



# Research on Bus Priority Control on Non-coordinated Phase Based on Transmodeler——A Case Study of Changjiang Road in Huangdao District of Qingdao

Zhang Junyou, Liao Yaping\*

College of Transportation, Shandong University of Science and Technology, Qingdao, China

## Email address:

junyouzhang@sust.edu.cn (Zhang Junyou), liaoyapingsk@163.com (Liao Yaping)

\*Corresponding author

## To cite this article:

Zhang Junyou, Liao Yaping. Research on Bus Priority Control on Non-coordinated Phase Based on Transmodeler——A Case Study of Changjiang Road in Huangdao District of Qingdao. *American Journal of Traffic and Transportation Engineering*.

Vol. 2, No. 3, 2017, pp. 32-38. doi: 10.11648/j.ajtte.20170203.12

**Received:** June 26, 2017; **Accepted:** July 11, 2017; **Published:** August 1, 2017

---

**Abstract:** Many studies focus only on the bus priority request on coordinated-phase in traffic signal coordination of artery, while ignoring the bus priority control on non-coordinated phases. For the non-coordinated phases with more bus traffic, it is necessary to achieve bus priority control on non-coordinated phases. Based on the coordinated control on artery and bus priority control on the coordinated phase, this paper put forward the control principle of bus priority on the non-coordinated phases for active early turning on and lately breaking green light and the calculation method of the green time on each phase with the limitation of upper and lower limits of the green belt and the minimum green time of every phase. This paper took the Changjiang Road in Huangdao District of Qingdao as an example, and established the existing signal control scheme of Changjiang Road in Transmodeler. After that, we input bus priority control principle on the non-coordinated phases and algorithm put forward in this paper into the simulation software system. Then, two traffic flow conditions were respectively simulated before and after implementing bus priority on the non-coordinated phases of the traffic signal on the Changjiang Road. Finally, the output evaluation index of each intersection signal on two conditions were compared and analyzed. The results showed that the proposed control principle and algorithm could reduce the traffic delay and improve the efficiency of road operation effectively.

**Keywords:** Non-coordinated Phase, Bus Priority, Green Light, Mode, Transmodeler

---

## 1. Introduction

Now most of national cities are implementing signals coordinated control on urban artery, in which the signal coordinated control on urban artery is to make all the signals on the main line control for joint, to achieve green belt, so that reducing the frequency of encountering red light while the vehicles are running at a set speed, and achieving the purpose of opening the main road [1]. Green belt bandwidth and signal phase difference on the main road are optimized by the social traffic detected through the detector. The coordinated control on the main road may be undermined if the bus priority control strategies are implemented simultaneously. Therefore, it is of great practical significance to realize the bus priority on intersections without damaging signal coordinated control system on the main road.

In the field of implementing bus priority on signal

coordinated control, many scholars have done a lot of research. Yang Xiaoguang et al. [2] used the linear programming model to propose a method to determine the bus priority signal with the overall best efficiency of the system under fixed cycle conditions, and to make a case study, however only the first phase was assumed in this study that there were buses to through, there were no explanations on how to determine the bus priority application of other phases, the timing did not consider pedestrian phase with many limitation. Zhang Weihua et al. [3] proposed to take the minimum per capita delay as the optimize target for the signal cycle, and the split was determined by passenger ratio of phase and the phase saturation. The case analysis showed that make timing according to the minimum total delay could reduce per capita delays though increasing average delay. Nicholas E. Lownes [4] established per capita delay model on the main line, assumed that the travel time of each travel mode was equal,

