

Utilization of the spare capacity of exclusive bus lanes based on a dynamic allocation strategy

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Abstract

Under the unbalanced allocation of road resources between bus lanes and adjacent lanes, this paper primarily focuses on the utilization of spare capacity of exclusive bus lanes by automobiles during peak hours and aims at alleviating traffic jams and balancing road resources under the premise of the principle of public transportation priority. It is operated by the traffic control centre, which is responsible for dynamically declaring information and adjusting the dynamic bus lanes. The vehicles qualified to the utilization of bus lanes should meet the requirement that no malignant or illegal incidents happened during the past year. Actually, during the operation, only high-occupancy vehicles with more than three passengers can be allowed to enter into the bus lanes. In addition, it is tightly regarded as compensation to the vehicles limited by the tail number limitation strategy in Hangzhou. As a result, nearly 20 percent of vehicles are qualified to use the spare capacity of bus lanes and more than 5 percent of traffic volume is expected to increase during peak hours with the guarantee of the service level of exclusive bus lanes, and it is found that nearly 87.5% of car drivers accept this strategy.

Keywords: exclusive bus lane, dynamic allocation, priority of public transportation, spare capacity, high-occupancy vehicle.



1 Introduction

With the rapid increase of the number of vehicles, road conditions tend to be more and more serious in most countries as well as China. According to the experiences of most countries, public transportation is the most suitable strategy to solve the traffic problems. Thus, the strategy of bus priority has already been carried out by the government of China and encouraged to be widely developed and implemented. To date, it has been well developed in recent decades in several large and medium-sized cities in China, such as Beijing, Shanghai and Hangzhou.

Hangzhou, the capital city of Zhejiang province, is an important transportation hub in China's south-east. In recent decades public transportation in Hangzhou achieves an unprecedented attention. By 2012, there are 7450 buses running on the road which is 0.3 percent of the total number of motor-vehicle within Hangzhou City. Aiming at alleviating congestion and encouraging green transportation, Hangzhou had the first exclusive bus lane in 2000. And by now, 24 exclusive bus lanes aside roads in Hangzhou is in use, including 17 lanes for whole day, 3 lanes for fixed time from 7 a.m. to 9 p.m. and 4 lanes for morning/evening peak-hour time, and the route of exclusive bus lanes is totally 70 kilometers long. Since the establishment of exclusive bus lane system, reduction of bus travel time and increase of bus speed is successfully achieved. According to statistics, the share rate of public transportation reached 20.92 percent in the end of 2012 [1].

Apparently exclusive bus lane is of great benefit to supply a green, fast and convenient access to public transit and make an effective influence on priority of transportation. However, automobile lanes near the exclusive bus lane suffer a saturated even super saturated condition during peak hours while the exclusive bus lane is still spare for bus. With respect to this phenomenon, field investigations were required to collect traffic data on several arterial roads with exclusive bus lanes. The average volume during peak hours has a large difference between exclusive bus lane and adjacent lanes. In addition, over 77 percent of drivers think it is really a waste of road resources when it is severely crowded in automobile lanes, but the cars are not allowed to run on the unoccupied bus lanes. Under such an unbalanced allocation of road resources, it is sometimes occupied by car drivers even though they are at risk of 200 RMB (33 dollars) fines and 3 points deduction.

Consequently, the unbalanced utilization of road resources is certainly a problem since the set-up of exclusive bus lanes. This paper discusses the strategy of making efficient utility of spare capacity of exclusive bus lane to relax the over-saturated lanes near exclusive bus lanes according to dynamic allocation strategy in the premise of public bus priority.

2 Literature review

Katsuragi [2] studied 19 exclusive lanes during morning/evening peak hours in Japan and made a conclusion that the permission of high occupancy vehicles,



more than 4 passengers including driver, to run on the exclusive bus lanes can probably make an increase of nearly 33 percent traffic volume per route in a degree. Vreeswijk *et al.* [3] presented the concept of Flexible Bus Lanes and set up a test to analyze its practicability in Bologna. The Flexible Bus Lanes obviously enables a temporary use by automobiles without disturbance to the public transportation. And it is managed and controlled by information interaction between vehicles and infrastructure by roadside unit (RSU). This scheme makes an optimal use of road capacity and has been proved that it is only 3 seconds delayed of buses while the average travel time of vehicles are decreased by 53% according to the test. A new innovative dynamic bus lane system was initially introduced by Hong Yang and Wei Wang [4]. The system is significant to relax the congestion on adjacent lanes and meanwhile do less effect on bus lanes. Compared to the exclusive bus lane, the dynamic bus lane is proved to be another efficient alternative on reduction of conflicts and lane allocation.

