Study on the setting of non-motor vehicle left turn waiting area at typical intersection

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Abstract. Intersection as a vehicle intersection affects the traffic efficiency of the whole road network, and the mixed traffic of motor vehicles and non motor vehicles brings traffic pressure to the intersection. In order to operate and manage the intersection more efficiently, according to the setting principle of non motor vehicle left turn waiting area, this paper expounds the setting conditions and application scope in detail, and puts forward the setting and research of non motor vehicle left turn waiting area at the intersection. It is found that the setting of non motorized vehicle left turn waiting area can make effective use of the internal space of the intersection and improve its traffic capacity.

1. Introduction

Usually, we call standard T-shaped and cross intersections as typical intersections. As the node of urban road network, the safety performance and operation efficiency of intersections seriously affect their operation state. The non motorized vehicles at intersections are mainly composed of bicycles and electric vehicles. Due to the lack of popularity of electric vehicles abroad, the wide non motorized lane, and the traffic volume of non motorized vehicles is far lower than that in China, there is little research in this field. In China, the situation in this aspect is very serious. Through the analysis of many domestic scholars' existing research in this aspect, it is found that the setting of non motor vehicle left turn waiting area can not only effectively use the space resources of the road network, but also improve the traffic capacity of the road network, and also plays a very important role in reducing the delay of intersections[1].

2. Description and mathematical model of vehicle and non-motor vehicle

2.1. Expansion effect theory

As the name suggests, the expansion effect is that the traffic flow is no longer kept in the original fixed transverse width, but presents a spray well umbrella type forward way, thus expanding its transverse width. For non motorized vehicles, this usually occurs during the time when the right of way is changed from no right of way to right of way, especially when the signal light in the intersection is changed from red light to green light. Due to the flexibility of non motorized vehicles, the large difference in acceleration and the non motorized vehicles in the back row surpass the vehicles in front, the non motorized vehicle flow in the same cross section tends to expand horizontally, This results in expansion effect, as shown in Figure 1[2].

In particular, when the expansion benefit of non motor vehicles is particularly significant, the expansion range of vehicle flow direction on both sides is expanded. At this time, non motor vehicles...
are likely to run on the same route of releasing motor vehicles, and form a conflict with it.

![Figure 1](image1.png)

**Figure 1.** Description of expansion effect

When the expansion effect is produced, the expansion width can be a good quantitative expansion effect, which refers to the deviation difference of the optimal route of non motor vehicles in the whole driving process. The expansion width increases from 0 at first, and then decreases to 0 after reaching the critical value. As shown in Figure 2.

![Figure 2](image2.png)

**Figure 2.** Diagram of transverse width of $L_i$ non-motor vehicles at intersections

The basic formula for calculating the flow expansion width of non motor vehicles is as follows:

$$L = L_1 - L_0$$  \hspace{1cm} (1)

Where $L$ represents expansion width of non-motor vehicle flow (m), $L_1$ represents lateral width of non motor vehicle in popular driving (m) and $L_0$ represents lateral width of non motor vehicle flow while waiting for parking (m).

### 2.2. Conditions of conflict between motor vehicles and non-motor vehicles

Through observation, the left turning traffic flow usually passes through the intersection with a quarter arc. Figure 3 is a traditional intersection. The coordinate system is established by taking the intersection of the south entrance and west entrance parking line extension line as the origin of the two-dimensional coordinate system. The X and Y coordinate systems are established in the direction of the figure, and the motion trajectory of the traffic flow is represented by the coordinate system.
As shown in the figure above, the streamline equation of \( y_1 \) motor vehicle is as follows:

\[
y_1 = \sqrt{d_4^2 - \frac{d_1^2 \cdot x_1^2}{d_3^2}} (x_1 \geq 0)
\]  

Streamline equation of \( y_2 \) non-motor vehicle is:

\[
y_2 = \sqrt{d_2^2 - \frac{d_2^2 \cdot x_2^2}{d_1^2}} (x_2 \geq 0)
\]

Therefore, if the width of the motor vehicle is set to 2m, the conflict between the motor vehicle and the non-motor vehicle will occur when

\[
y_2 - y_1 \leq \frac{L_1}{2} + 1.
\]

2.3. Expansion model of motor vehicle and non-motor vehicle

Based on the analysis of the theory of expansion conflict, the three main factors which may lead to the conflict are studied reasonably, which are the traffic volume of motor vehicles, the volume of non motor vehicles and the channelization of intersections. It is speculated that the number of non motor vehicle expansion conflicts should be positively related to the total traffic volume of left turn to some extent. Therefore, the traffic volume of non motor vehicles should be the most critical factor, and the traffic volume data of bicycles and electric vehicles should be counted separately.

