# Research on Priority Control Method of Conventional Public Traffic Signals

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**Abstract.** In this paper, for the bus on the main road of the single intersection, the main road of the bus is given priority. According to the strategy of early green light and green light extension, the bus time of the main bus is given more green time, and the bus is guaranteed while ensuring the efficiency of the intersection. Delays are minimized. At the multi-intersection transit priority, the analysis will focus on the possible delays caused by the motorcade at the intersection, and analyze the relationship between the delay and the non-heading delay in terms of the delay between the vehicle fleet and the intersection, and establish the per capita Delayed the smallest coordinated control model to achieve priority control of public transport signals. And the examples are introduced for verification. The results show that the green light extension and the green light early rise two different signal priority methods can effectively reduce the delay of the intersection bus.

## 1. Introduction

The theory and practice of "public transit priority" was proposed in Paris in the middle of the 20th century, and then rapidly developed into major cities in developed countries such as Europe and the United States. After the 1970s, it mainly studied the setting of bus lanes. After the 1990s, under the promotion of emerging technologies such as computer technology, detection technology, communication technology, and intelligent control technology, public transportation was preferentially focused on the control of public transportation priority signals. The main research is as follows: Peter G Furth[1]analyzed the changes in the total delay of the intersection of the bus in the priority, partial priority, and full priority. Wonho Kim [2]designed the time model of bus stop at the bus stop, and developed how to control the priority of the bus under the influence of the bus stop of the bus, so as to improve the punctuality rate of the bus . Heydecker [3]analyzed the changes in capacity through a number of different priority methods based on the impact of bus priority on intersection capacity. Yagar S [4] analyzed the arrival of the intersection traffic, aiming to reduce the delay time of the bus at the intersection.

At present, the focus of research on the priority control methods of public transport signals by domestic scholars is still the bus priority signal control at a single intersection under the development of technical conditions, and the signal timing optimization algorithm at the intersection to ensure bus priority. On the basis of the adaptive bus signal priority correlation theory, Fan Guang [5] defined the bus priority pre-judgment index R, which greatly simplified the complicated steps of bus signal priority pre-judgment, and focused on the analysis of adaptive bus signal priority strategy. Delay

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estimation, establish the delay estimation objective function . Li Ruimin [6] proposed a one-way multi-layer fuzzy control model based on traffic demand intensity for urban traffic signal control and bus priority problems. Then, considering the bus priority, the model is extended to the multi-layer fuzzy control model of the bus priority traffic signal, and the model structure and control method are given. Zhang Weihua [7] proposed the peak hour arrival rate of the bus, the red light duration of the main signal phase, the number of imported roads, and the number of individual bus vehicles. The method of determining the distance between the main signal stop line and the pre-signal line is determined by the length of the required stop, etc. The deficiencies of the coordination relationship between the main signal and the pre-signal timing are analyzed, and an improved method is proposed. According to the actual situation of the bus arriving at the intersection, this paper gives priority to the bus signal, so that the bus signal priority has more practical meaning.

## 2. Bus priority control model construction

*2.1.Busy signal priority assumptions and evaluation indicators for single intersections*

It is assumed that the intersection meets the following conditions: it can acquire the running time of the bus from the detector to the parking line; it does not consider the interference of pedestrians and non-motor vehicles on the traffic flow. In order to optimize the traffic efficiency after the implementation of public transport priority, the benefit evaluation index function is constructed $PI = \Delta D_b - \Delta D_c$ (1)[08]. Where: PI - utility indicator function; ΔDb - bus delay (s) to implement bus priority phase reduction; ΔDc - social vehicle delay (s) without phase increase of bus priority.

