Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2022, 9(9):26-32

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Research on the Design of Variable Lane Signal Control

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Abstract In order to alleviate intersection in the rush hour traffic because of left turn traffic supersaturated and peaked in the morning and evening tide phenomenon induced congestion, conventional four-way intersection, for example, supersaturation are presented with the intersection of supply and demand condition variable lane of intersection set reverse variable lane, synthetic signal phase sequence, cycle, the green light time, green light and bright and clear ahead of time the calculation method of analysis and combined with examples.

Keywords Variable lane; Signal timing; Dynamic control

0 Preface

Insufficient traffic capacity at intersections will lead to congestion at intersections, which in turn will reduce the efficiency of vehicles in the urban road network. Compared with the method of road traffic infrastructure construction to solve the congestion of the intersection, the reverse variable steering lane is to solve the congestion of the intersection through reasonable traffic control under the existing road conditions, which has the advantages of saving manpower, material resources and financial resources. advantage. By adding some road infrastructure, changing the lane attributes at the intersection, and designing a reasonable signal timing scheme, the congestion problem of the intersection in the tidal traffic phenomenon is solved. In terms of foreign research, Oakes J. [1] and others first proposed the method of setting up pre-signals and double-stop lines at intersections when studying bus priority to allow buses to enter intersections first. This method can be used for reference from intersections. Application of the control method of the variable steering lane. WW Zhou, P. Livolsi, E. Miska [2], etc., based on the actual application of variable lanes in the George Massey Tunnel in Vancouver, Canada, studied a system that dynamically adjusts the attributes of variable lanes according to actual traffic flow conditions. In terms of domestic research, Xu Hongling [3] et al. studied the threshold conditions of variable steering lane attribute transition based on the main pre-signal coordinated control method, and determined the timing of the main pre-signal when the entrance road is widened. The method was studied. In the research on the control method of the fixed time period, Li Lili [4] and others proposed the use of the main pre-signal and the setting method of the double stop line to reasonably induce the vehicles that need to enter the variable guide lane, and to adjust the variable direction. Guidance Lane property required.

1 Reverse variable lane signal control design

1.1 Setting conditions of reverse variable steering lanes

The reverse variable steering lane traffic management method can make full use of the road resources of the exit road, thereby alleviating the congestion problem caused by the oversaturation of the left turn lane at the entrance road caused by the tidal traffic phenomenon. It is realized by utilizing the road, and the cost is low, the time is short, and the operation is convenient. However, not all intersections can be set with reverse variable steering lanes, and the settings must meet the following conditions:

1) The intersection must be a regular plane signal intersection without a signal-controlled intersection. The traffic order is chaotic and the traffic conflict is large, so it is not suitable to set up a reverse variable steering lane. Reverse variable guide lanes need to be managed by signal control to achieve the effect of use. It is not suitable to set up reverse variable steering lanes at interchanges, roundabouts, and deformed intersections. The road channelization conditions of these intersections are complex, and other problems are likely to occur after setting. Therefore, regular cross-shaped and T-shaped signal-controlled intersections can be used. Set up reverse variable steering lanes.

2) It is necessary to set up a separate left-turn phase at the intersection and the setting of the reverse variable steering lane of the left-turn lane not only improves the road resource utilization of the exit road, but also improves the traffic efficiency of left-turn vehicles. Therefore, it is necessary to have a separate left-turn lane. Turn phase and left-turn lanes to control left-turn vehicles and prevent left-turn vehicles from colliding with vehicles in other directions.

3) There are at least 3 lanes at the exit road where reverse variable steering lanes are set. Setting reverse variable steering lanes needs to occupy at least one exit lane, and at least one exit lane is reserved for right-turning vehicles in other directions to pass, and considering that the vehicle is in the In the case of an early U-turn at the intersection, in order to meet the requirement of its turning radius, there are at least 3 lanes at the exit road where the reverse variable steering lane is set.

4) The utilization rate of the exit road is low, and there are fewer vehicles queuing on the upstream of the exit road. Set up a reverse variable steering lane to use the exit road. If there are many queued vehicles upstream of the exit road, setting a reverse variable steering lane will affect the vehicles upstream of the exit road. The traffic efficiency is easy to cause new congestion.