3 Dynamic allocation strategy

The dynamic allocation strategy aims to make optimal use of spare capacity of bus lanes, to allocate part of traffic volume on the adjacent lanes to balance road resources, and finally to improve the overall capacity and the level of service. By defining limitation of bus lane utilization for automobiles on traffic behavior, it also contributes to discourage drivers from illegal and harmful behaviors of driving, which is helpful for a safety, smooth and civilized road environment.

There are six principles set as basic ideas to favorably implement this strategy:

1. Public transportation priority is the basic guarantee to the development of public transportation. The strategy to allow automobile running on the bus lane is a great challenge to this principle, because it will inevitably influence the efficiency of bus driving. Therefore the qualified vehicles should not break the priority and smooth of bus driving. On the other hand, the number of qualified vehicle is also has an upper bound which changes dynamically based on the actual condition. In a word, it is necessary to do research on the premise of public transportation priority.
2. Resource equilibrium principle, which plays an important role in road allocation, is presented to be abided to improve the operating efficiency of road traffic and make optimal use of public road resources.
3. Dynamic allocation principle, based on the principle of public transportation priority, is used to reasonably allocate the traffic flow between bus lanes and adjacent lanes and to save the spare capacity on bus lanes to alleviate traffic congestion on automobile lanes according to the real-time traffic volume, speed and time headway.
4. People centered principle. This paper is to guide people to obey the traffic laws and regulations and normalize traffic behaviors by limiting the qualification based on illegal behaviors. It is finally expected to construct a safety and civilized traffic environment.



5. Credit principle depends on the drivers' self-consciousness to meet the limited conditions of qualification to the utility of exclusive bus lane. Also it can hardly be avoided that a few drivers enter into the bus lanes without qualification. So it is obvious that camera and police inspection are necessary for this system.
6. Principle of compensation to the strategy of tail number limitation. To solve the traffic congestion problems, Hangzhou city carried out a measurement that the number of vehicles entering into the city center is limited by the tail number of the license plate during peak hours on workdays. For example, the tail number of the license plate 1 and 9 will be limited on Monday, 2 and 8 on Tuesday and so on. In order to compensate the vehicles limited on the previous day and also because of the limited spare capacity of bus lanes, the strategy is only available to these vehicles which are not permitted by tail number limitation on the previous day.

4 Exclusive bus lane composite utilization system

The Exclusive bus lane composite utilization system consists of variable message system (VMS), induction loops or other detectors, cameras and traffic control center. Induction loops are set about 500 to 1000 meters before the entrance/exit of bus lanes to detect real-time conditions such as traffic volume, queue, delay and bus situation. In this study, we set q_0 , which is related to the service level of exclusive bus lanes and is decided by traffic management dynamically, as a threshold value of traffic volume. If actual traffic volume is lower than αq_0 (α is equal to 0.9 in this paper, which depends on the entire conditions and service level of the bus lanes), it means there is enough spare capacity remained and available for vehicles to enter into the bus lane and a series of information will be sending and analyzing over entire system. Significantly VMS will in-timely shows the enter/exit information, "qualified automobile are permitted", to guide the qualified drivers changing into bus lane once the driver is going to use the bus lane. On the contrary, if it reaches the upper bound βq_0 (β is equal to 1.05 in this paper, which also depends on the entire conditions and service level of the bus lanes), the VMS will show the message, "unavailable for automobile". During the operation, cameras installed above the lanes will detect and capture the traffic behaviors of vehicles. And meanwhile traffic control center plays a powerful role in the system that it is responsible to respond immediately to special cases and master the overall situation to insure the safe and smooth running on roads.