and analyzed the traffic benefit change of implementing bus priority under the main line. Ma Wanjiang et al. [5] aimed at the minimum impact of social traffic and put forward a bus priority control model on the main road to ensure that the negative impact of social traffic was minimal and could reduce the bus delay. Wang Dianhai et al. [6] had did the bus priority control research on coordinated phase according to the bus priority and coordination priorities of arterial green wave. Li Zhenlong et al. [7], taking the influence of the bus priority control strategy at the upstream intersection on coordinated control of the green wave and the downstream intersection into account, put forward a bus priority model on the main road considering the delay of the upstream and downstream intersections. In the distributed intelligent control, Francois Dion [8-9] proposed an optimization algorithm with minimum weighted delay and parking times, and established the conversion rules of coordinating the upstream and downstream vehicles, and assigned different priority weights according to the priority levels. Alexander [10] adopted conditional public transport strategy under the coordinated control on the main road to determine whether the bus with priority request was late, only the late bus could be controlled for priority, then used the large time headway appeared the end of phases to provide signal control for the bus with the constraints of upper and lower limits of the green band. Yu Honghong [11], taking the per capita delay as the control target, the remaining road space as the dynamic constraint, constructed bus signal priority coordinated-control model on the multi-intersection using VISSIM software by the example. Xue Changsong et al. [12] took the Longpan middle Road of Nanjing as an example, and studied the feasibility and effectiveness of bus signal priority control method under the coordinated control through the comparative analysis of the road traffic under the five different signal control strategies.

The common points of above bus priority research on the coordinated control of the main line are that they all study the bus priority of the coordinated phase under the coordinated control on the main line, and there is little research on bus priority of the non-coordinated phases, which dose not applicable for the main roads with more buses on non-coordinated phases than that on coordinated phase and cannot make improvement on their traffic efficiency, so only implementing bus priority on the coordinated phase does not accord with the characteristics of many bus lines in China. Therefore, referring the research at home and abroad, this paper proposes a bus priority control strategy on non-coordinated phase based on coordinated control of the main line and the calculation method of green time of each phase after implementing bus priority, and takes the Changjiang Road bus line system in Huangdao District of Qingdao as the studying case. Finally, based on the Transmodeler software, we compare the total delays, the average delay, the per capita delay and the total number of stops at the intersection of the main roads after implementing the above proposed method with that before implementing this method, and then make the conclusion analysis.

## 2. Research Ideas

The non-coordinated phase bus signal priority layer is added to the trunk signal which has achieved the signal coordination level. The core module of this layer is the mode of early-starting green light and mode of lately breaking green light. Two modes of bus priority should be based on the premise of not destroying the coordination of the main road. When the bus issues a bus priority request, and the request phase is the current release phase, if the bus arrived at the parking line of the intersection at the green time, the system will keep the signal unchanged, if not, then open the mode of lately breaking the green light, and compress green time of other phases, so as to provide the maximum available extended green time for the bus priority; When the request phase is not the current release phase, if the current phase has reached its shortest green time, then the mode of early open green light to immediately cut off the phase, and compress the green time of non-coordinated phases located behind this phase and before the coordinated phase; If the current phase does not reach its shortest green time, compress the green time of the other non-coordinated phases located behind the current phase and before the coordinated phase until the current phase reaches the minimum green time, and provide the maximum advance opening green time for the bus priority when the precondition is met. The control flow of bus signal priority layer on the non-coordinated phases is shown in Figure. 1 below.

### 2.1. Mode of Lately Breaking Green Light

#### 2.1.1. Determine the Available Extended Green Time on the Non-coordinated Phase

According to the positions of non-coordinated phase  $l^n$  with the bus priority request and the coordinated phase  $h$ , it can be divided into two cases to determine the maximum available extended time provided for the non-coordinated phase  $l^n$ :