5) The traffic flow of straight and left-turn vehicles on the entrance road is large, the lane saturation is high, and the road resources are tight. The purpose of setting up reverse variable steering lanes is to improve the traffic efficiency of left-turn vehicles. If it is small, it is meaningless to set the reverse variable steering lane. Therefore, when the traffic flow of straight and left-turn vehicles on the entrance road is large, the saturation of the entrance road is high, and the road resources are tight, the adjacent exit road can be used to set up a reverse variable steering lane. The increase will be more obvious.

6) The reverse variable steering lane should meet the requirements of the turning radius of left-turning vehicles

When setting up a reverse variable guide lane, the turning radius requirements of left-turning vehicles should be considered to ensure the smooth flow of left-turning vehicles.

1.2 Analysis of Control Mode of Reverse Variable Guidance Lane

In the control method of the reverse variable steering lane, the following points should be paid attention to [5-9]:

1) Signal control must be adopted at the intersection where the reverse variable steering lane is set, and the signal phase sequence can be set in the normal release sequence of going straight first and then turning left, and there must be a dedicated left turn phase.

2) The reverse variable steering lane is used as a left-turn entrance during a certain period of time during the peak traffic period, and is used as an exit road during a certain period of time. Therefore, attention should be paid to controlling the early opening and advance of the reverse variable steering lane. The closing time is related to the speed of the vehicle entering and exiting the intersection, the length of the reverse variable steering lane, etc. It cannot be too long or too short.

3) In the case of tidal traffic phenomenon, the flow of left-turn traffic will remain at a relatively large level during most of the time period, so the opening and closing of the reverse variable steering lane should not be too frequent to reduce the number of vehicles Lost time at the intersection, so it should be reasonably controlled according to the actual flow situation.

4) After setting the reverse variable steering lane, make a U-turn in advance for the U-turn vehicle at the entrance, if the U-turn is in the intersection, it will cause vehicle conflict.

5) Guidance signal lights and signs should be set at the entrance to guide vehicles entering the reverse variable steering lane and complete the clearing of the reverse variable steering lane.

1.3 Research on the control method of reverse variable steering lane

1.3.1 Research on the length control of reverse variable lanes

The setting length of the reverse variable guide lane should not be too short or too long. Too short can not improve the efficiency of left-turn traffic and cannot achieve the expected effect. If it is too long, the lane may take too long to clear or cannot be completely cleared, which will reduce the utilization efficiency of the reverse variable steering lane and cause vehicle conflicts. Therefore, the following two points should be considered for reasonable settings.

1) Minimum length of the reverse variable steering lane

The length of the reverse variable guide lane should be greater than the length of the guide lane line at the entrance of the intersection. If it is less than the length of the guide lane line, it will affect the queuing of left-turn vehicles at the adjacent left-turn entrance, and it is too short for left-turn traffic. The improvement in efficiency is not significant.

2) Maximum length of the reverse variable steering lane

Under normal circumstances, the vehicle will not be divided into lanes upstream of the intersection before the second set of guide arrows on the approach road, so the length of the reverse variable guide lane is less than the length of the second set of guide arrows on the access road to the stop line.

1.3.2 Research on the setting quantity control of reverse variable steering lanes

If setting up a reverse variable steering lane cannot meet the demand for left turn, and after re-optimizing the signal timing at the intersection, there are still many left-turn queued vehicles, and the saturation of the left-turn lane is still large, the channelization can be adjusted according to the actual situation. Consider whether to increase the number of reverse variable steering lanes depending on the situation, and consider the number of lanes in other directions at the intersection.

When adding reverse variable steering lanes, it is necessary to consider not conflicting with right-turning and left-turning traffic in other directions and considering the situation of vehicle U-turns. The number of them is limited by the current intersection channelization. The number N1 of reverse variable steering lanes is affected by the number of adjacent left-turn lanes N2 and the number of right-turn lanes on the opposite entrance. N3 , the number of right - turn lanes in the intersection direction N4 , the number of exit lanes in the intersection direction N5 , and the limit on the number of exit lanes in this direction N6 , as shown in Figure 1-1 .

