Transportation Research Part A 77 (2015) 225–248

Contents lists available at ScienceDirect

Transportation Research Part A

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

Estimating cycleway capacity and bicycle equivalent unit for electric bicycles

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ARTICLE INFO

Article history:
Received 18 November 2014
Received in revised form 22 March 2015
Accepted 21 April 2015
Available online 16 May 2015

Keywords:
Electric bicycle
Regular bicycle
Capacity
Bicycle equivalent unit
Speed–density relationship

ABSTRACT

With the rapid increase of electric bicycles (E-bikes) in China, the heterogeneous bicycle traffic flow comprising regular bicycles and E-bikes using shared cycleway creates issues in terms of efficiency as well as safety. Capacity and bicycle equivalent units (BEUs) for E-bikes are two most important parameters for the planning, design, operation, and management of bicycle facilities. In this paper, eight traffic flow fundamental diagrams are developed for one-way cycleway capacity estimation, and a novel BEU estimation model is also proposed. Eleven datasets from different shared cycleway sections with different cycleway widths were collected in Hangzhou, China for estimation and evaluation purposes. The results indicate that, with around 70% share of E-bikes, the mean estimated capacity is 2348 bicycle/h/m. The effects on the capacity of the proportions of E-bikes, gender of cyclists, age of cyclists, and cyclists carrying things were also analyzed. The results implied that the estimated capacity is independent of a cyclist's gender and age, but increases with the proportion of E-bikes. According to this study, the mean BEU for the E-bike is 0.66, and the converted capacities of pure regular bicycles and pure E-bikes are 1800 and 2727 bicycle/h/m, respectively. These findings can be used to propose practical countermeasures to improve the capacity of heterogeneous bicycle traffic flow on shared cycleway.

1. Introduction

Non-motorized traffic trips form one of the main trip modes in developing countries, especially in Southeast Asian countries such as China, Indian, and Vietnam. The average proportion of trips using non-motorized traffic is very large in most southern Chinese cities. In recent years, because of its low-cost, convenience, and relative energy-efficiency, the electric bicycle (E-bike) has quickly become one of the main non-motorized travel modes in China (Weinert et al., 2007a, 2007b; Rose, 2012). E-bike ownership in China reached approximately 200 million in 2013 (Xinhua News, 2013).

There are several reasons for the quick development of E-bikes in China. First, compared with the price of a typical car (around CNY 100,000–150,000 or $16,393–24,590), which is equivalent to four times the average annual household income of city residents, the price of an E-bike is much lower (below CNY 2000 or $328, 1/15 of the average annual household income). Second, in the southern Chinese cities of Guangzhou, Dongguan, and Shenzhen, motorcycles and mopeds are

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http://dx.doi.org/10.1016/j.tra.2015.04.013
0965-8564/

completely banned from certain downtown districts. There are also bans in place in small areas of Shanghai, Hangzhou, and Beijing. E-bikes represent the best alternative to motorcycles. Third, E-bikes currently are under the same classification as regular bicycles and hence operating one does not require a driver license. Fourth, according to the Electric Bicycles General Technical Requirements issued by the Standardization Administration of China (1999), "the maximum speed of Electric bicycles should not be greater than 20 km/h and the total weight of the vehicle should not exceed 40 kg". In reality, most E-bike riders do not follow these rules which are not easy to enforce. Last, in terms of modal share, as the public bus service has a low level of service and large delays, they have been shown to have only about a 22% share in Hangzhou (Zhang et al., 2014). Therefore, due to low prices, there being no need for a license, and inefficient public transport, the E-bike travel mode looks likely to continue for a long term.