- (1) When  $l^n < h$ , that is, in the  $n$ th cycle, when the non-coordinated phase  $l^n$  with the bus priority request is in front of the coordinated phase  $h$ , to compress the green time of phases from the phase  $l^n + 1$  to the coordinated phase  $h$ , then the calculation method of the maximum available extended green time provided for the non-coordinated phase  $l^n$  is:

$$t_{gxl^n}^n = \sum_{i=l^n+1}^{h-1} t_{gxi}^n + t_{gxh}^n \quad (1)$$

Where:  $t_{gxl^n}^n$ : The maximum extended green time can be provided to the non-coordinated phase with the bus priority request in the  $n$ th cycle;  $t_{gxi}^n$ : The available compressed time of the non-coordinated phase  $i$  in the  $n$ th cycle, s;  $t_{gxh}^n$ : The difference between the lower time  $G_{eh}^n$  of the green wave and the start time  $G_{sh}^n$  on the coordinated phase  $h$  in the  $n$ th cycle, which can be calculated by the following formula:

$$t_{gxi}^n = G_{eh}^n - G_{sh}^n \quad (2)$$

Assume that the extended green time required for bus priority request is  $t_{gb}^n$ , if  $t_{gxi}^n \leq t_{gb}^n$ , the timing of the

non-coordinated phase with the bus priority request is unchanged, otherwise, the mode of lately break green light is adopted.