*2.2. Single intersection intersection bus signal priority control strategy*

*2.2.1 Green light extension delay analysis*

Green light extension delay analysis includes delay analysis of bus phase and analysis of non-transit phase delay. The first is the delay of the bus phase bus. If the period of the intersection is C, the detector detects the arrival of the bus at time $t_0$ and predicts the time when the bus arrives at the intersection. The extended green time is *Δt*. After implementing the green light extension strategy, the total delay for bus reduction is

$\Delta D_{des}^{b} = p^{b}(C - g_1 - \Delta t)$ (2).$p^b$ is bus passengers.The total delay in the reduction of social vehicles is $\Delta D_{des}^{c} = p^{c}\frac{\Delta tq}{2}(2r_1 + \frac{\Delta tq}{S} - \Delta t)$ (3).$p^c$ is the number of passengers in a social vehicle.

The second is the non-transit phase delay analysis. After the green light is extended, the other phase green time is compressed, and the time at which each phase is compressed is $\Delta t_i$. $g_i$、$g_i'$ is the green time (s) before and after the bus priority is implemented for the phase.$\Delta T_i$ is the green time of the phase i extension (s).$\Delta T_i'$ is the Green time of phase i compression (s).$k_i$ indicates the number of entrance lanes in direction i.The total delay reduced under the green light extension strategy is:

$$PI = p^{b}(C - g_1 - \Delta t) + \sum_{j=1}^{k_1} p^{c}\frac{\Delta tq_{1j}}{2}(2r_1 + \frac{\Delta tq_{1j}}{S_{1j}} - \Delta t) - \sum_{i=2}^{n}\sum_{j=1}^{k_i}(\frac{p^{c}\Delta T_i q_{ij}}{2(1 - q_{ij}/S_{ij})}(2r_i + \Delta T_i) - \frac{p^{c}\Delta T_i' q_{ij}}{2}\left(2r_i + \frac{\Delta T_i' q_{ij}}{S_{ij}} - \Delta T_i'\right)) \quad (4)$$

*2.2.2 Green light early delay analysis*

The bus delay of the bus phase is that after the detector detects the bus, it predicts the time t1 at which it arrives at the intersection, and starts the green phase in advance *Δt*. At this time, the delay of the bus reduction is: $\Delta D_{des}^{b} = p^{b}(g_2 - \Delta t)$ (5) The social vehicle delay is the amount of delay reduction of the social vehicle in this phase within*Δt* time, and the reduced person delay is:

$$\Delta D_{\text{des}}^{c} = p^{c} \frac{\Delta tq}{2(1-q/S)}(2r_1 - \Delta t) \tag{6}$$

Since the green light time of the bus application phase is advanced by Δt, the green time of the non-bus phase is shortened by Δt, which increases the delay of the phase vehicle. The non-transit phase delay under the green light early warning strategy is

$$PI = p^{b}(g_2 - \Delta t) + \sum_{j=1}^{k_i} p^{c} \frac{\Delta tq_{1j}}{2(1-q_{1j}/S_{1j})}(2r_1 - \Delta t) - \sum_{i=2}^{n}\sum_{j=1}^{k_i} p^{c} \frac{\Delta tq_{ij}}{2(1-q_{ij}/S_{ij})}(2r_i + \Delta t) \tag{7}$$

*2.3. Multi-intersection bus signal priority control method*

The traffic flow state of urban traffic is complex and changeable. The implementation of bus signal priority does not necessarily produce the expected effect, and may even lead to more disordered traffic order.