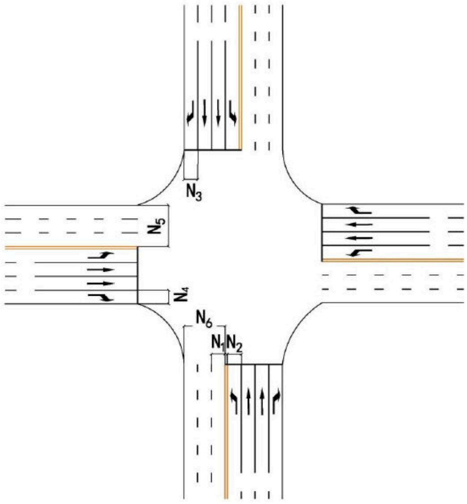

Figure 1.1: Schematic diagram of reverse variable guide lane length setting

N1 of reverse variable steering lanes and the number of lanes in other directions is:

$$N_1 \leq \min\left(N_5 - N_3 - N_2, N_6 - N_4\right)$$

When setting multiple reverse variable steering lanes, their lengths should be equal, the same central isolation opening and guidance signal lights should be used, and vehicles are not allowed to change lanes at will between multiple reverse variable steering lanes to ensure normal operation. Traffic order and safety.

1.4 Research on dynamic control system of reverse variable steering lane

1.4.1 The establishment of the system

At present, the reverse variable steering lanes are rarely used in cities in my country, and the control methods that have been applied are mostly manual control or fixed-time control. Compared with the dynamic control method, it cannot better adapt to the real-time change of traffic flow, and cannot maximize the degree of control. Improve road resource utilization at exit roads. In order to make the reverse variable steering lane have a better use effect, a dynamic control method should be adopted.

In the idea of dynamic control, a dynamic control system should be established, which includes four parts: the collection and summary analysis of traffic data, the processing of traffic data, the determination of lane opening and closing thresholds, and the control of induced facilities. The work completed by the dynamic control system mainly has two parts: one is to determine whether the threshold of lane opening and closing has been reached through the collection and analysis of traffic flow data; Lane, and when the threshold is not reached, the reverse variable steering lane is cleared. This not only achieves the purpose of improving traffic efficiency, but also achieves the purpose of dynamic control to make full use of road resources.

1.4.2 Detector and Induction Signal Lamp Settings

In order to realize the real-time collection and analysis of traffic flow data, and to complete the induction of vehicles entering the reverse variable steering lane, detectors and induction signal lights should be set up at the intersection for dynamic control.

Two sets of detectors at the entrance to obtain detailed traffic flow data, and set up guidance signal lights at the opening of the reverse variable steering lane to induce vehicles. 1 to The No. 5 detector is used to detect the specific data of the traffic flow distribution in the reverse variable steering lane and the entrance road, and the No. 6 to No. 10 detectors are used to detect the queuing of vehicles in the entrance road.

1.4.3 Research on the control thresholds for opening and closing of reverse variable steering lanes

The main purpose of setting the reverse variable steering lane is to relieve the traffic pressure of the left-turn lane. Therefore, the current saturation of the left-turn lane, the length of the vehicle queue, and the vehicle delay should be considered in the control of the opening and closing of the reverse variable steering lane. In order to better realize the dynamic control of the reverse variable steering lane, the timing of opening and closing of the reverse variable steering lane should be pre-judged in advance. The opening and closing control threshold judgment process designed in this paper is as follows.

1) Collect and analyze the data of the turning traffic flow in the entrance lane through the detector, use the calculation model to predict the distribution of the turning traffic flow in the next cycle, and judge in advance the queue length, saturation, and vehicle delays.

2) Determine whether the vehicles in the left-turn lane are about to queue up again, whether the saturation of the left-turn lane is greater than 0.9, and whether the delay time of vehicles increases.

3) When it is judged that the vehicles in the left-turn lane will have a secondary queuing phenomenon, the saturation of the left-turn lane is greater than 0.9, and the delay time of vehicles increases in two of these three situations, then the cycle for these two situations will continue. number to judge.

4) Considering safety and errors, when it is judged that the duration of the two conditions is at least 2 cycles, the reverse variable steering lane is opened and the signal timing of the intersection is adjusted.