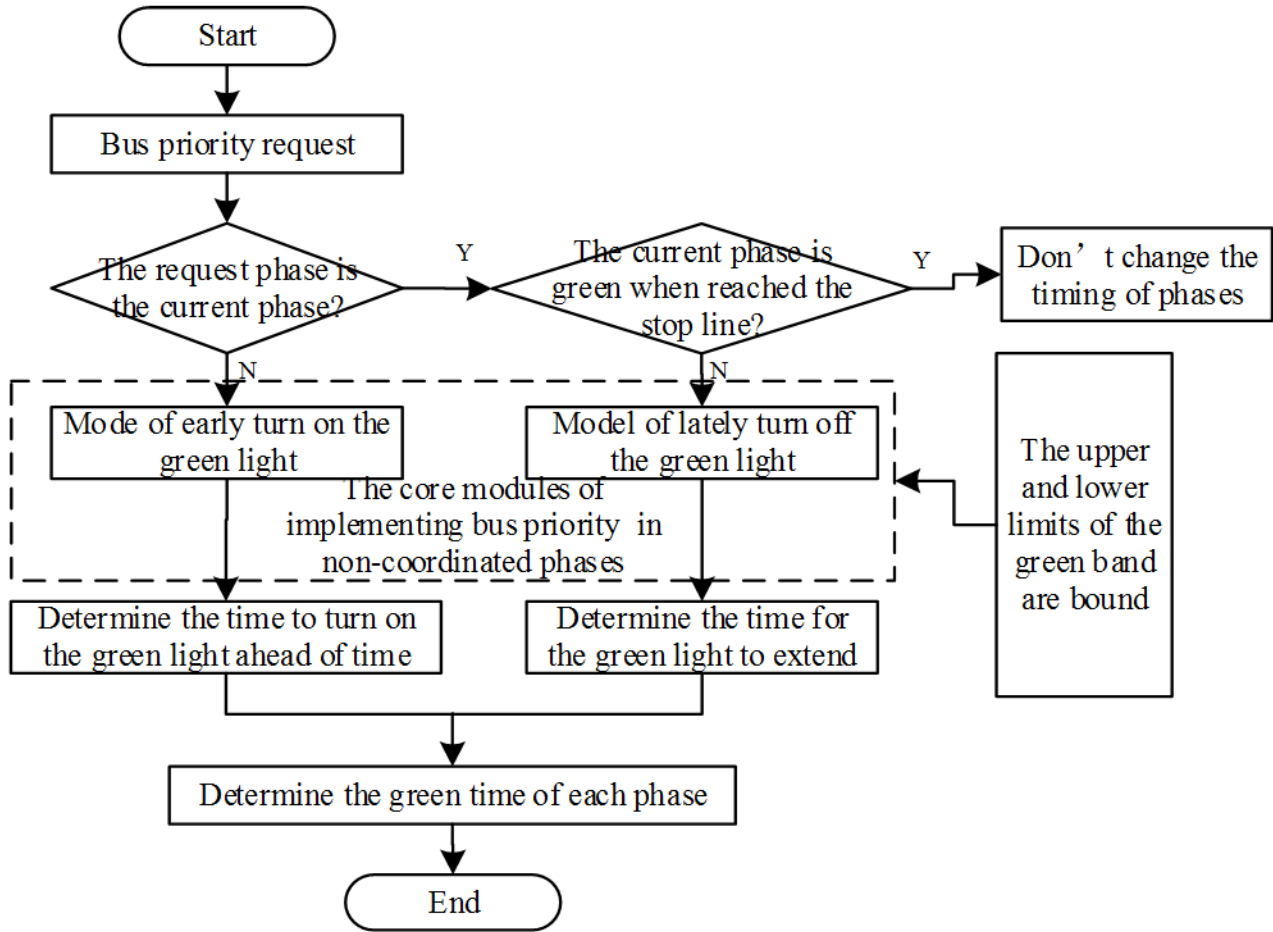


Figure 1. The control flow chart of Implementing bus priority on the non-coordinated phases.

(2) When  $l^n > h$ , that is, in the  $n$ th cycle, when the non-coordinated phase  $l^n$  with the bus priority request is behind the coordinated phase  $h$ . Then all the available compressed green time of the non-coordinated phases behind the phase  $l^n$  in the  $n$ th cycle, the non-coordinated phases in front of the phase  $h$  in the  $n+1$  cycle and the coordinated phase  $h$  in the  $n+1$ th cycle are used to provide extended green time for non-coordinated phase  $l^n$  with a bus priority request in the  $n$ th cycle. The calculation method is:

$$t_{gxi}^n = \sum_{i=l^n+1}^k t_{gxi}^n + \sum_{i=1}^{h-1} t_{gxi}^{n+1} + t_{gxi}^{n+1} \quad (3)$$

Where:  $t_{gxi}^{n+1}$ : The available compressed green time of the non-coordinated phase  $i$  in the  $n+1$ th cycle, s;  $t_{gxi}^{n+1}$ : The available compressed green time of the coordinated phase  $h$  in the  $n+1$ th cycle, s.

Assume that the extended green time required for bus priority request is  $t_{gb}^n$ , if  $t_{gxi}^n \leq t_{gb}^n$ , the timing of the

non-coordinated phase with the bus priority request is unchanged, otherwise, the mode of lately break green light is adopted.

### 2.1.2. Determine the Green Phase of Each Phase After Implementing the Bus Priority on Non-coordinated Phase

(1) The green time  $G_{gbl^n}^n$  of the non-coordinated phase with a bus priority request

In the mode of lately break green light, the green time  $G_{gbl^n}^n$  of the non-coordinated phase with a bus priority request is the sum of the original green time  $G_{gl^n}^n$  and the extended green time  $t_{gbl^n}^n$ . That is:

$$G_{gbl^n}^n = G_{gl^n}^n + t_{gbl^n}^n \quad (4)$$

(2) The green time  $G_{gbi}^n$  of other compressed non-coordinated phases

Use the equal flow ratio to share the total compressed

green time to calculate the green time  $G_{ghi}^n$  of other compressed non-coordinated phases. That is:

$$G_{ghi}^n = \max\left(G_{ghi,\min}^n, G_{gi}^n - t_{gbl^n}^n \frac{y_i}{Y}\right) \quad (5)$$

Where:  $G_{ghi,\min}^n$ : The shortest green time that must be maintained for the non-coordinated phase  $i$  of the  $n$ th cycle.

