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Study on the influence of bus front-end intrusion-free distance to the bus moving characteristics

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Abstract

Buses are usually loaded with many passengers and cannot start and turn around flexibly while cars are light and maneuverable. Sometimes, cars may cut in front of a bus as long as the gap is available, and buses have to reduce their speed, which affects the traveling speed and smoothness of buses. In order to improve the bus riding quality, this paper proposes a model of setting front-end intrusion-free distance, in which social vehicles are not allowed to cut in. If buses accelerate, the distance from front vehicles can be smaller than the intrusion-free distance. With open boundary conditions, social vehicles and bus departure mechanism were reenacted, and a two-lane mixed traffic cellular automaton model based on different lane changing conditions and whistle effect was established respectively. Simulation results demonstrated that the model reproduced the operation rules of mixed flow on driveways, with good performance in describing lane changing rules. According to numerical simulation, the suggested vehicle changing lane regulation not only accelerated buses, but also increased the average speed of overall passengers, with improved smoothness of road vehicles, and reduced lane changing times and vehicle acceleration and deceleration frequency. It was demonstrated that the front-end intrusion-free distance for public buses can optimize bus operation efficiency.

Keywords: Public buses; Intrusion-free distance; Two-lane cellular automaton model; Traffic flow simulation

1. Introduction

"Public transport priority" (PTP) is the abbreviation of the priority development of public transport systems, which fully embodies the concept of public priority development, and can ease traffic pressure and ensure the sustainable development of cities. The implementation of bus priority can improve the running speed of buses, reduce the running time, improve the reliability of bus operation, save the cost of resident trips, and reduce the emission of automobile exhaust to the environment.

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The priority for the passage right of public transportation is the key to public transport priority. PTP can be divided into spatial priority and time priority. Time priority mainly refers the PTP signal control technology. By extending the length of green time, the punctuality rate and operation efficiency of buses are improved obviously [3]. In order to ensure the efficiency of buses and general vehicles, a bandwidth approach to arterial signal optimization with bus priority is proposed [1]. Space priority is mainly for bus lanes. Providing dedicated way right for buses can avoid the mixed lanes for bus and other vehicles which causes interference of each other, and can effectively improve the bus speed, increase bus service reliability, and improve the bus running environment [2]. According to the present situation in China, the establishing dedicated bus lanes needs less investment and has quick effect, so it can be used as the transition form for big cities from slow conventional bus transportation to high speed rail transportation, which is beneficial to improve the operation of public transport [12]. Beijing's passenger traffic increased by 6% in one month after the implementation of dedicated bus lanes, and Kunming opened a 15-km medium-sized bus lane, and one-way traffic capacity increased to 6000/h [15]. However, dedicated bus lanes reduce the number of lanes and the capacity of roads, which have some limitations. Intermittent bus lanes (IBL) mean that when buses are present, the lanes are used as the bus lanes, and the rest of the time is open to all vehicles [13]. Constraining vehicles changing to the bus lanes, but not requiring to drive away from the bus lanes, combined with signal control, the way right can be strived for buses [14]. However, this approach may reduce the capacity of the bus. Based on IBL, the bus lane with intermittent priority (BLIP) was proposed [8]. Combining with signal control, this method is applicable to streets with traffic situations or bus frequency changing over time [7]. However, setting bus lanes is greatly affected by road conditions. It was regulated in "Rules of bus lane setting" by the Ministry of public security in 2004 that the number of one-way driveway lanes in urban arterial road sections with bus lanes be more than 3 (including 3). For one-way double-lane streets (most typical in old cities), setting dedicated bus lanes is likely to cause serious congestion of social vehicles, and is not conducive to the development of city traffic. Meanwhile, with the continuous increase of bus routes and public transport vehicles, setting bus lanes may not meet the needs of public transport [5].

In this study, the front-end intrusion-free distance for buses was proposed, which avoids not only the spatial interference by social vehicles to buses, but also has no special requirements for street and avoids the waste of bus lane in resources. For the development of urban public transport, buses are no longer limited to the bus lanes, and the increase of the bus numbers will not adversely affect the road traffic. The two lane cellular automaton model was adopted to evaluate the effect of front-end intrusion-free distance. Numerical simulation demonstrated that after setting the front-end intrusion-free distance, not only buses speed up, but also the average speed of overall passengers increases, with more smooth public transport vehicle operation. Generally, the method can improve the level of public transport service, improve the efficiency of transportation resource utilization, and ease traffic congestion.

2. Model

The good operation of buses can promote the city public transportation development and reduce road congestion. However, limited by the width, it is difficult to set bus lanes for some streets. Taking two-way four-lane streets in old cities as a kind of examples, the dedicated bus lanes not only cause social vehicles to form congestion, but also seriously destroy the fairness of the vehicle driving, which is also a waste of road resources. In order to ensure the fairness and meet the requirements of efficient driving of buses, in our model, an intrusion-free distance in front of buses was established. The insertion of other vehicles is not allowed within this distance. Specifically, when a vehicle on a neighboring lane wants to insert in front of a bus, the distance of the bus from the front vehicle must be greater than the intrusion-free distance, and in this situation the lane changing requirements can be satisfied. If the bus accelerates, the gap from the front vehicle can be less than the intrusion-free distance.

In order to study the influence of bus front-end intrusion-free distance on the driving characteristics of buses, the cellular automaton of traffic flow was used to model and simulate the actual road operation. By comparing the operating characteristics of buses before and after setting up the distance, the implementation effect of the scheme was obtained.

2.1. Two lane cellular automaton model

In order to simplify the modeling process, the traffic operation should be discretized by the discretization of time, space and velocity in integers [4]. A road is divided into discrete cells, with each cell being empty or occupied by a car, and the speed of each car can take the value of 0, 1, 2, ... $v_{\max}$, where $v_{\max}$ is the maximum speed.

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