5) After opening, when the judgment result does not meet any one of the above three conditions, the reverse variable steering lane can be closed, and the signal timing of the intersection can be readjusted.

6) Input the above scheme of judgment conditions and procedures into the threshold determination system to complete the judgment of the opening and closing of the reverse variable steering lane in each cycle.

1.4.4 Induction signal light control research

The setting of the reverse variable lane has certain requirements for the main signal scheme, and it must be ensured that the reverse variable lane has a certain "car storage" time before the same-turn left turn phase is turned on. In order to avoid conflicts, left-turn vehicles in the opposite straight and intersecting directions are prohibited from entering the exit road, so the preceding phase of the same left-turning phase must be the straight-going phase in the intersecting direction. Taking the conventional four-phase as an example, the main signal scheme is a phase sequence scheme of "turn left first and then go straight".

In order to ensure the safety of the vehicle in the reverse variable steering lane and achieve the ideal use effect of the reverse variable steering lane, the reverse variable steering lane needs to be opened and closed in advance. Therefore, both the green light and the red light of the induction signal light need to be turned on in advance. Through the coordinated control of the guidance signal light and the intersection signal light, the use efficiency of the reverse variable steering lane is improved.

Minimum time for early opening of reverse variable lanes:

When the pre-signal is on, the left-turn vehicle is in a waiting state after the pre-signal stop line, which can be used as the starting stage of queuing. The green light early turn-on time cannot be too large or too small. If it is too large, vehicles entering the reverse variable steering lane will easily conflict with the left-turn traffic flow in the intersecting direction. If it is too small, it will cause a waste of road resources in the reverse variable steering lane. The time for the green light to be turned on in advance is related to the length of the reverse variable steering lane and the vehicle speed.

$$t_{nk} = t_0 + \frac{L_1}{v_k}$$

In the formula:

t_{nk} — the advance opening time of the reverse variable lane;

L_1 - Set the length of the reverse variable lane at the intersection (m);

t_0 - Time ( ) for the first vehicle to start into the reverse variable lane s , 2.3 can be used s .

Minimum time for early closing of reverse variable lanes:

The determination of the early closing time of the pre-signal must ensure that the last vehicle entering the reverse variable lane can pass the intersection smoothly, so the early closing time T_{ng} is:

$$T_{ng} = t_0 + \frac{l_n}{h_s} \times h_t$$

In the formula:

T_{ng} — time of closing in advance (s);

l_n - Length of reverse variable lane channelization section (m);

h_s - Saturated head spacing;

t_0 - Time (s) for the first vehicle to start to enter the reverse variable lane, 2.3s can be used;

h_t - Saturated headway.

1.5 Optimization model

Considering that the average vehicle delay, queuing length and the number of stops have a relatively significant positive correlation, therefore, the reverse variable lane opening time and the average vehicle delay are respectively selected as the safety control and efficiency indicators for the model construction. The model is constructed as follows:

$$\mathrm{Min}\,(D/\sum_{j=1}^{m} q_j)\ ,$$

$$\mathrm{Min}\,(g_1 - t_{1c})\ ,$$

$$\text{s. t.} \begin{cases} g_i \geqslant g_{\min} \\ c_{\min} \leqslant \sum_{i=1}^{n} g_i + L \leqslant c_{\max} \\ g_6 \geqslant t_{1t} \\ g_3 \geqslant t_{1t} \end{cases}$$

D is the sum of all vehicle delays, m is the total number of lane groups, q_j is the flow of lane group j , g_i is the effective green light time of the ith phase, g_{min} is the minimum green light time, c_{min} is the minimum cycle duration , c_{max} is the maximum cycle duration , and t_{1t} is the reverse possible The advance light-up time for changing lanes .

The above formula can be solved by the MATLAB optimization algorithm to solve the multi-objective optimization problem. γ Termination parameter for the optimization solution.

$$\frac{d(t_n) - d(t_{n+1})}{d(t_n)} < \gamma$$

d (t_n), d (t_{n+1}) is the average delay in the period $t_n$and t_{n+1}period

After many optimization iterations, the delay reduction rate for each additional cycle is less than γ, the corresponding solution is taken as the optimal solution.

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