters in two-wheeled vehicles, the physical separation between motorized, bicycle and pedestrian lanes, the slope of bicycle lanes, the roadside access points and the roadside land use. Ordered probit models were developed to quantitatively evaluate the impacts of different contributing factors on the comfort perception of the riders of e-bikes, e-scooters and bicycles. The results showed that compared to the riders of bicycles, the riders of e-bikes and e-scooters were more likely to perceive a poor comfort level. The comfort perception of the cyclists increased with an increase in the width of the mid-block bicycle lane, whereas it decreased with an increase in the volume of two-wheeled vehicles. The proportions of e-bikes and e-scooters in two-wheeled vehicles negatively affected the comfort perception of the cyclists. In addition, the presence of physical separation between the motorized, bicycle and pedestrian lanes significantly increased the comfort perception of the cyclists. With the comfort perception models, a procedure was developed and insights were gained to help transportation professionals estimate the BLOS of a mid-block bicycle lane with mixed two-wheeled traffic.

1. Introduction

Electric bicycles have been considered an environmental friendly alternative to automobiles, and their usage has increased dramatically during the past decade in China. Two major types of electric bicycles are currently being used: bicycle-style electric bicycles (e-bikes) and scooter-style electric bicycles (e-scooters). E-bikes are similar to bicycles in terms of size and weight, and are usually equipped with 36-V batteries and 180–250-W motors. By contrast, E-scooters are more similar to motorcycles, and are usually installed with 48-V batteries and 350–500-W motors (Cherry and Cervero, 2007; Lin

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http://dx.doi.org/10.1016/j.tra.2017.04.031
0965-8564/

et al., 2008). The major difference between e-bikes and e-scooters lies in their operating speeds. More specifically, the average speed of e-scooters, e-bikes and bicycles is approximately 18, 16 and 13 km/h, respectively (Cherry, 2007; Lin et al., 2008; Jin et al., 2015). The maximum operating speed of electric bicycles can reach up to 30 km/h. In China, both e-bikes and e-scooters are legally classified as bicycles, and are required to be operated in bicycle lanes. The presence of different types of two-wheeled vehicles results in mixed traffic flow in bicycle lanes. A critical question arises: how two-wheeled vehicles with distinct operational characteristics influence the level of service (LOS) of mid-block bicycle lanes?

The bicycle LOS (BLOS) is an important indicator that is used for planning, design, monitoring, prioritization and strategizing of mid-block bicycle lanes. Several studies have measured the BLOS of mid-block bicycle lanes using single parameters, such as traffic volume, operating space, density, free-flow speed, or the hindrances experienced by cyclists. Botma (1995) suggested that the proportion of the cyclists that experienced hindrances could be used for measuring the BLOS, and the method was adopted by the 2000 edition of the Highway Capacity Manual (HCM, 2000). The BLOS was measured as the frequency of the events or hindrances that cyclists experienced in a bicycle lane in the length of one kilometer.

The single parameter approach does not consider the various environmental factors that may affect the BLOS. By contrast, more recent studies have evaluated the BLOS using multiple performance measures (Callister and Lowry, 2013; Dixon, 1996; Dowling et al., 2008; Elias, 2011; Fagnant and Kockelman, 2014; FDOT, 2013; Harkey et al., 1998; Hummer et al., 2006; Jensen, 2007; Landis et al., 1997; LaMondia and Moore, 2015). The assumption is that the BLOS is influenced by a set of environmental factors, such as traffic volume, roadway widths and the presence of bicycle facilities (Jones and Carlson, 2003; Kang and Lee, 2012; Yamanaka and Namerikawa, 2007). Most of these studies have followed a similar procedure in which a weighting factor was assigned to each influence factor to compute a numerical score that fell into different categories. The estimated numerical score has been used for measuring the BLOS (LaMondia and Moore, 2015; Lowry et al., 2012; Petritsch et al., 2014). Previous researchers have proposed various methods, such as the point system, the bicycle compatibility index model, the linear regression model, the cumulative logit regression model, the ordinal regression model, the and the cumulative logistic model for developing the weighting factors and for estimating the numerical score (CDOT, 2007; Dixon, 1996; Jensen, 2007; Jones and Carlson, 2003; LaMondia and Moore, 2015; Mozer, 2016; Ophartd, 2005; Parkin et al., 2007; Yamanaka and Namerikawa, 2007). The multi-parameter approach was also adopted by the 2010 edition of the Highway Capacity Manual (HCM, 2010) for estimating the BLOS on the link, the road segment, the intersection and the facility.

The LOS is a quantitative stratification which describes from travelers' perspective how well transportation facilities or services operate (HCM, 2010). So far, however, it is still not clear how the BLOS measured using the multi-parameter approach relates to travelers' subjective perception. In recent years, researchers have gradually recognized that the BLOS should be directly measured by comfort perception experienced by cyclists when they are cycling (ABC, 2013; Foster et al., 2015; Kang et al., 2013; Li et al., 2012). The perception of comfort is a state of harmony between humans and environment in three aspects: physiological, psychological and physical (Slater, 1985). The cyclists' comfort perception may differ from one person to another and is influenced by environmental conditions. Researchers have developed statistical models to relate the comfort perception of cyclists to the influence factors such as the demographic characteristics of cyclists, characteristics of bicycle facilities, traffic conditions, etc. (Ayachi et al., 2015; Landis et al., 1997; ABC, 2013; Foster et al., 2015).

Even though there have been numerous investigations into the influence factors for the BLOS, there has been little discussion about the BLOS of the mid-block bicycle lanes with mixed two-wheeled traffic. The current design guidelines and standards for bicycle lanes mainly focus on the characteristics of bicycles. Without considering the difference in the mobility of e-scooters, e-bikes and bicycles, the estimates of BLOS could be biased. Furthermore, environmental factors and traffic conditions also influence the operations of bicycle facilities, and the impacts of these factors need to be fully considered when estimating the BLOS. Research is urgently needed to better understand the impacts of various influence factors and to help address the design and planning issues regarding the mid-block bicycle lanes with mixed two-wheeled traffic.

The aim of this paper is to: (a) identify the factors that influence the comfort perception of e-bike, e-scooter and bicycle riders in mid-block bicycle lanes on urban streets; and (b) estimate the BLOS of a mid-block bicycle lane with mixed two-wheeled traffic. In this paper the BLOS of a mid-block bicycle lane was defined on the basis of cyclists' perception of comfort when they were cycling. We expect that the research results will help traffic engineers develop design guidelines and standards to improve the operations of the mixed two-wheeled traffic flow in a bicycle lane. The research results could also provide traffic management authorities with insights to establish policies or regulations regarding the use of electric bicycles.

2. Data and methods

This study utilized a case study in the city of Nanjing to illustrate the procedure for estimating the BLOS of mid-block bicycle lanes with mixed two-wheeled traffic. Nanjing is the capital city of the Jiangsu province, and is located in southeastern China. The total population in the Nanjing metropolitan area exceeded 8.2 million at the end of 2014. In this study, data were collected at thirty locations on thirty different streets in Nanjing. The riders of e-scooters, e-bikes and bicycles were surveyed to assess their comfort perception of bicycle lanes. Ordered probit models were then developed to establish a relationship between the comfort perception of cyclists and various environmental factors. The aggregation of comfort perception of all the cyclists was used for measuring the BLOS, and a procedure was proposed for estimating the BLOS of a mid-block bicycle lane with mixed two-wheeled traffic under given conditions. The basic research framework is illustrated in Fig. 1.