(3) Determine the green time of the coordination phase

In order to ensure that the green belt is not damaged, and the compressed coordinated phase  $h$  is compensated for the green light, we need to backward the coordinated phase for this compensation time  $G_{ghc}^n$ . Then the compensation time  $G_{ghc}^n$  is:

$$G_{ghc}^n = t_{gbl^n}^n - \sum_{i=1}^{h-1} t_{gsi}^n \quad (6)$$

## 2.2. Mode of Early Turning on Green Light

### 2.2.1. Determine the Available Advanced Start Time of Green Light that Other Phases Can Be Provided for the Non-coordinated Phase $l^n$ with a Bus Priority Request

When the non-coordinated phase  $l^n$  with the bus priority is triggered, and the bus arrives at the stop line at the time of the non-coordinated phase  $o^n$ , according to whether the phase  $o^n$  has finished the minimum green time, determining the available advanced start time can be divided into the following two cases (We take the situation that the coordination phase  $h$  is in front of the non-coordinated phase  $o^n$  and  $l^n$  as an example to discuss. Other situations' study ideas are similar to this situation, such as the situation that the coordinated phase  $h$  is between the non-coordinated phase  $o^n$  and  $l^n$ , and the situation that the coordinated phase  $h$  is behind the non-coordinated phase  $o^n$  and  $l^n$ ):

(1) When the phase  $o^n$  does not finish the minimum green time, if  $l^n < o^n$ , then the available advanced start time of green light that other phases can be provided for the non-coordinated phase  $l^n$  with a bus priority request can be calculated by:

$$t_{gyl^n}^n = \min\left(\sum_{i=o^n}^k t_{gyi}^n + \sum_{i=1}^{h-1} t_{gyi}^{n+1} + \sum_{i=h+1}^{l^n-1} t_{gyi}^{n+1}, g_{he}^{n+1} - g_{hm}^{n+1}\right) \quad (7)$$

Where:  $t_{gyl^n}^n$ : the available advanced start time of green light that other phases can be provided for the non-coordinated phase  $l^n$  with a bus priority request in the  $n$ th cycle, s;  $t_{gyi}^{n+1}$ : the available advanced start time of green light that the non-coordinated phase  $i$  can be provided for the non-coordinated phase  $l^n$  with a bus priority request in the  $n+1$ th cycle, s;  $g_{he}^{n+1}$ : The ending moment of the green light on the coordinated phase  $h$  in the  $n+1$ th cycle, s;  $g_{hm}^{n+1}$ :

The upper limit moment of the green belt on coordinated phase  $h$  in the  $n+1$ th cycle, s.

If  $l^n > o^n$ , then the available advanced start time of green light that other phases can be provided for the non-coordinated phase  $l^n$  with a bus priority request can be calculated by:

$$t_{gyl^n}^n = \min\left(\sum_{i=o^n}^{l^n-1} t_{gyi}^n + \sum_{i=l^n+1}^k t_{gyi}^n + \sum_{i=1}^{h-1} t_{gyi}^{n+1}, g_{he}^{n+1} - g_{hm}^{n+1}\right) \quad (8)$$

Where its symbolic meanings are the same as the above formula.

(2) When the phase  $o^n$  has finished the minimum green time, the available advanced start time of green light that other phases can be provided for the non-coordinated phase  $l^n$  with a bus priority request can be determined by the following formula:

If  $l^n < o^n$ , then

$$t_{gyl^n}^n = \min(G_{o_1^n}^n - G_{o_2^n}^n + \sum_{i=0^n+1}^k t_{gyi}^n + \sum_{i=1}^{h-1} t_{gyi}^{n+1} + \sum_{i=h+1}^{l^n-1} t_{gyi}^{n+1}, g_{he}^{n+1} - g_{hm}^{n+1}) \quad (9)$$

If  $l^n > o^n$ , then

$$t_{gyl^n}^n = \min(G_{o_1^n}^n - G_{o_2^n}^n + \sum_{i=0^n+1}^{l^n-1} t_{gyi}^n + \sum_{i=l^n+1}^k t_{gyi}^n + \sum_{i=1}^{h-1} t_{gyi}^{n+1}, g_{he}^{n+1} - g_{hm}^{n+1}) \quad (10)$$

In the formula (9) and (10):  $G_{o_1^n}^n$ : The original green time on the phase  $o^n$  in the  $n$ th cycle, s;  $G_{o_2^n}^n$ : The green time has ran by the phase  $o^n$  after it turning off the green light, s. And other symbolic meanings have been described above.

