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Evaluation of the dispersion effect in through movement bicycles at signalized intersection via cellular automata simulation

Hang Jiang [a,b], Yongjian Ma [b], Lin Jiang [c], Guozhou Chen [b], Dongwei Wang [a,*]

[a] School of Civil Engineering, Zhengzhou University, Zhengzhou, 450001, China
[b] Henan Urban and Rural Planning & Design Research Institute CO., LTD., Zhengzhou, 450044, China
[c] School of Land and Tourism, Luoyang Normal University, Luoyang, 471934, China

HIGHLIGHTS

- The study simulates the dispersion effect in through bicycle traffic at intersection area.
- Cellular automata model is utilized to simulate maneuvers of bicycles and vehicles.
- Simulation of bicycle dispersion effect on different intersection approaches are conducted.
- Bicycle interferences and vehicle delays are evaluated for different traffic situations.
- Policy suggestions in regard to through traffic operations at intersection area are proposed.

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ABSTRACT

At signalized intersection areas, bicycle traffic presents a dispersion feature which may influence the movements of vehicles during peak period. The primary objective of this study is to simulate the dispersion effect in through-movement bicycle traffic at intersection areas and evaluate its influence on through-movement traffic. A cellular automata (CA) model is developed and validated to simulate the operations of through-movement bicycle traffic departing from two types of intersection approaches. Simulation results show that bicycles benefit from the dispersion effect when they depart from the approach with an exclusive right-turn vehicle lane. But when bicycles travel from the approach with a shared right-turn and through vehicle lane, the dispersion effect will result in friction interference and block interference on through-movement vehicles. Bicycle interferences reduce the vehicle speed and increase the delay of through-movement vehicles. The policy implications in regard to the dispersion effect from two types of approaches are discussed to improve the performance of through-movement traffic operations at signalized intersections.

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1. Introduction

In recent years, simulation technique is widely utilized in urban transport regime by statistical physicists, primarily addressing sophisticated traffic operations at intersection areas and road segments [1–5]. It well fills the gaps where the traditional analytical tools via field investigations cannot cover all traffic situations to fully evaluate the traffic operations. Traffic simulation technique is to develop a simulation model in order to reproduce traffic phenomena, and moreover

* Corresponding author.
E-mail address: dongweiwang@zzu.edu.cn (D. Wang).

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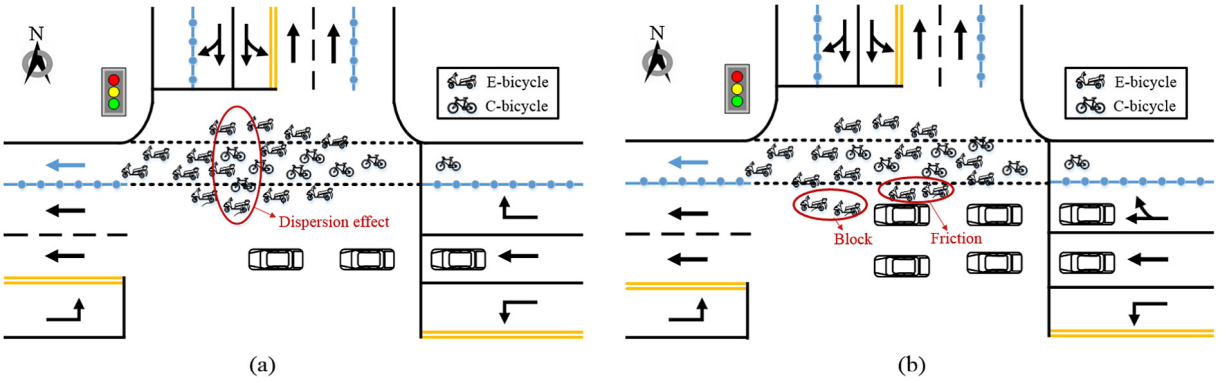

Fig. 1. Dispersion effect in through-movement bicycle traffic from two typical intersection approaches.

produce some traffic conditions that are hardly observed from field data. Previous studies mainly focused on homogeneous motorized traffic [6–9]. However, experience with the usage of simulation tools to investigate chaotic phenomena that occur in the heterogeneous traffic (various transport modes such as vehicles, bicycles, pedestrians) is comparatively limited.

