Traffic optimization design of The Intersection of Zhan Qian Road and Min Zhu Zhong Road in Jiaozuo City

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Abstract. In recent years, my country’s road infrastructure has been vigorously constructed, urban road network density has increased, and road intersections have also been formed. There are more and more T-shaped intersections. Such intersections often have the characteristics of serious traffic intertwining and difficult traffic organization. Opposite the intersection of Zhan Qian Road and Min Zhu Zhong Road is the railway station. A large number of pedestrians have to pass through the intersection at rush hour or when the train arrives at the station. This road has a lot of people and a large number of non-motorized vehicles. The signal lights at the intersection are not perfect, and the traffic demand is large. In this paper, based on the current signal timing plan and the current status of the crosswalk at the intersection, based on the actual current data survey and service level analysis, the optimization design of the intersection signal timing plan and the crosswalk width optimization are completed. The results showed that the average delay at the intersection was improved by nearly 21 seconds, and the crosswalk lengths at the east entrance, west entrance and north entrance were optimized to 2.5m, 2.4m and 2.6m, respectively. Improved road capacity and reduced vehicle delays.

1. INTRODUCTION
Pedestrian traffic participants are the vulnerable groups, in order to ensure the pedestrian traffic safety and efficiency, through the study of traffic intersection situation and existing problems, and optimize the pedestrian crossing signal lamp design, and through the case analysis the importance of optimization settings, thus improving pedestrian street environment, increasing the comfort and safety of pedestrians crossing the street. Improve transportation efficiency, ensure people’s travel safety, and promote green travel.

Huang Huixian [1] pointed out that urban traffic signal control is to improve the safe transportation of people and goods and improve the operation efficiency by adjusting, warning and inducing the traffic flow. The goal is to improve the quality of traffic flow, make better use of existing transport capacity, and achieve traffic flow safety, speed and comfort. Yang Dongyuan [2] pointed out that modern traffic control is one of the main measures to solve urban traffic safety and improve road traffic capacity. The purpose of traffic control is to separate the traffic flow in different directions in time. Signal control is one of the main methods of traffic control. The technical key of signal control is signal timing.

Jiaozuo City Zhan Qian Road and Min Zhu Zhong Road interchange in the opposite of the railway station, a large number of pedestrians out of the station to pass, But the traffic lights at this intersection are not perfect, and there is a great demand for traffic. Therefore, we need to start from the aspects of planning, design, management, and control to improve the current general traffic problems on the Zhan
Qian Road in Jiaozuo City and improve various unfavorable travel conditions on the road, and provide people with a good traffic environment.

2. INVESTIGATION AND ANALYSIS OF CURRENT SITUATION

In order to ensure the safety and efficiency of pedestrian traffic, the optimal design of signal timing and crosswalks is carried out through the investigation and analysis of the current situation of intersections, so as to improve the unfavorable conditions for pedestrians to cross the street and improve the speed and safety of pedestrians to cross the street.

2.1. Intersection geometry

The figure 1 below is the plan of the intersection of Zhan Qian Road and Min Zhu Zhong Road. Although the intersection is a T-shaped intersection, a large number of people will come out of the railway station every day, which makes the traffic situation at the intersection more complicated and chaotic.

![Figure 1: Plan of the intersection of Zhan Qian Road and Min Zhu Zhong Road.](image)

2.2. Intersection signal light phase timing diagram

The phase diagram of the intersection of Zhan Qian Road and Min Zhu Zhong Road is shown in Figure 2.

![Figure 2: Phase diagram of the intersection of Zhan Qian Road and Min Zhu Zhong Road.](image)

2.3. Intersection peak hour signal timing diagram

East entrance left green time 35s, left red time 77s, yellow time 3s. South entrance left green time 41s, left red time 71s, yellow time 3s. The green time of the west entrance is 30s, the red time is 82s, and the yellow time is 3s. The timing diagram of intersection signal is shown in Figure 3.

