Optimization of slow Traffic system at intersection based on Service level Analysis

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Abstract

This paper is based on the service level analysis of the traffic system optimization of the intersection, and on the basis of the research of the service level of the slow traffic system at home and abroad, according to the standard of the Code for Design of Urban Road Engineering *CJJ37-2012* [1]and the Code for Planning of Urban Road Crossing *GB50647-2011*, The survey data of various indexes of the current road service level of the pedestrian, the bicycle and the electric vehicle at the intersection are calculated and analyzed, so as to evaluate and verify the current service level and the current service level of the non-motorized vehicles at the intersection. on the basis of the intersection of the Liberated Road and the Huaihe Road the basic characteristics of the traffic service level of the slow line and the traffic condition of the intersection are calculated and analyzed on the traffic problem of the present situation of the intersection and the factors that affect the traffic service level of the slow traffic,Finally, the optimization scheme for the service level of the intersection and the improvement measures for the real-time traffic of the intersection are designed.

Keywords

Slow traffic; service level; optimization.

1. Introduction

With the continuous upgrading and development of urban traffic mode, motor vehicle travel has become the main mode of traffic travel. However, the serious problems it brings to traffic gradually appear,the urban traffic structure with motorization as the main body makes the traffic problems of the city more and more serious,and the development of slow traffic can solve a series of problems very well. The docking of slow traffic and many kinds of traffic modes of the city can effectively improve the connectivity and accessibility of traffic in Bengbu City. The environmental protection and energy saving of slow traffic is in line with the development goal of Bengbu traffic to low carbon transformation. Through the investigation of the road service level of intersection, this paper combines the actual traffic demand and perfects the optimization.Based on the service level model of slow traffic, the improvement of slow traffic service level is beneficial to the harmonious development of urban traffic system.On the one hand,more traffic participants can reasonably choose the travel mode according to their own travel needs,BLOS model [2] on the other hand, they can give full play to the advantages of different traffic modes, so that the development of traffic system can really realize people-oriented.

2. Standard specification for slow traffic systems at intersections

2.1 Code for planning of pedestrian crossing facilities

2.1.1 Specification for the setting up of pedestrian crossing roads

(1). the pedestrian crosswalk should be located in a position that the vehicle driver can easily see,should be perpendicular to the driveway,should be parallel to the extension line of the kerb of the road section, and should be retreated 1 m≤2 m, and the length of the corner between the crosswalks should be greater than 6.0 m. In the intersection where the right-turn vehicle is prone to conflict with pedestrians,the retreat distance should be properly increased to 3 m≤4 m.

(2). the width of pedestrian crosswalk should be determined according to the number of pedestrians, the capacity of pedestrian crosswalk and the signal time of pedestrian crossing.

(3). the zebra crossing should be planned and arranged at the intersection without signal control and the crosswalk warning marking should be drawn on the upper motorway of the crosswalk;

(4). pedestrian guardrails or bushes should be planted along the kerbs on both sides of the crosswalk;the length of pedestrian guardrail or separation facilities should be 30m/120m,the main road should be 90m/120m,the secondary trunk road should be 60m/90m,and the branch road should be 30m/60m.

2.1.2 Code for the installation of pedestrian crossing safety islands

(1). When the length of pedestrian crosswalk is more than 16m (excluding non-motorized lanes),pedestrian crossing safety island should be set up in the central planning of pedestrian crosswalk. The width of pedestrian crossing safety island should not be less than 2.0m,and the difficult situation should not be less than 1.5m.

(2). for roads with central dividers,pedestrian safety islands may be set up by means of central dividers;roads without central dividers may take corresponding measures to add pedestrian safety islands according to the following circumstances, and shall comply with the provisions of Article B.0.3 of this Code:

- the intersection with corner traffic island can narrow the traffic island 0.75m~1.0m to set up pedestrian safety island;
- In the intersection of no corner traffic island, the pedestrian crossing safety island can be set up by using the extended space in the range of corner curve.
- When the crosswalk is set within the straight line section, the width of the entrance and exit lane can be narrowed and the pedestrian crossing safety island can be set up.

