ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

Public Transport Priority Method in The Environment of Internet of Vehicles

Feijie Duan[1, a]

[1]Department of Traffic and transportation science, Chongqing Jiaotong University, Chongqing, China

[a]dfj0128@163.com

Abstract

China's urbanization rate and the number of motor vehicles owned by the whole people have increased significantly year by year, and road resources have become increasingly scarce. Traffic congestion has become a very serious living problem for residents. At present, public transport priority has greatly helped to effectively improve the traffic rate of the road, but in the morning and evening rush hours, due to many factors, the fair traffic rate at urban road intersections is low, and there is still great traffic delay. However, some existing bus priority technologies also have many shortcomings, for example, in the "time priority" mode, the bus signal priority is achieved through the control means of the early cut-off of the red light or the extension of the green light, but it cannot guarantee that the coordinated traffic flow of the trunk line will not be affected, and the scope of such technologies is limited, and the proportion of bus priority is not high. In order to better improve the shortcomings of the existing public transport technology, after consulting and studying a large number of documents, I proposed a three-stage public transport priority signal control strategy. The first stage is to predict the traffic priority of the conflict phase; The second stage is the main line speed guidance control; The third stage is to fine-tune the traffic priority of the conflict phase. Using this optimization control strategy, public transport vehicles can pass faster at the urban intersection, or increase the waiting time for passengers to get on and off at the bus stops upstream of the intersection. The overall optimization strategy can significantly reduce vehicle delay and per capita delay.

Keywords

Intelligent Traffic System; Internet of Vehicles; Public transport priority; Trunk speed guidance; Coordinated signal control; Majority voting algorithm.

1. INTRODUCTION

With the rapid development of the national economy, China's national car ownership has increased significantly year by year, but the progress of urban road construction has been relatively slow. The road carrying capacity of many cities at high time has been seriously overloaded, resulting in serious traffic congestion. The serious traffic congestion problem is not only more prone to traffic accidents, but also more pollutants are emitted due to the frequent starting and braking of vehicles, and the travel experience of residents will also deteriorate due to the excessive extension of travel. This will not only cause serious economic losses, but also cause great pollution to the environment. Traffic congestion has already become a very serious problem of residents' travel. It is extremely urgent to put forward corresponding solutions in time to improve the current traffic congestion problem.

Public transport perfectly matches the green travel initiative, which has always been the focus of the national development policy. Public transport travel can carry more travelers to the destination within the same travel time, which can greatly reduce the vehicle exhaust pollution, reduce the participation of travel vehicles, and ease the traffic pressure. It is now the leading role of urban transport travel. However, public transport travel is easy to be affected by many factors and reduce travel efficiency. Therefore, adjusting the urban traffic structure, giving priority to ensuring public transport travel, and encouraging public transport travel are currently important means to solve urban traffic congestion.

Some existing bus priority technologies also have many shortcomings. For example, the existing bus priority technology can achieve bus signal priority through the extension of green light or the early break of red light, but it may destroy the coordinated traffic flow of the trunk line, and the scope of such technologies is limited, and the proportion of bus priority is not high. Domestic and foreign scholars often ignore the impact of uncertainties such as social vehicles, non-motor vehicles and pedestrians on public transport travel when carrying out public transport priority strategy research. Therefore, in the follow-up research, it is not only necessary to stay unilaterally in the strategy research of achieving "time priority" or "real-time priority" of public transport, but also to conduct a multifaceted and multi-level study of many factors.

2. RESEARCH BACKGROUND

According to Wang Yongsheng [1] 's research on bus priority at plane intersection, bus priority at plane intersection is technically divided into "space priority" and "time priority". "Space priority" refers to the priority given to buses in the process of passage, which is realized through the geometric design of the entrance road, and can be subdivided into private road priority and private road priority. "Time priority" refers to the priority signal provided for buses at the plane intersection, which can be divided into active priority, passive priority and adaptive priority according to the priority mechanism. Based on this, this paper summarizes the research status at home and abroad into two categories.