![Figure 3: Current signal timing diagram at the intersection of Zhan Qian Road and Min Zhu Zhong Road.](image)
3. SERVICE LEVEL ANALYSIS

3.1. Analysis of service level based on pedestrian delay at intersections

According to the investigation, the service level of pedestrian crossing at the intersection is mainly related to per capita delay. The calculation formula is as follows:

\[ d_p = 0.5(T_c - T_g)^2 / T_c \]  

(1)

Where: \( d_p \) — Per capita delay (s); \( T_c \) — Semaphore cycle Length (s); \( T_g \) — Effective green time for pedestrians (s).

Investigate the intersection signal cycle length and pedestrians effective green time data (Zhan Qian Road and Min Zhu Zhong Road intersection) and the calculated pedestrian delay time, according to the service level of pedestrian crossing delay [3] available Zhan Qian Road and Min Zhu Zhong Road intersection service level and the possibility of not obey the traffic rules, as shown in the table below:

| Cross     | Duration of signal lamp cycle (s) | Effective green time for pedestrian s (s) | Pedestrian delay (s) | Service level | Degree of disobedience to traffic rules |
|-----------|-----------------------------------|------------------------------------------|----------------------|---------------|----------------------------------------|
| East      | 113                               | 29                                       | 29.22                | C             | Medium                                 |
| west      | 115                               | 40                                       | 24.46                | C             | Medium                                 |
| South     | 115                               | 34                                       | 28.52                | C             | Medium                                 |

Analyse: Service standards based on pedestrian delays [3], by evaluating the service level of the pedestrian delay at the intersections, it is concluded that the service level of the intersections is C, and the possibility of disobeying traffic rules is medium. To assume the pedestrian crossing the road service level belongs to the medium stage, and in the rush hour, plus out of the crowd, from the railway station is across the street, during the peak of the pedestrians often can appear in the case of intersection delay, delay the travel time of people, so perfect traffic lights time, improve the road service level, so as to improve the efficiency of the street.

4. OPTIMIZATION DESIGN OF INTERSECTION SIGNAL CONTROL

4.1. Content and method of signal timing scheme design

According to the analysis of service level, the service level of pedestrian delay at the intersection of Zhan Qian Road and Min Zhu Zhong Road investigated is grade C, so it is necessary to improve the pedestrian signal lights at the intersection.

Pedestrian signal phase [4] mainly includes pedestrian green time, pedestrian flashing time and pedestrian red time. Next, the pedestrian green time and pedestrian flashing time are mainly optimized.

4.1.1. Pedestrian green time

The pedestrian green time should make all the waiting pedestrians leave the kerb and enter the intersection in a cycle. The pedestrian green time is mainly composed of reaction time and the time for the crowd to enter the crosswalk through the kerb, namely

\[ WALK = t_r^p + \frac{N_p}{S_p W_E} \]  

(2)

Where: \( WALK \) — Pedestrian green time (s); \( t_r^p \) — Pedestrian reaction time (s); \( N_p \) — The number of people waiting for the start of a pedestrian green light; \( S_p \) — Flow rate, that is, the number of people passing through a section per unit width of time(p/m/s); \( W_E \) — The effective width of the crosswalk (m)
According to the research, \( t_p^r = 3.2 \, s \), \( S_p^r = 1.32 \, p / m / s \), Moreover, the calculation formula of green time for pedestrians is given:

\[
WALK = 3.2 + 0.81 \frac{N_p}{W_E} \quad (W_E > 3.0 m)
\]

\[
WALK = 3.2 + 0.81 \frac{N_p}{3.0} \quad (W_E \leq 3.0 m)
\]

The above is to obtain the shortest green light time for pedestrians satisfying the requirements of pedestrian release.

It can be measured that the width of the crosswalk at the intersection is 5 meters, so it is greater than 3 meters. He calculated statistics of the survey data are as follows: The number of people waiting at the beginning of the green signal for pedestrians at the east entrance, west entrance and north entrance is 20, 10, 8 respectively. And the green time of pedestrians is 8.6s, 5.9s and 5.36s respectively. Therefore, the shortest green time for pedestrians in all directions to leave the kerb and reach the intersection is known.