(3). When the width of pedestrian crossing safety island is not enough, the crosswalk on both sides of safety island can be staggered,and safety guardrail should be set up.

2.1.3 Code for setting pedestrian crossing signals

(1). the pedestrian crossing signal phase should be coordinated with the vehicle signal phase, and the independent pedestrian crossing signal light should be set up when there is a safety island in the middle of the crosswalk.

(2). The green light time of pedestrians shall not be less than the time required for pedestrians to cross the street safely, and the pedestrian red light time shall not exceed the waiting time that pedestrians can bear;

(3). In the intersection where the pedestrian flow to the street is large, the all-green phase of pedestrians crossing the street in all directions can be adopted.

2.2 Planning of non-motor vehicle crossing facilities

2.2.1Code for the establishment of independent entrances and exits for non-motor vehicles

(1). when the traffic flow of non-motor vehicles at urban road intersections is large or there are isolation facilities between motor vehicles and non-motor vehicles on road sections, independent non-motor vehicle entrance and exit roads should be set up at intersections, and physical separation facilities should be set up between motor vehicles and non-motorized lanes;

(2). The independent entrance and exit roads of non-motor vehicles may adopt the same traffic planning and traffic organization mode as non-motor vehicles and motor vehicles or between non-motor vehicles and pedestrians,and shall comply with the provisions of Article B.0.4 of this Code.

(3). Motor lanes should not be set up on independent entrances and exits of non-motor vehicles.

2.2.2 Code for the installation of pedestrian-non-motor vehicle mixed entrances and exits

(1). it is not suitable to plan pedestrian-non-motor vehicle mixed import and exit roads at the new intersection;

(2). to reconstruct and control the intersection planning, when the non-motor vehicle flow is large or the sidewalk width is narrow, the non-motorized road and the sidewalk should not be combined into pedestrian-non-motor vehicle mixed entrance and exit road at the intersection;

(3). the width of the sidewalk of the mixed entrance and exit road should not be less than 3m,and a solid separation facility should be set up between the mixed entrance and exit lane and the non-motorized lane;

(4). the pedestrian-non-motor vehicle mixed entrance and exit shall adopt the same mode of traffic organization as the pedestrian,and shall comply with the provisions of Article B.0.2 of this Code.

2.3 Code for slow traffic capacity and service level at intersections

2.3.1 pedestrian lane

(1). the designed capacity of a bicycle road that is not affected by a planar intersection should be 1600veh/1800veh/h when organic non-segregated facilities and 1400veh/1600veh/h/h when there is no separation.

(2). The design traffic capacity of a bicycle lane affected by the plane intersection shall be 1000veh/h~ 1200veh/h when organic non-separated facilities; When there is no separation,800veh/h~1000veh/h shall be taken.

(3). The design capacity of a bicycle lane at the entrance of the signal intersection is 800veh/h~1000ve h/h.

(4). The classification standard of bicycle service level in section 4 should conform to the provisions of Table 1, and the third grade service level should be adopted in the design.

Table 1. Service level of bicycle road section

service level index	one-level	two-level	three-level	four-level
Cycling speed (Km/h)	>20	20~15	15~10	10~5
Occupied road area	>7	7~5	5~3	<3
Load degree	<0.40	0.55~0.70	0.70~0.85	>0.85

(5). Classification standard of bicycle service level at intersection shall comply with Table 2, and Class III service level shall be adopted for design.