2.1. Research status of "space first"

Bus "space priority" has been studied earlier at home and abroad, and has been applied in the current traffic optimization control measures. For example, special bus lanes are set up on urban roads or special bus lanes are forbidden to change lanes. In this simple and direct way, we can reduce the influence of social vehicles on buses and improve the efficiency of bus traffic.

In recent years, some domestic and foreign researchers have also optimized it for higher efficiency. An Shi [2] designed a new type of intersection that uses the bus lane to turn left, and formulated the driving rules of each flow to social vehicles and the phase scheme of the main signal and pre-signal to solve the interweaving phenomenon between the Chinese bus lane and social vehicles when passing through the intersection. Yuan Qiufang [3] took the bus lane of Dagzha South Road in Ningbo City as the research object and designed the green wave belt for public transport considering social vehicles to solve the problem that buses could not meet the green wave belt due to parking delay. On the basis of considering road conditions, Gao Kun [4] designed the signal priority system scheme of Beijing South Central Bus Rapid Transit (BRT) line. Tian Xiujuan [5] studied the setting method and application of the bus priority lane in the rapid transit system, and took the bus priority lane constructed from the Fried oil yard to the Chongqing-Lu interchange in the main urban area of Chongqing as an example to verify the feasibility of the implementation of the conventional bus priority lane system setting method in the road system of Chongqing. Wu Dingxin [6] put forward the setting conditions of designated intermittent priority bus lanes, which can provide decision-making basis for improving bus lanes or building new intermittent bus lanes, and play an essential role in promoting public transport attraction and alleviating urban traffic problems. You Shiyuan [7] analyzed the layout mode of bus lanes in mountainous cities, and explored the layout form of bus lanes in mountainous cities from the perspectives of intersection entrance way setting, section exit setting and lane setting. Michael and Eichler[8] evaluated the operation strategy of buses using special lanes on signal-controlled arteries and proposed the strategy of intermittently providing dedicated lanes for general traffic to run buses on signal-controlled arteries.

2.2. "Time first" research status

Compared with "space priority", "time priority" reduces the requirements for road setting, and realizes bus priority by optimizing signal control, which has deeper research value. At the same time, it can be combined with "space priority" to better realize bus priority. In recent years, domestic and foreign researchers have prioritized optimization studies on this type of bus as follows:

2.2.1 Active priority aspect

Aiming at reducing bus delay and per capita delay at intersections, Yu Zhongdong [9] proposed an active control model of bus signal priority at intersections based on three-layer fuzzy controller for bus signal priority control. He analyzed average bus delay and per capita delay according to simulation examples, and demonstrated the effectiveness of this method. Shu Bo [10] proposed a new urban bus signal priority control strategy based on reinforcement learning algorithm. Kong Xiangjie [11] proposed an intelligent coordinated control technology for road network traffic flow with bus priority. Qiu Dunguo [12] proposed the concept of critical saturation queue length, and used saturation to determine the hysteresis problem of traffic congestion at intersections. Aiming at maximizing the common interests of buses and social vehicles, Wang Bin [13] proposed an active bus signal priority method based on the coordinated control background of trunk lines. Li Qi [14] proposed a bus signal priority implementation method based on different control levels of induction control system.

2.2.2 Passive priority aspect

Wang Dianhai [15] proposed the bus signal priority method for two-layer trunk lines to solve the problem that the early break of red light, the extension of green light and other bus priority control methods may destroy the coordination and optimization of traffic flow. CAI Yaping [16] proposed an integrated scheme of multi-intersection signal timing optimization and bus priority variable speed guidance. Through simulation examples, it was concluded that this method maximized the number of stops and effectively reduced bus delays. Kuang Transcendental [17] proposed a bus priority intelligent control method based on variable domain fuzzy neural network to solve the problem of bus priority traffic signal control. Shu Aibing [18] analyzed the current situation of public transport vehicles at intersections, and conducted in-depth research on timing optimization method of signalized intersections with bus priority.