### 2.2.2. Determine of the Green Time of Other Phases

(1) Determine the green time of other non-coordinated phases

Similar to the mode of lately breaking green light, the non-coordinated phases uses equal flow ratio to share the compression time, the calculation method is:

$$G_{gsi}^n = \max(G_{gi,\min}^n, G_{gi}^n - t_{gsl^n}^n \frac{y_i}{Y}) \quad (11)$$

Where:  $G_{gsi}^{n+1}$ : The green time of phase  $i$  in the  $n$ th cycle, s;

$t_{gsl^n}^n$ : The advanced start time of green light on the non-coordinated phase with the bus priority request in the  $n$ th cycle, s.

## 3. Simulation Research on Bus Priority of Non-coordinated Phase of Changjiang Road in Huangdao District

### 3.1. Premise Assumptions on the Main Road

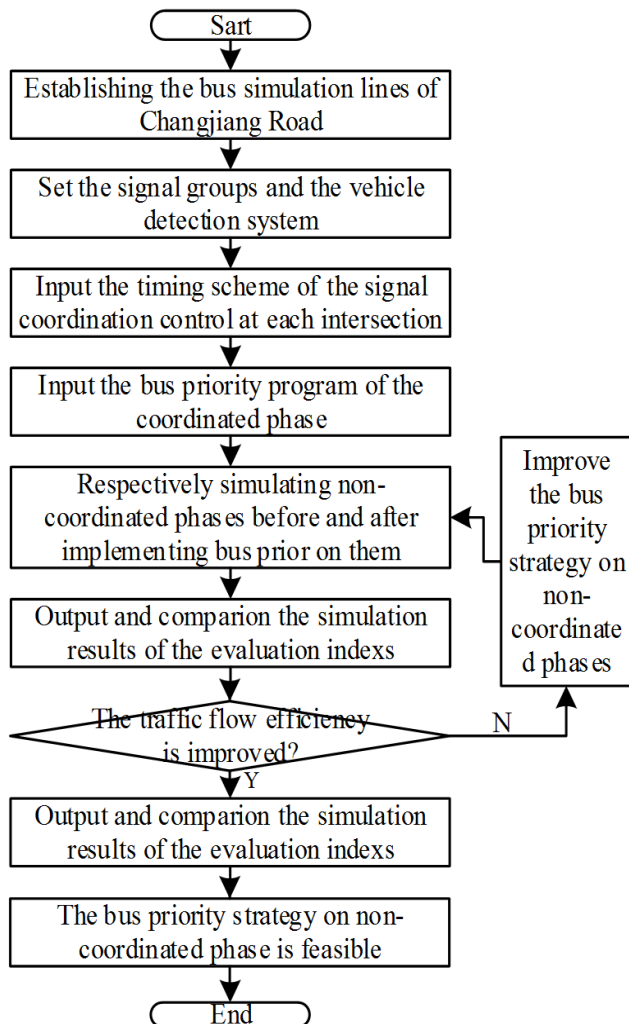
(1) The main road is equipped with bus priority system, including bus priority request system, communication system

and traffic signal control system, and has implemented the signal coordination control and bus priority signal control on the coordinated phase;

(2) The main road includes bus lanes and special entrance road for public transportation;

### 3.2. The Bus Line System of Changjiang Road

Changjiang Road area of Huangdao Development Zone is densely populated with a blooming territory, and the roads in the area are equipped with bus lanes and special entrance road for public transportation. The bus lines are dense, including 6, 9, 18, 22, 28, 31 and 801 bus, the layout of each line as shown below in Figure.3, the yellow area in the Figure.3 on behalf of the construction section. In addition, five signaled intersections of the main road, including the intersections respectively cultivated by Changjiang Road with Jiangshan Road, Lushan Road, Jinggangshan Road, Wuyishan Road and Alishan Road, have been implemented the signal linkage control.