As a beneficial and optimized strategy, it has severe limitation that those who want to apply for permission should meet the conditions as follows:

1. No record of severe traffic violations behaviors within one year, such as speeding, drink-driving, red light running.
2. High occupancy vehicle with more than 3 passengers when driving on the road.
3. Vehicles which are not permitted on previous day by tail number limitation strategy.



The first two limitations above are to discourage traffic violations behaviors and encourage high occupancy vehicles. That means, vehicles without violations record within one year and with more than 3 passengers is available to gain permissions, but it is not equal to get the qualification to use the bus lane whenever and wherever you like. It is also combined with the strategy of tail number limitation in peak hours. Only the vehicles suffered the tail number limitation on previous day can be allowed to enter into the bus lanes when available on that very day, which is the content of indemnity principle related above. All the requirements lie on the credit of drivers, that is, the implementation of the dynamic strategy mostly depend on self-consciousness of drivers. And it will be seldom managed and controlled by the enforcement of video surveillance and police inspection by the traffic management department.

In addition, aiming at convenient management of the strategy, a data base containing the information of permitted drivers is set up and also connected to the national public security control system to achieve a scientific, efficient and integrated management system.

5 Feasible evaluation

As listed in Table 1, questionnaire surveys geared to drivers and traffic police are carried out for feasibility and acceptance investigation. According to the results, about 80 percent of car drivers want to use the dynamic bus lane and 76.7 percent are acceptable with the requirements of high occupancy vehicles and 82.5 percent with compensation principle, 88.3 percent with no record of severe violation, 70 percent with cancelling the qualification when nonobservance of the rules. As the administrative department, traffic police take a positive attitude toward this strategy that over 87.5 percent of them are favorable of the dynamic strategy and especially the percent of acceptance of violation limitation is 97.5 high, for it is of great benefit to balance road resources and to guide the drivers to obey the traffic rules.

Table 1: Attitude about the dynamic strategy.

	Bus driver	Vehicle driver	Traffic police
There is a great spare capacity in exclusive bus lanes during peak hours.	45	95	33
Acceptance of the strategy of dynamic bus lane	28	105	35
Acceptance of HOV ≥ 3	43	74	35
Acceptance of Compensation principle	43	99	34
Acceptance of Violation limitation	52	106	39
Acceptance of Punishment	44	84	31
Total	60	120	40

6 Conclusions and future work

This work is aiming at taking optimal use of spare capacity of exclusive bus lane by changing the fixed bus lane into a dynamic lane with the principle of public transportation priority. It describes the limitation of qualified vehicles to enter into the exclusive bus lanes, and finally carry out an evaluation by questionnaire survey. According to the analysis of the results, this strategy is accepted by 87.5 percent of drivers and over 50 percent of drivers are in favor of the limitations and punishments for this strategy. In addition, there are 20 percent of vehicles are qualified to use the spare capacity of exclusive bus lanes. It also contributes to encourage a regular, civilized and safety conditions on road and to relax the severe congestion in Hangzhou to improve the service level of exclusive bus lanes. This study tightly combines the present strategy in traffic management field and considers the demand of traffic participants. However, it is still need a further investigation and experiments to improve the strategy. And how it impacts on both bus lanes and adjacent lanes and how to analyze the system more specific and considerable are expected to be contained in the future.

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References

- [1] Hangzhou Municipal Bureau of Statistics, the State Statistical Bureau Hangzhou investigation team & Hangzhou Social and Economic Investigation Bureau. *Hangzhou statistical yearbook 2013*, China Statistics Press: Beijing, 2013.
- [2] Katsuragi M., Multilateral use of exclusive bus lanes in Kanazawa City. *1999 IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems*, pp. 181-183, 1999.
- [3] Vreeswijk J, Armandi M & Campello P., Flexible bus lanes in Bologna. *7th European Congress Exhibition on Intelligent Transportation System and Services*, pp. 1-8, 2008.
- [4] Hong Yang & Wei Wang, An innovative dynamic bus lane system and its simulation-based performance investigation. *2009 IEEE Intelligent Vehicles Symposium*, pp. 105-110, 2009.