2.2.3 Adaptive priority aspects

With the gradual maturity of Internet of vehicles technology and its application in the field of transportation, it can realize a more comprehensive perception of person-vehicle-road and intelligent processing of all road information, which is the inevitable result of intelligent transportation system. Compared with the spatial priority and the other two time priority means, adaptive priority takes more comprehensive consideration. All information on the road is processed comprehensively, and the influence of social vehicles on bus priority is not ignored. The relevant studies are as follows:

Wang Yongsheng [1] proposed a bus adaptive priority (ABP) model to solve the problem that the existing bus priority system does not excavate enough rational capacity and the response of the priority system lags behind. After an in-depth study on signal priority, Gao Kun [4] designed

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

the signal priority system scheme of Beijing South Central Bus Rapid Transit (BRT) line, and the practical application effect is good. Wang Dianhai [15] proposed a two-layer optimization method of bus signal priority in trunk lines to solve the traffic flow problem that active priority mode may destroy the coordination of trunk lines.

2.3. Technical route

The first stage: Before the bus enters the prohibited lane changing line, it obtains real-time road and vehicle information and status changes of signal lights by virtue of the technical environment of the Internet of vehicles, establishes the signal coordination control model, allocates according to the corresponding weight ratio, and uses the voting algorithm to predict the traffic priority of the conflicting phase.

The second stage: according to the predicted arrival time of buses at the intersection, the speed guidance model is established to guide buses to speed up, slow down or maintain the original speed, so as to ensure that buses can pass the intersection before the end of the green signal this week or just reach the stop line when the green signal lights up in the next cycle.

The third stage: After the bus enters the prohibited lane changing line, the real-time vehicle and road information is captured again, and the voting algorithm is used to fine-tune the traffic priority.

3. CONTROL METHOD OF BUS PRIORITY CONFLICT

3.1. Using voting algorithm to predict the traffic priority of conflicting phases

Basic principle: In a set composed of different elements, different elements can be compared one by one and cancel each other out to get more than half of the elements in the set.

Solve the problem: multi-route bus priority conflict

Solution: Determine the priority level

Weight index:

(1) emergency degree (refers to the degree of bus delay compared to the schedule)

(2) The number of buses and the number of passengers

(3) Number of social vehicles (queue number of social vehicles in front of public buses)

3.2. Establish speed guidance model

At the actual speed V_m, Set the bus speed range $[V_1, V_2]$ according to the upper and lower limit of 50% of the vehicle speed, and set it as t when the bus passes the detection point A_ At moment A, the time when the bus arrives at the detection point B is $t_B = t_A + t_{AB}$, t_{AB} is the time required from detection point A to detection point B,

$$t_{AB} = \frac{S_{AB}}{V_m} \tag{1}$$

The time t_s of waiting for passengers to get on and off the bus at the bus stop again. Between the road section AB, the maximum time that can be changed by slowing down and accelerating is:

$$T_{max1} = \frac{S_{AB}}{V_1} - \frac{S_{AB}}{V_m} \tag{2}$$

$$T_{max2} = \frac{S_{AB}}{V_m} - \frac{S_{AB}}{V_2} \tag{3}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

The traditional bus priority control focuses on the optimal control of vehicles or intersections, often ignoring the bus stops upstream and downstream of the intersection. Proper guidance of bus speed can make the bus pass without waiting at the intersection or increase the waiting time for passengers at the rush hour, which can further optimize the bus traffic efficiency. According to the actual speed of vehicles, the time of bus vehicles arriving at the intersection is predicted, and a signal cycle is specifically divided into the following five periods for discussion:

Figure 1. Schematic diagram of signal cycle segmentation

Among them $T_{max1} \geq t_5 - t_4$, $T_{max2} \geq t_3 - t_2$.

Case 1: Maintain the original speed. According to the actual traveling speed and real-time speed of the bus, it is predicted that the bus will arrive at the intersection within the green time after waiting for passengers to get on and off the bus at the stop. The bus maintained its original speed $V_t = V_m$.