**Figure 2.** The specific flow of the bus priority simulation on the non-coordinated phase of the Changjiang Road by Transmodeler.

And in order to alleviate the traffic congestion in the peak of Changjiang Road, the traffic government departments of

Huangdao have been implemented the signal coordinated control on the road and bus priority control on the coordinated phase in the previous few years, so this article selected the Changjiang Road as a research object to research on the bus priority simulation on the non-coordinated phase

### 3.3. Bus Priority Simulation Environment on Transmodeler

1) Transmodeler software is a multi-function traffic simulation package developed by the United States Caliper company for urban traffic planning and simulation. The specific flow of the bus priority simulation on the non-coordinated phase of the Changjiang Road by Transmodeler is shown in the Figure.2. The distance between the five intersections of the green belt is 350m, 270m, 450m, 245m respectively, the loss time of the green light for each phase is 4s, the common cycle of the signal is 94s, the velocity of the green band is 47.5Km/h, and the two directions of the bandwidth is 25s, and the direction of the Changjiang Road is the direction of coordinated phase. The bus flow detector is set in the import of the intersection before the stop line 80m. And the bus priority control on the coordinated phase also includes two control modes of lately breaking green light and early turning on green light. The lane saturation rate set in the Transmodeler is 2000pcu/h, the average passenger loaded by bus is 30 people and by car is 1.5 people, the conversion rate of bus is 2 to the standard car. The current basic flow of intersections in the Changjiang Road is captured by the video device and acquired by algorithm. In order to verify and evaluate the benefit of implementing bus priority on the non-coordinated phase of the main road signal, this paper selects the per capita delay, the total delay, the average delay and the total parking number output by Transmodeler as the evaluation index.



**Figure 3.** The layout of each bus line of Changjiang Road in Huangdao.

2) In the Transmodeler, the traffic conditions of Changjiang Road before and after implementing bus priority on the non-coordinated phase are respectively simulated for 1 hour. Then, all the evaluation index data of each intersection output from the software after simulating are analyzed and compared, as shown in Table 1 and Table 2 below:

*Table 1. Simulation results of each evaluation index on five intersections.*

Intersection	The simulation results before implementing bus priority on the non-coordinated phase				The simulation results after implementing bus priority on the non-coordinated phase			
	Per capita delay	The total delay	the average delay	the total parking number	Per capita delay	The total delay	the average delay	the total parking number
Changjiang Road-Jiangshan Road	54.9	77761	56.9	1020	44.9	73800	55.2	1011
Changjiang Road-Lushan Road	56.8	49650	45.1	790	46.9	49330	40	773
Changjiang Road-Jinggangshan Road	65.7	204120	52.3	2800	59.1	183240	46.9	2848
Changjiang Road-Wuyishan Road	77.1	88210	43.5	1170	69.8	86760	39.6	1064
Changjiang Road-Alishan Road	88.7	84250	37.4	1520	78	82810	36.7	1467

*Table 2. The benefit evaluation form of implementing bus priority on non-coordinated phase.*

Intersection	Per capita delay	The total delay	the average delay	the total parking number
Changjiang Road-Jiangshan Road	18.21%	5.09%	2.99%	0.88%
Changjiang Road-Lushan Road	17.43%	0.64%	11.31%	2.15%
Changjiang Road-Jinggangshan Road	10.05%	10.23%	10.33%	-1.71%
Changjiang Road-Wuyishan Road	9.47%	1.64%	8.97%	9.06%
Changjiang Road-Alishan Road	12.06%	1.71%	1.87%	3.49%

From the above two tables, we can see that after implementing the the bus priority strategy on non-coordinated phase of Changjiang Road coordination signal, the above-mentioned evaluation indicators have been greatly reduced, such as the per capita delay of Changjiang Road - Jiangshan Road intersection was down to 44.9s from the original 54.9s for 18.21%, the average delay down to 55.2s from the original 56.9s for 2.99%, the total parking delay down to 1011s from 1022s for 0.88%, the total delay down to 73800s from the original 77761s for 5.09%. And the various evaluation indicators of the other four intersections also had basically large or small reduction. It can be seen that the implementation of bus priority on non-coordinated phase is conducive to improving the efficiency and the service level of road traffic.