With the increasing use of E-bikes along with regular bicycles, a public bike-sharing system offering flexible short-term public bicycle access, targeting daily mobility and allowing users to access shared bikes at multiple stations (Shaheen et al., 2010) is also growing in many Chinese metropolises and tourism cities. For example, the public bike sharing system in Hangzhou had 2674 stations and 65,000 bicycles at the end of February 2012 (Zhang et al., 2014). Due to the fact that bicycles and E-bikes are under the same classification and management, heterogeneous traffic comprising E-bikes and slower-moving regular bicycles sharing non-motorized facilities is and will continue to be very common in many Chinese cities. This heterogeneous traffic brings about issues in terms of efficiency and safety. The size and speed differences between these two modes will inevitably lead to more complicated characteristics and a higher risk of traffic collisions. Due to such challenges, the planning, design, and management of shared bicycle facilities need to take into account the mixed bicycle traffic flow and new criteria and standards should be proposed accordingly. In this study, we defines "cycleway" as the non-motorized facilities which regular bicycles and E-bikes share. Different with "bicycle path" in Highway Capacity Manual (2000), where the bicycle paths are defined as exclusive off-street bicycle paths or shared off-street paths, cycleway is adjacent to highway traffic lanes, mostly one-way, has one or more bicycle lanes, and some of them separated with motorized vehicles by physical barriers.

Based on the above reasons, the efficiency of bicycle facilities shared between regular bicycles and E-bikes is an important topic for analysis and improvement. Unfortunately, to the best of our knowledge, little if not none research has ever focused on cycleway capacity and the equivalent units of E-bikes, especially under conditions of heterogeneous bicycle traffic flow. Accordingly, in this paper, we focus on estimating the capacity of a shared one-way cycleway under heterogeneous bicycle traffic flow, and the bicycle equivalent unit (BEU) for E-bikes. These two parameters, which vary according to traffic conditions (e.g., volume, speed, proportion of E-bikes), road geometries (e.g., lane width, gradient) driver characteristics (e.g., age, gender), and weather conditions, must be considered under these different conditions. The purpose of this paper is to accurately estimate the capacity and the BEU for E-bikes, and comprehensively analyze the factors that influence them, based on a large amount of field survey data collected from Hangzhou, China. We believe that the findings offer some effective countermeasures for improving the planning and management of non-motorized vehicle facilities.

The rest of the paper is organized into five sections. The next section briefly describes the development of E-bikes and reviews the literature. Section 3 explains how the field data were collected and analyzed. Section 4 proposes a method of capacity estimation and analyzes the factors that influence capacity. Section 5 presents the estimation method and the results for the BEU for E-bikes. Section 6 concludes the paper with a summary of our findings.

2. Literature review

Bicycles, as an inexpensive and convenient trip mode, have become a significant mode of transportation in the past decade and are being used more widely in many developed countries, such as the United States and the countries of the European Union (Nosal and Miranda-Moreno, 2014; Ruiz and Bernabé, 2014; Fernández-Heredia et al., 2014). Though the use of bicycles in China has decreased significantly since 1995 due to the rapid motorization and expansion of urban regions (Zhang et al., 2014), with the development of E-bikes and public bike-sharing schemes, the government has been gradually realizing the potential benefits of bicycles and is proposing to plan new cycleway systems, to build bicycle corridors and to improve the level of service for bicycle facilities in many Chinese cities. Therefore, research into the efficiency and safety of bicycles and bicycling facilities has long been an important topic.

2.1. Development of bicycles and E-bikes

The development of bicycles and E-bikes, which form one of the primary trip modes in developing countries, especially China, is the key pathway to understanding and researching the motorization and transformation of this travel mode. Zhang et al. (2014) examined four phases of bicycle evolution in China, from initial entry and slow growth (1900s to 1978), to rapid growth (1978–1995), to bicycle use reduction (1995–2002), and finally to policy diversification (2002 to the present). They also explored two bicycle innovations, the E-bike and public bike sharing (the shared use of a bicycle fleet), and describing their characteristics in details. Weinert et al. (2007a, 2007b) examined how and why E-bikes have developed so quickly in China, with particular focus on the key technical, economic, and political factors involved. Their case study provided important insights for policy makers in China and abroad, on how timely regulatory policy could change the purchasing choices of millions and create a new mode of transportation.