Establish an objective function with per capita delay as the evaluation index, let $p^s$ be the average number of passengers in the social vehicle (persons); $p^b$ is the average number of passengers (number of passengers); $q_{ij}s$ is the society Vehicle arrival rate (pcu/s); $q_{ij}b$ is the bus arrival rate (pcu/s); $d_{ij}s$ is the average delay (s) of the social vehicle; $d_{ij}b$ is the average delay (s) of the bus.The total number of people passing through the unit time can be calculated based on the passenger capacity of social vehicles and buses, namely: $N=\sum_{\text{i}=1}^{\text{n}}\sum_{j=1}^{m_i}(p^s q_{ij}^s + p^b q_{ij}^b)$ (8) .The constraint is：The minimum period length is determined by the minimum green time and loss time of each phase $C_{\min} = \sum_{i=1}^{n} g_{\min} + L \; L = \sum_{k}(L_s + I - A)$ (9)Phase green time is greater than or equal to the minimum green time $\lambda_i \geq \frac{g_{i\min}}{C}$ (10) Each phase saturation is not greater than the given value $\lambda_i \geq \frac{Y_i}{X_f}$ (11)The phase difference between two adjacent intersections should be satisfied $\phi_{n,n+1} \leq \frac{L_n - L_n^c}{L_p^c} h - \frac{L_n}{S}$ and $0 \leq \phi_{n,n+1} \leq C_n$ (12) $g_{\min}$ Indicates phase i minimum green time；$L_s$ Indicates the startup time, which is 3s;A Indicates yellow light time；k Indicates the number of phases in a cycle； $X_f$ Indicates the given saturation $L_n$ Indicates the length of the segment n (m)；$L_n^c$ Is the length of the vehicle queue on the road segment n (m); $L_p^c$ Indicates the average effective length of the car（m/veh）;S Is the speed at which the queue is dissipated when the green light is released (m)；h Indicates the headway.

## 3. Case Study - Intersection of Chang'an Road and Xiaozhai Road is the object of analysis

*3.1Current status of intersection*

This case analysis uses the intersection of Chang'an Road and Xiaozhai Road as the analysis object. Chang'an Road in the north-south direction of the intersection is the main road of the city, with 8 lanes in both directions. At the intersection, the north entrance expands into 3 straight lanes, 1 left turn lane, 1 right turn lane, 1 turn lane, and south entrance expansion. It is 4 straight lanes, 2 left-turn lanes, and 1 right-turn lane. The Xiaozhai Road in the east-west direction is the regional trunk line, and the two-way 6-lane road has extended left turn and extended right turn at the intersection. The basic information of the intersection is as shown in figure 1.

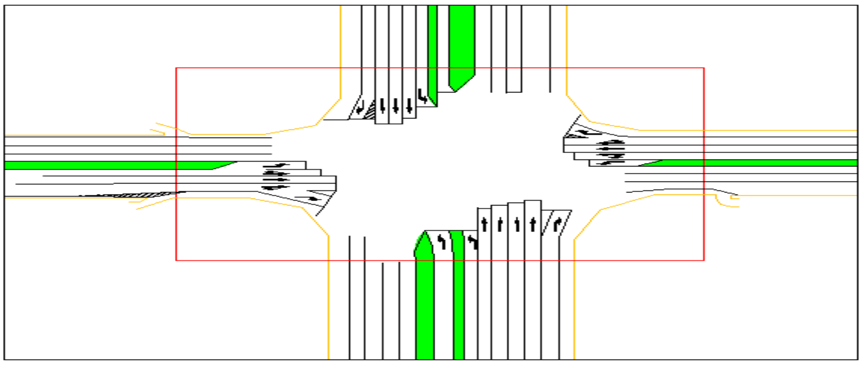

Fig. 1: Chang'an Road - Xiaozhai Road intersection

In terms of signal, the left turn in the north-south direction has a separate left turn protection phase, and the right turn traffic of the intersection is not affected by the intersection signal. The signal timing is as shown in figure 2.