Then, the model of conflict number between left turning non motor vehicles and left turning motor vehicles in the same direction entrance is established\(^{[3]}\):

\[
C_1 = \frac{a_1 \cdot X_{b}^{d_1} \cdot X_{s}^{e_1}}{D_1}
\]  

In this equation, where \( C_1 \) represents the number of conflicts between the expansion of the direct left turning non motor vehicle and the left turning motor vehicle in the same direction entrance road; \( X_f \) represents the traffic volume of left turning vehicles on the same direction entrance road; \( X_b \) represents the left turn bicycle traffic; \( X_{s} \) represents the left turn E-bike traffic and \( a_1, b_1, d_1, e_1 \) represents the relationship between them.
3. Illustrative example

3.1. Results of vehicle and non-vehicle inflation models

At present, the commonly accepted standard definition is produced in the 1970s. In a popular sense, when two road participants change with time and space, if they do not change their original trajectory, they will collide in a short time. This is called traffic conflict. There are many factors causing traffic conflicts, among which the management and distribution of traffic flow is one of the key points to be solved in today's society.

This paper makes a field investigation on the intersection of Jiefang Road and Youth Road in Tinghu District, Yancheng City, obtains the individual movement track of the intersection by video camera, and determines the intersection parameters by artificial investigation. Then, the video analysis software tracker is used to analyze the video taken, and the data of peak period and conflict occurrence between motor vehicles and non motor vehicles are recorded. The non expansion model of machine is constructed.

To ensure the accuracy of the model, take the 1 hour data as a group, and then make statistics in the following table, and input the model data. The detailed data is shown in the following table:

| Number of conflicts | Vehicle traffic volume | Bicycle traffic | Traffic volume of e-bike |
|---------------------|------------------------|-----------------|-------------------------|
| 20                  | 318                    | 60              | 208                     |
| 15                  | 244                    | 52              | 163                     |
| 16                  | 295                    | 57              | 155                     |
| 15                  | 287                    | 48              | 178                     |
| 12                  | 199                    | 43              | 156                     |

The model is as follows:

\[ C_f = \frac{0.0125 \cdot X_I^{0.1732} \cdot X_s^{0.6547} \cdot X_b^{0.6971}}{D_i} \]  

We use the relevant data to test the model, and the results are as follows:

| Actual conflicts | Forecast conflicts | Vehicle traffic volume | Bicycle traffic | Traffic volume of e-bike |
|------------------|--------------------|------------------------|-----------------|-------------------------|
| 10               | 10                 | 162                    | 36              | 149                     |
| 13               | 13                 | 179                    | 47              | 163                     |

After verification, the number of conflicts predicted by the model does meet the accuracy requirements, and can be used to predict the traffic conflict and safety index of Yancheng intersection.

3.2. Design of left turn waiting area for non-motor vehicles

When the non conflict situation is serious, the reasonable use of the location of the intersection internal area, the parking line forward, reduce the distance between the entrance and exit. When the straight green light is on, the left turning non motor vehicles will move along with the straight traffic flow to the waiting area to wait. When the green light on the exit road is on, they will leave the intersection and cross the intersection twice to eliminate the interference of the conflict between vehicles and non motor vehicles, improve the operation efficiency and traffic capacity of the
intersection to a certain extent, and alleviate the degree of traffic flow mixing. It can also play a good role in safe driving\cite{4}. The design scheme is shown in Figure 4.

![Figure 4 use of the left turn waiting area for non-motor vehicles within the intersection](image)

Finally, we take the intersection of Jiefang Road and Qingnian Road in Tinghu District of Yancheng City as an example to verify the feasibility of non motor vehicle left turn waiting area according to the passing time standard.

The normal driving speed of motor vehicles on the road is 30 ~ 50 km / h, and the normal driving speed of motor vehicles is 40 km / h, equivalent to 11.11 m/s; The normal driving speed of non motor vehicles on the road is 20 ~ 30 km / h, and the normal driving speed of non motor vehicles is 25 km / h, equivalent to 6.95 m/s. The distance between the entrance lane stop line and the exit lane of a typical urban road intersection is 60m. After setting a non motor vehicle left turn waiting area at the intersection, the non motor vehicle stop line is 10m in front of the motor vehicle stop line, and the distance from the intersection is shortened to 50m. The effect of setting a non motor vehicle left turn waiting area is calculated. After time verification, it is found that before setting the left turn waiting area, it takes 7.65 seconds for motor vehicles to pass the intersection, while it takes 10.64 seconds for non motor vehicles to pass the same intersection. After setting the left turn waiting area, it only takes 9.20 seconds for non motor vehicles to pass the intersection. Through this traffic optimization method, the possible collision time of 1.5 seconds is reduced, the probability is reduced, and the traffic safety of the intersection is more guaranteed.

4. Conclusions

This paper discusses the conflict mechanism from the perspective of traffic conflict and left turn non motor vehicle conflict with intersection motor vehicle conflict, analyzes and considers the vehicle traffic characteristics and vehicle flow expansion characteristics, obtains the quantitative relationship between the conflicts, and establishes the number model of vehicle non conflict and expansion conflict, and obtains the influence of various types of traffic conflicts on the safety level of intersection. This shows the necessity of setting left turn waiting area. Through the investigation of traffic safety and traffic efficiency, it shows that the setting of left turn waiting area can effectively improve the utilization rate of time and space resources of the intersection, and also can reduce the congestion and congestion caused by traffic delay.
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