During the last decade, the importance of non-motorized mode, particularly bicycle is recognized. Recreational and commuting trips with bicycles have experienced a measureable increase around the world. Electric bicycle (e-bicycle), characterized by having much larger operational speed than conventional bicycle (c-bicycle), is at a very prevalent state in most cities of China [10]. The bicycles of highly heterogeneous traffic comprised by e-bicycles and c-bicycles occupy in the basis of the availability of space any convenient lateral position on the road without any lane discipline [11,12]. These varying operational characteristics and erratic riding behaviors in the heterogeneous traffic conduce to a particular traffic phenomena termed as *dispersion effect* at signalized intersections as shown in Fig. 1.

Fig. 1 presents two typical lane groups in the intersection approaches in China. At signalized intersections, through-movement bicycles arrive and then wait at the intersection approach. When the through-movement traffic light turns green, bicycles go straight across the intersection together with through-movement vehicles. In the through-movement traveling, faster cyclists such as e-bicycles would like to overtake slower cyclers from the edges of bicycle platoon. As a result, the width of crossing bicycle platoon could turn large and the dispersion effect begin to emerge.

The main distinction between the two typical lane groups in Fig. 1 is the right-turn movement for the westbound approach. Fig. 1(a) consists of an exclusive right-turn lane dedicated for use by right-turn vehicles. In this type of approach, the through-movement bicycle traffic has sufficient space during the departure period because they can occupy the exclusive right-turn lane, and its dispersion effect has little interaction with the through-movement vehicles. Nevertheless, the westbound approach in Fig. 1(b) only has a shared right-turn and through lane. The dispersion effect in through-movement bicycle traffic would occupy spaces of this vehicle lane and influence the operation of through-movement vehicles. These influences can be separated into two categories, namely friction interference and block interference. Friction interference forms when the bicycle travels very close to a vehicle in the lateral direction. In this case, the lateral vehicle has to reduce its speed due to the lack of ride-side lateral clearance. Block interference occurs when the bicycle occupies part of the through lane of vehicles, and blocks the way a vehicle forward. In this case, the vehicle has to follow forward bicycles in a much slow speed. Thus, the dispersion of bicycles in Fig. 1(b) will increase the delay of through-movement vehicles.

Currently, there are a quite large through-movement bicycle demand in cities of China, and the dispersion effect of through-movement bicycle traffic commonly exists at signalized intersections. The interactions between through-movement vehicles and bicycles under such dispersion effect is highly complex. Although the interactions among mixed traffic at intersections have drawn a great interest from researchers [13–15], until recently none of these studies have considered the impacts of dispersion effect in through-movement traffic. In practice, such dispersion effect produces interferences on through-movement vehicles and delay these vehicles passing through the intersection area. Thus it is necessary to particularly investigate the bicycle–vehicle interactions resulted from the dispersion effect.

Microsimulation, as stated, has its advantage of modeling and quantifying the detailed process of dispersion effect under different traffic conditions. The Cellular Automata (CA) model, a recent entrant in this field, can reflect many critical characters of traffic with realistic manner and appropriate accuracy. Simulating the dispersion effect in through-movement bicycle traffic, CA models would help estimate its influence on the departure time of through-movement bicycle and evaluate its impacts on the delay of through-movement vehicles. Herein, CA model was proposed in this paper to reflect the dispersion effect in through-movement bicycle traffic from two types of approaches at intersection area. Some policy suggestions were also discussed in order to improve the operations of through-movement traffic. The remainder of the study is organized as follows. With the purpose of validating the CA model, a total of 34 h traffic data are collected in Section 2. Section 3 presents the rules of the proposed CA model. The simulations for dispersion effect are reported in Section 4. Finally, Section 5 concludes this paper.

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