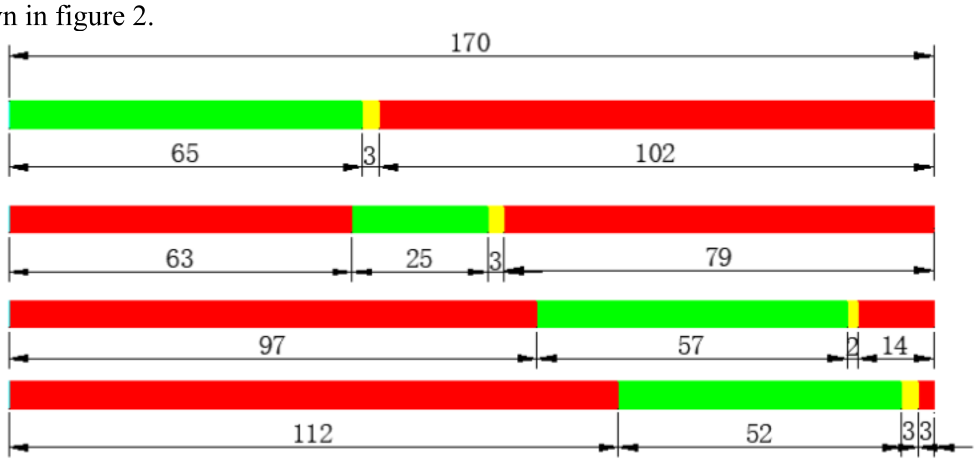


Fig. 2: Signal timing at the intersection of the current stage

In terms of traffic flow at the intersection, according to the field survey, the current traffic information is as follows:

Table 1: Traffic volume at intersection

| Import road | Channelization | Capacity(pcu/h) | flow（pcu/h） | | | Bus flow (vehicle / h) |
|---|---|---|---|---|---|---|
| | | | Turn left | straight | Turn right(RTOR) | |
| South import | | 2300 | 300 | 1886 | 63（6） | 192 |
| North import | | 2300 | 180 | 1686 | 84（3） | 228 |
| West import | | 1560 | 72 | 1200 | 13(3) | 132 |
| East import | | 1560 | 72 | 1380 | 11(3) | 66 |

Arrival rate and departure rate of each import channel:

Table 2: Vehicle arrival and departure rates in all directions of intersections

| Import road | Arrival rate（pcu/s） | | | | Departure rate (pcu/s) |
|---|---|---|---|---|---|
| | Turn left | straight | Turn right | Bus | |
| South import | 0.08 | 0.523 | 0.023 | 0.063 | 0.638 |
| North import | 0.08 | 0.523 | 0.023 | 0.063 | 0.638 |
| West import | 0.02 | 0.383 | 0.003 | 0.036 | 0.433 |
| East import | 0.02 | 0.383 | 0.003 | 0.036 | 0.433 |

*3.2Intersection main bus signal priority*

Before implementing the priority of the intersection main road, the relevant parameters need to be calibrated. Now assume that the number of passengers in the bus is 30 people/veh, the passenger number of the car is 2 people/veh, and the minimum green time of the north-south phase is 55s. The left-turn phase minimum green time is 20s, and the east-west phase minimum green time is 40s. First analyze the main path priority in the case of green light extension and green light early strategy.

In the case of the main path priority under the green light extension strategy, it is assumed that the bus is detected at the end of the first phase, and the green light extension application is triggered. If the controller detects that the green time required to be extended is 5 s, the calculation can be obtained by matlab. The total delay for one phase reduction is 3531.1s, and the total delay for other phase increases is 2290.22s. The total delay reduced after implementing the greenlight extension strategy is 1240.88s. After the first phase green light is extended for 5s, the green time of the subsequent phase is reduced by 3s, 1s, and 1s, which can reduce the total delay. The example shows that the green light extension strategy constructed in this chapter can really reduce the bus delay and the delay of the intersection.

In the case of the main road priority under the green light early-rising strategy, when the bus arrives at the main road intersection at the red light time, the system detects the arrival of the bus, and gives the green light to get up early to achieve the bus priority. If the bus arrives in the first phase and needs to advance 5 seconds, the total delay of the first phase reduction is 4297s, and the total delay of the previous phase increase is 3897.2s. Therefore, the overall delay of the intersection is 399.8s. Therefore, the implementation of the green light early warning strategy can also effectively reduce bus delays and total delays at intersections, proving that the early green light strategy constructed in this chapter is feasible.

