Unconventional Outside Left-Turn Lanes

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For countries driving right, left-turn lanes are usually on the inside of roads. However, when there are a large number of vehicles turning left in the outer lane of the upstream section of the intersection, these vehicles will be forced to pass many consecutive parallel lanes and then enter the left-turn lane. During this process, many traffic conflicts will occur between left-turning vehicles and going-straight vehicles, which will lead to longer traffic delays.

traffic engineering | route optimization | genetic algorithm | feeder bus | station transfer

1. Background

There are two models of road traffic all over the world: one is left-hand traffic (LHT) and the other is right-hand traffic (RHT). Most countries implement RHT, such as China, the United States, and Russia. Signalized intersections are the main places in urban traffic where traffic conflicts occur. For right-hand traffic (RHT) countries, left-turn traffic is one of the main causes of traffic conflicts. Signalized intersections are key nodes and capacity bottlenecks in the urban road network system. Reasonable and effective organization of left-turn traffic is one important way to improve the operating status of intersections. The setting of the left-turn lane is related to the overall operating quality of the intersection, which has attracted a lot of attention for a long time. With the increase in traffic load in all directions of urban signalized intersections and the frequent occurrence of upstream lane changes in recent years, some applications of unconventional outside left-turn lane have emerged at intersections in RHT countries. On the contrary, traffic organization of right-turn vehicles at intersections and outside right-turn lanes are the main problems in LHT countries, such as the United Kingdom and Japan.

Relevant studies have shown that if there are more left-turn vehicles on the outside lane upstream segment of intersection entrance, the outside left-turn lane can effectively alleviate the interweaving phenomenon among these vehicles and straight-going vehicles (Li J. W. et al., 2010) [1]. However, some scholars have evaluated the safety impact of this traffic organization mode based on video traffic conflict automatic technology and found that the intersection approach with an outside left-turn lane has more conflicts than an intersection with an inside left-turn, and an improper setting will adversely affect overall operation efficiency and safety of the intersection (Guo Y. et al., 2016) [2]. Therefore, it is necessary to carry out quantitative research on the influential factors and setting conditions of the outside left-turn lane.

Although domestic and foreign scholars have conducted some research on the external placement of the left-turn lane, they mainly focus on the influence of changing only one factor—the location of the left-turn lane. The analysis of how to set the left-turn lane is usually based on the staggered behavior of the vehicle. In addition, most research on the socialization of left-turn lanes is generalized, and they ignore the special case of setting left-turn lanes. There are many research findings on using a BP neural network to solve traffic problems, but most of them are predictions of traffic flow. The gap in research on the prediction of traffic delay is still huge.

2. Research on Left Turn Lane

At present, domestic and foreign scholars have conducted relevant research on the setting of left-turn lanes. In terms of influencing factors, Ma W. et al. (2017) [3] studied the variation law of the maximum passing rate and blocking probability of the left-turn lane, adopting the approach of changing influencing factors, such as the storage capacity, cycle length, green diversion, phase sequence, and traffic flow, when the left-turn lane is blocked to find the law. Additionally, the volume and capacity of the left-turn lane are taken into account for the improvement of signalized intersections. Sando T. et al. (2009) [4] surveyed three left-turn lanes, analyzed the influence of geometric factors on the utilization rate of left-turn lanes, vehicle saturated flow, and other factors, and considered that the main factors of highly saturated flow were a downhill direction and a turning angle less than 90°. From the perspective of system design, Kikuchi S. (2021) [5] predicted the optimal length of right-turn and left-turn lanes at an intersection, and the relevant parameters affecting the length of left- or right-turn lanes were considered and analyzed. Persaud B. et al. (2010) [6] analyzed the queue length from the perspective of preventing vehicles from changing lanes due to congestion and developed a left-turn lane length calculation framework under different signal timing. Wang X. et al. (2020) [7] believed that lane width, the proportion of large vehicles, and the proportion of left-turning vehicles were important factors that affect the saturation flow of the lane. Daamen, W. (2010) [8] considered the interweaving flow rate and length important influential factors of the traffic operation at the entrance and exit. Xu Y. et al. (2018) [9] established a service level calculation model for the interweaving section and obtained the minimum weaving section length required to meet a certain service level and interweaving traffic. Han Y. et al. (2021) [10] analyzed the changes in vehicle interaction under different driving modes and then established a vehicle lane change model that can better adapt to difficult traffic conditions, which was validated through practice cases. Yao, R.H. (2009) [11] found that vehicles were more inclined to change lanes in the first half of the weaving area under crowded conditions but in the second half under free-flow conditions through investigation. Fitzpatrick Kay et al. (2014) [12] found the influential factors of geometry and traffic composition of double left-turn lanes after comparing the saturation flow rate of inside and outside left-turn lanes.

In terms of setting conditions, Wu J. et al. (2019) [13] proposed a procedure to optimize the distance between the upstream central divider opening and the main signal light using the CLL design method to allow more cars to go through the left-turn lane, thus maximizing the emission rate of left-turning vehicles and the utilization rate of the countercurrent lane. Zhou H. et al. (2010) [14] studied the saturated lane and lane distribution of inside and outside two-way left-turn lanes and found that the utilization rates of the inside and outside left-turn lanes were 46% and 54%, respectively. Zheng C. et al. (2013) [15] put forward the design method of replacing the left-turn lane and right-turn lane. They also analyzed the delay of the entrance lane in the case of a bus lane. Liu Pan et al. (2013) [16][17] quantitatively studied the impact of outside left-turn lanes on the traffic capacity and the intersection's operating efficiency with the binary Logit model. They believe that the probability of a driver choosing to drive in the outside left-turn lane increases with the increase in the traffic volume of the main line and the length of the queue in the inside left-turn lane. It decreases as the distance from the upstream right auxiliary side road to the intersection increases.

Domestic and foreign research has been conducted on the issue of outside left-turn lanes. However, most of them are limited to the impact of a single influential factor on the location of left-turn lanes, while other factors remain unchanged. They lack quantitative research on the location of left-turn lanes when multiple factors are involved. In addition, there are also special case studies on outside left-turn bus lanes, but general social lane conditions are ignored. Therefore, the delay data of inside and outside left-turn lanes are obtained under the comprehensive influence of multiple factors through the VISSIM simulation experiment. Based on the analysis of influential factors, the BP neural network delay model is constructed to comprehensively determine the location of the left-turn lane.

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