## 4. Conclusion

In this paper, we first put forward the bus priority algorithm for the non-coordinated phase of the coordinated control on the road signals, and then took the five intersections of Changjiang Road as the study case to establish the simulation system of implementing bus priority on the non-coordinated phase of Changjiang Road signals in Transmodeler, inputting parameters and the control algorithm proposed in this paper, and then the two traffic situations of before and after implementing bus priority on non-coordinated phase at each intersection were simulated respectively for 1 hour. After that, the output index results of the two traffic conditions were compared and analyzed. The result showed that the control algorithm could effectively reduce the delay of the road and improve the service level of the road. But this study is limited to use for the main roads that are suitable for implementing coordinated signaled control, and with more buses on non-coordinated phases.

## Acknowledgements

This study was supported by The Scientific Research Foundation of Shandong University of Science and Technology for Recruited Talents (2015RCJJ035).

## References

- [1] Z. Hui. Research on signal control method of bus priority on the main road [D]. Jilin University, 2011.
- [2] Y. Xiaoguang, L. Yu, M. sheng. Research on the determination method of bus priority signal on signalized intersection [J]. Chinese Journal of highway and transport, 2001, (S1): 103-106+110.
- [3] Z. Weihua, L. Huapu, S. Qin, L. Qiang. Timing optimization method for signalized intersection with bus priority [J]. Journal of traffic and Transportation Engineering, 2004, (03): 49-53.
- [4] P. Mirchandani, L. Head, A. Knyazyan. An approach Towards the integration of Bus Priority and Traffic Adaptive Signal Control [C]. Washington D. C: Transportation Research Board 80<sup>th</sup> Annual Meeting, 2000.
- [5] MA W, NI W, HEAND L, et al. Effective coordinated optimization model for transit priority control under arterial progressing [J]. Transportation Research Record: Journal of the Transportation Research Board, D. C, 2013 (2356): 71-83.
- [6] W. Dianhai, Z. Hui, B. Yiming, W. Qiang. Coordination control method for bus priority signal on the main road [J]. Journal of Southeast University (Natural Science Edition), 2011, 04: 859-865.
- [7] L. Zhenlong, Z. Minghao, W. Baoju, L. Peikun, Dong Wenhui. The bus priority model on the main road consider the delay at the upstream and downstream intersections [J]. Traffic Information and Security, 2015, 05: 36-42.
- [8] F. Dion, B. Hellinga. A rule-based real-time traffic responsive signal control system with transit Priority application to isolated intersection [J]. Transportation Research Part B, 2002 (36): 325-343.
- [9] F. Dion, B. Hellinga. A Methodology for Obtaining Signal Coordination within A Distributed Real-Time Network Signal Control System with Transit Priority [J] Transportation Research Board 80<sup>th</sup> Annual Meeting, January7-11, 2001, Washington, D. C.

- [10] A. Skabardonis. Control Strategies for Transit priority, Transportation Research Board. Washington D. C. November 17, 1999. PP. 1-3 Richardson A J Ogden K W. Evaluation of active bus-Priority signal [J]. Transportation Research Board, 1979, 718:5-12.
- [11] Y. Honghong. Bus Priority Coordinated-Control method Based on Multi-intersection [J]. Gansu Science, 2016, 03: 54-58.
- [12] X. Changsong, Y. Xiaowan. Research on The Technology of Bus Signal Priority Based on Microscopic Simulation - A Case Study of Longpan Middle Road in Nanjing [J]. Journal of Transportation Engineering and Information, 2015, 13(03): 102-112.