*3.3 Bus priority effect analysis of multi-intersection*

*3.3.1 Intersection traffic conditions*

The traffic capacity on the road is 1800pcu/h, and the traffic flow is 1440pcu/h. The current traffic of the bus is 108 veh/h. The arrival rate of the vehicle is 0.4pcu/s, the queue dissipating speed is 0.5pcu/s, and the arrival rate of the bus is 0.03/s. The signals of a and intersection b are two phases, and the period is 100s, where in the main road has a green time of 60s, a red time of 37s, and a yellow time of 3s. The phase difference between the two intersections is 60s. The minimum green time of the branch road is 20s. The signal timing of the intersection is as follows:

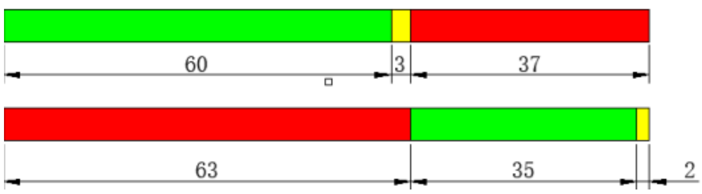


Fig. 3: Multi-intersection signal timing

It is recorded that there is a train team consisting of 25 vehicles (including 3 buses), and the average car is 2 passengers per car passenger. people. The train team sailed through the a intersection and headed for the b intersection. The relevant parameters are set as follows:

Table 3：Multi-intersection parameter setting

| | |
|---|---|
| Phase difference Φ(s) | 60 |
| Schedule time t(s) | 50 |
| Vehicle arrival rate q（pcu/s） | 0.4 |
| Green time g(s) | 60 |
| Red light time r(s) | 37 |
| Long cycle C(s) | 100 |
| Vehicle arrival flow Q（pcu） | 25 |
| Queue dissipating speed S（pcu/s） | 0.5 |

*3.3.2Fleet delay calculation*

If the head of the train arrives at the b-intersection, it is the red light phase with the red light time remaining for 10 s. The phase of the last car arriving at the intersection may be the green light phase or the red light phase of the next cycle. According to the above-mentioned multi-intersection bus signal priority control model, it can be obtained by matlab calculation:

When the last car arrives at the intersection with a green light phase, at this time, the delay of the bus delay is 159s, the social vehicle reduction delay is 1093.75s, and the total delay in this direction is 1018.1s. If the first vehicle in the direction is a bus, when the bus is detected, give the green light for 10s in the early direction. At this time, the traffic delay is 0s. Therefore, when the front is a bus, the green light can effectively reduce the bus. When the phase of the last car arrives in the red phase of the direction, the delay in bus reduction is 215.37s, the delay in the reduction of social vehicles is 4305.75s, and the total delay in this direction is 3738.43s. If the direction requires a green light to get up early for 10s, the delay of bus reduction is 208.5s, the delay of social vehicle reduction is 4154.75s, and the total delay in this direction is 3151.45s. Relative to the absence of green light, the delay is reduced by 120.98s. If the green light is extended for 10s, the bus delay at this time is 191.88s, the social vehicle delay is 2999.75s, and the total delay in this direction is 2572.49s, which is relatively longer than the green light extension, and the delay is reduced by 1065.94s.

Therefore, green light extension and early green light can effectively reduce delays. Among them, the green light extension reduces the delay more, which is more conducive to the main road.

## 4.Conclusions

In this paper, the conventional public transportation is taken as the analysis object, and some methods of implementing bus priority at the intersection are introduced. For the current technical conditions, the strategy of selecting green light extension and green light early rise is taken as the basic priority strategy of this paper, and the case is calculated and analyzed. The results show that the bus priority strategy has a certain optimization effect on the intersection while ensuring the effect of the bus operation, which ensures the overall traffic efficiency of the intersection. The conclusions reached in this paper are:

(1) The article summarizes and analyzes the main types of bus signal priority and various priority strategies at this stage, and selects the priority strategy suitable for this paper.

(2) According to the two different signal priority modes, the green light extension and the green light early rise, the paper establishes a delay model in the direction of the main road of a single intersection, and calculates the delay by example. The results show that these two signal priority methods can effectively reduce the delay of the intersection bus, and also make the delay of the intersection at the intersection at a relatively low level.

(3) In the priority of bus intersections at multiple intersections, this paper analyzes the relationship between the different delays caused by the fleet and the non-head vehicles and the period and phase

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difference of the intersections under the conditions of multiple intersections.

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