Case two: One acceleration. According to the actual traveling speed and real-time speed of the bus, after waiting for passengers to get on and off the bus at the stop, the bus is predicted to arrive at the intersection stop line between the time period $[t_1, t_3]$, then the real-time data is calculated to provide a guide speed for the bus, so as to accelerate the bus and ensure that the bus can reach the stop line before the end of the green time. The speed after acceleration is:

$$V_t = \frac{S_{AB}}{t_{AB} - T_{max2} + t_s} \tag{4}$$

Where t_s is the time when the bus waits for a passenger to get on and off at the station.

Case three: A slowdown. According to the actual traveling speed and real-time speed of the bus, after waiting for passengers to get on and off the bus at the stop, it is predicted that the bus will reach the intersection stop line between the time period $[t_4, t_5]$. At this time, if the bus wants to accelerate to reach the intersection before the end of the green light, it will exceed the speed limit. Therefore, the bus needs to be guided to decelerate, so that the bus can just end the signal cycle. When the green signal starts in the next cycle, it will just reach the stop line, and the speed is:

$$V_t = \frac{S_{AB}}{t_{AB} + T_{max1} + t_s} \tag{5}$$

Case four: secondary acceleration. On the basis of situation 2, according to the actual speed and real-time speed of the bus, after waiting for passengers to get on and off the bus at the stop, the bus still cannot reach the intersection at the green time. Then, the bus speed is guided for a second time (but the bus speed cannot exceed the speed limit of the lane) to ensure that the bus can pass the stop line before the end of the green light. The speed is:

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

$$V_t = \frac{S_{AB}}{t_{AB}-T_{max2}+t_s-T'_{max2}} \tag{6}$$

Where T'_{max2} is the maximum time for the second acceleration change,

$$T'_{max2} = \frac{S_{AB}}{V_t} - \frac{S_{AB}}{V_2} \tag{7}$$

Case 5: Second deceleration. According to the actual speed, the bus carries out the simulation control process as in Scenario 3. It is found that the bus cannot pass the intersection without waiting as expected, so it is necessary to guide and decelerate the bus for the second time so that the bus can reach the stop line of the intersection when the next green light signal is on.

Decelerate the bus for the first time, and the guiding speed is:

$$V_t = \frac{S_{AB}}{t_{AB}+T_{max1}} \tag{8}$$

According to the prediction, the guiding speed of the bus's secondary deceleration is:

$$V_t = \frac{S_{AB}}{t_{AB}+T_{max1}++t'_s+T'_{max1}} \tag{9}$$

Where $T^{'}_{max1}$ is the maximum time of secondary deceleration change,

$$T'_{max1} = \frac{S_{AB}}{V_1} - \frac{S_{AB}}{V_t} \tag{10}$$

t'_s to extend the time the bus waits at a stop for a passenger to get on or off.

3.3. Voting algorithm fine-tuning traffic priority

After the bus speed changes under the guidance, it enters the prohibited lane changing line. The Internet of vehicles technology is used to capture the real-time vehicle and road information again, and then the voting algorithm is used to fine-tune the traffic priority according to the corresponding weight ratio allocation. After the weight value comparison again, the output result is the same as the predicted result, so there is no need to adjust the predicted traffic priority and keep the traffic priority unchanged. According to the proportion of waiting vehicles in conflicting lanes, the passage time in this signal cycle is allocated according to the ratio. After entering the next cycle, the voting algorithm is used to determine the passage priority.

ACKNOWLEDGMENTS

This paper studies the bus priority method in the environment of the Internet of vehicles. For vehicles in a traffic area, from the perspective of "God's eye", the traffic behavior that buses and social vehicles will take at the next intersection is understood. Then, according to the corresponding weight index, the traffic priority and phase duration of the conflict phase are allocated at the intersection. After the right of way is determined, the real-time speed and location of buses on the road are captured by using the Internet of vehicles environment, and then the time of bus arrival at the intersection is predicted. In order to ensure that the signal

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

light at the intersection is just the green time when the bus arrives at the intersection, the acceleration and deceleration guidance instructions are issued to the vehicles according to the traffic signal duration. After the bus enters the prohibited lane changing line, because some vehicles may change lanes during the running process, the voting algorithm is used again to verify the traffic priority and make fine adjustment.