4.1.2. Pedestrian flashing time

Pedestrian flashing time is when pedestrians entering the crosswalk near the end of the green time pass through the conflict point before the conflicting traffic gets the green light.

\[
FDW = \frac{L_p}{S_{15}^p}
\]

Where: \( FDW \) —Pedestrian flashing time (s); \( L_p \) —The length of the crosswalk (m); \( S_{15}^p \) —Average speed for 15% of pedestrians (m/s). According to the survey, the walking speed is generally 1.2(m/s).

According to the field measurement of the pedestrian crossing length at the entrance of east and west, that is, the length of the crosswalk is 28m, which is substituted into the formula (4) to obtain the pedestrian flashing time of 23s. The length of pedestrian crossing from north to south is 18m. By substituting into formula (4), the pedestrian flash time is 15s. Therefore, the green time of the east import is 32s, the green time of the west import is 29s and the green time of the north import is 21s. Therefore, the green time of each direction before and after optimization is shown in the following table:

| Table 2  | Green Time of Each Direction Before and After Optimization |
|----------|-----------------------------------------------------------|
| Direction | East entrance | West entrance | North entrance |
| Before optimization (s) | 34 | 40 | 29 |
| After optimization (s) | 32 | 29 | 21 |

According to the optimized data, the green time of pedestrians is smaller than before, and the average delay of the intersection is increased by nearly 21 seconds. Therefore, the phase time of pedestrians should be adjusted appropriately, and the phase time of motor vehicles should also be adjusted accordingly. When the green time of pedestrians is reduced, the green time of motor vehicles will also be relatively reduced. Therefore, the timing of signals at the intersection with slow traffic priority will generally cause the delay of motor vehicles at the intersection.

4.2. Optimized setting of crosswalk at intersection

After measuring the length of the crosswalk of Zhan Qian Road in Jiaozuo City is 5 meters, the following part mainly optimizes the crosswalk at the intersection of Zhan Qian Road and Min Zhu Zhong Road. Generally, the width of the crosswalk is mainly related to the pedestrian crossing rate, pedestrian walking speed and pedestrian green time.
4.2.1. Crosswalk width threshold [5]
The minimum width of pedestrian crossing shall not be less than 1.5m in accordance with China’s Urban Road Traffic Planning and Design Code. The general width of the crosswalk should be the width required for two adults with children to walk opposite each other and the safe distance between them can be set at 2.5m or 3.0m.

4.2.2. Crosswalk width optimization
The width of the crosswalk is also one of the important factors that determine the pedestrian crossing. According to Traffic Design [5], the calculation formula of the width of the crosswalk is as follows:

$$W_p = \frac{M \left( q_i + q_o \right)}{v_p g_p}$$

(5)

Where: $W_p$—Width of pedestrian crossing (m); $M$—The average area of modulus, namely each pedestrian passage area ($m^2$/person); $q_i$—Pedestrian flow rate entering the crosswalk (person/s); $q_o$—Pedestrian flow rate leaving the crosswalk (person/s); $v_p$—Pedestrian walking speed (m/s); $g_p$—Pedestrian signal green time, including green light flashing time (s).

Minimum crosswalk width for Service level C pedestrians:

$$W_p = \frac{1.2 \left( q_i + q_o \right)}{v_p g_p}$$

(6)

When crossing the street, some non-motor vehicles also pass through the crosswalk, so it is necessary to convert the non-motor vehicles into pedestrians, and calculate the pedestrian flow rate according to the following table. Among them, the pedestrian is taken as a reference, and both electric vehicles and bicycles are converted into pedestrians. According to the study, the pedestrian covers an area of 1 square meter, and the e-bike covers an area of 5 square meters, and the conversion factor of pedestrian and e-bike is 5:1.