REFERENCES

[1] Wang Yongsheng, Tan Guozhen, Liu Mingjian, Ding Nan. Adaptive prioritization Method for Public Transportation in Internet of Vehicles [J]. Journal of Computer Applications,2016,36(08):2181-2186.

[2] An Shi, Song Lang, Wang Jian, Wang Yaqing, Hu Xiaowei. Optimization of Main Pre-signal Control Scheme for Left Turn Using Bus Lane [J]. China Journal of Highway and Transport,20,33(04):115-125.

[3] Yuan Qiufang, Guo Lin, Ye Qiming. Design and application of two-way green wave for public transportation considering social vehicle signal coordination [J]. Journal of Ningbo Institute of Technology, 2019, 31(03):53-59+70. (in Chinese).

[4] Gao Kun, Zhang Hai. Public Transportation Priority Strategy in Urban Transportation [J]. Transportation System Engineering and Information,2006(02):23-26.

[5] Tian Xiujuan. Research on Method and Application of Bus Priority Lane Setting [D]. Chongqing Jiaotong University,2019.

[6] Wu Dingxin. Research on Capacity and Impact of Intermittent Priority Bus Lanes [D]. Southeast University,2019.

[7] You Shiyuan. Study on Suitability Evaluation and Optimization of Bus Lanes in Mountainous cities [D]. Chongqing Jiaotong University,2020.

[8] Eichler, M., & Daganzo, C. F. (2005). Bus lanes with intermittent priority: Screening formulae and an evaluation. St. Louis: Federal Reserve Bank of St Louis.

[9] Yu Zhong-dong, LIU Shu-qing, SHEN Wen-chao, XU Jian-min, LU Rui-qi. Research on Bus Signal Priority Control Based on Fuzzy Control [J]. Traffic Information and Safety,2015,33(01):35-40.

[10] Shu Bo, LI Daming, ZHAO Xinliang. Bus signal priority Strategy based on Reinforcement Learning Algorithm [J]. Journal of Northeastern University (Natural Science),2012,33(10):1513-1516.

[11] Kong Xiangjie, Shen Guojiang, Liang Tonghai. Intelligent Coordinated Control of Road Network Traffic Flow with bus priority [J]. Journal of Zhejiang University (Engineering Science), 2009, 43(06): 1026-1031.

[12] Qiu Dunguo, Hu Shu, Wang Maoning, Yang Hongyu. Priority Control Strategy for Bus Traffic Congestion at Intersections [J]. Journal of Sichuan University (Engineering Science Edition), 2014, 46(04): 111-119.

[13] Wang Bin, Liu Xin, Li Yuegao, Chen Xiaoming, WANG Huawei. A Bus signal Priority Method Based on Trunk Line Coordination and Its Verification Analysis [J]. Journal of Highway and Transportation Science and Technology, 2011,28(S1):36-39.

[14] Li Qi. Bus Signal Priority Realization Method in Induction Control System [J]. Jiangxi Building Materials, 2016 (05):187-188.

[15] Wang Dianhai, Zhu Hui, don't shout all at once, Wei Qiang. Coordinated Control Method for priority Signals of Trunk Buses [J]. Journal of Southeast University (Natural Science Edition), 2011, 41 (04): 859-865.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202304_9(4).0026

[16] CAI Ya-ping, Wang Wei-zhi. Multi-junction speed guidance Control Method based on Bus Priority [J]. Journal of Fuzhou University (Natural Science Edition),2019,47(05):700-706.

[17] Kuang Transcendental, Xu Lun-hui, HUANG Yan-Guo. Control Theory and Applications, 2012, 29 (10): 1284-1290.

[18] Shu Aibing, Liu Ming, Gong Chengyu, Zhang Zhiyun. Timing Optimization Method for signalized intersections with bus priority [J]. China Science and Technology Information, 2021 (16):64-65.