The traffic flow rate of each crosswalk at the intersection in the peak hour was investigated and counted. According to the above, the service level of the intersection was C. The electric self-propelled traffic flow rate is converted into pedestrians, and the average walking speed of pedestrians in peak hours is 1.0(m/s). The following table is calculated and calculated by using the formula:

| Flow rate (Person/s)       | East entrance | West entrance | North entrance |
|---------------------------|---------------|---------------|---------------|
| Pedestrian $q_i$          | 3             | 5             | 3             |
| Electric bicycle $q_e$    | 4             | 7             | 5             |
| After the conversion $q_e$ (Person/s) | 28            | 40            | 28            |
| After the conversion $q_e$ (Person/s) | 23            | 15            | 14            |
| Pedestrian signal green light | 34            | 40            | 29            |
| Crosswalk width (m)       | 1.8           | 1.65          | 1.74          |

Therefore, after calculation, the width of the crosswalk in the three entrance directions is no more than 2.0m. Because of the intersection of different geographical position, located near the train station, so the pedestrian and the arrival time of the train has a certain relationship, and then on a pedestrian crossing at different times of the flow rate of the investigation and data statistical analysis as follows, which after the non-motor vehicles have conversion according to the conversion factor for pedestrians.
Table 4 Pedestrian Flow Rates at Different Time Periods

| Different times | Flow rate | East entrance | West entrance | North entrance | Average pedestrian speed (m/s) |
|-----------------|-----------|---------------|---------------|----------------|-------------------------------|
| One             | \(q_1\)  | 22            | 16            | 27             | 1.23                          |
|                 | \(q_2\)  | 20            | 13            | 26             |                               |
| Two             | \(q_1\)  | 25            | 20            | 38             | 1.03                          |
|                 | \(q_2\)  | 24            | 24            | 38             |                               |
| Three           | \(q_1\)  | 19            | 28            | 14             | 1.18                          |
|                 | \(q_2\)  | 20            | 29            | 17             |                               |
| Four            | \(q_1\)  | 40            | 45            | 25             | 1.05                          |
|                 | \(q_2\)  | 35            | 39            | 25             |                               |

The data of table 4 shows that east and west import line flow rate in the fourth period, the largest north line flow rate in the second period, the biggest import respectively to select time line flow rate and the pedestrian average pace. And according to the green time of pedestrian signal in Table 3 and formula (6), the length of the crosswalk at the east entrance, the west entrance and the north entrance is 2.5m, 2.4m and 2.6m respectively. It can be seen from the above that comprehensive consideration should be taken in the optimization process to obtain the value with the minimum error, so as to achieve the optimal.

5. SUMMARY

This paper mainly optimizes the timing of traffic lights and crosswalks at the intersection of Zhan Qian Road and Min Zhu Zhong Road in Jiaozuo City, in order to improve the traffic environment, improve the safety of traffic, and increase the efficiency of people's use of traffic modes. The main optimization content is summarized as follows:

The signal timing of pedestrian crossing intersection is improved, the setting of pedestrian crossing signal is optimized, and then the pedestrian crossing is optimized. Through these optimized Settings, the pedestrian crossing environment is improved on the one hand, and the safety and efficiency of pedestrian crossing is ensured on the other hand. The results show that the average delay of the intersection is improved by nearly 21 seconds, and the length of the crosswalk at the east entrance, the west entrance and the north entrance is optimized to 2.5m, 2.4m and 2.6m. The optimization effect is remarkable. The optimization scheme and related measures can provide an effective reference for alleviating the current increasingly serious urban road congestion.

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REFERENCES

[1] Huang, H.X. (2000) Study on optimal control method of urban traffic Signal. Northwestern Polytechnical University.
[2] Yang, J.D., Yang, D.Y. (2001) Optimization model of signal cycle length at urban signal-controlled intersections. Journal of Tongji University (Natural Science edition), 07: 789-794.
[3] Li, X., Tang, H.B., Liu, Z.Q. (2017) Research on pedestrian crossing Service Level at signalized Intersections. Highway and Motor Transport, 03: 40-43.
[4] Yuan, Z.Z. (2016) Road traffic Management and Control. People's Communications Press, Beijing.
[5] Yang, X. G., Bai, Y. (2010) Traffic Design. People's Communications Press, Beijing.