Table 2. Service level of Bicycle intersection

service level index	one-level	two-level	three-level	four-level
Parking delay time (s)	<40	40~60	60~90	>90
Cycling speed through intersections (km/h)	>13	13~9	9~6	6~4
Load degree	<0.7	0.7~0.8	0.8~0.9	>0.9
Parking rate at intersection (%)	<30	30~40	40~50	>50
Occupied road area(m2)	8~6	6~4	4~2	<2

2.3.2 sidewalks

The grading standard of sidewalk service level should conform to the provisions of Table 2 and 3, and the third grade service level should be adopted in the design.

Table 3. Sidewalk service level

service level index	one-level	two-level	three-level	four-level
per-capita occupied area(m2）	>2.0	1.2~2.0	0.5~1.2	<0.5
per-capita longitudinal spacing (m)	>2.5	1.8~2.5	1.4~1.8	<1.4
per-capita lateral spacing (m)	>1.0	0.8~1.0	0.7~0.8	<0.7
walking speed (m/s)	>1.1	1.0~1.1	0.8~1.0	<0.8
maximum service volume [per/(h. m)]	1580	2500	2940	3600

3. Slow traffic background at intersection

3.1 Overview of intersection.

The intersection of the research and research in this thesis is the intersection of the Jiefang Road and the Huaihe Road in the Bengbu city, and is located in the north of the Bengbu city, in which the North-South direction, the Jiefang Road and the Huaihe Bridge of the huaihe highway bridge of the Bengbu city,the traffic volume is large, In the east and west, the traffic flow of the Huaihe Road is relatively small, and the geographic position of the intersection is shown in Fig.1.

Fig. 1 intersection of Jiefang Road and Zhihuai Road

3.2 Basic data collection and arrangement

3.2.1 investigation of geometric structure of intersections

The north-south direction of the intersection is Jiefang Road, Jiefang Road is a main road in Bengbu City,for two-way six lanes.The east-west direction is Zhihuai Road,the east entrance of Zhihuai Road has four lanes, the right turn motorway is mixed with the non-motorized lane, the east exit has only two lanes,no motorized lane.The west entrance consists of a regular four lanes and a 4.5 m wide non-motorized lane;there are three lanes in the west exit entrance, as shown in figure 2 for details of the intersection.

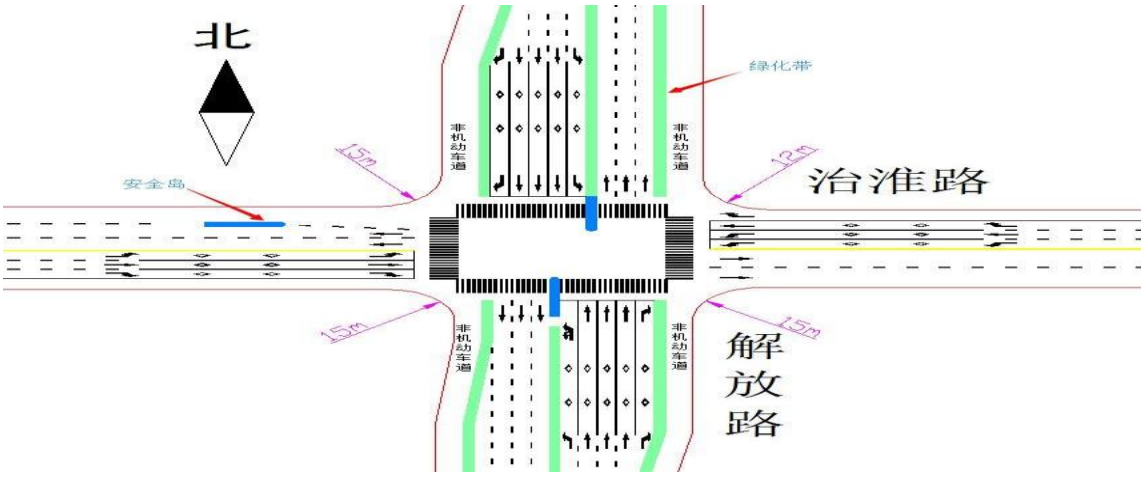

Fig. 2 intersection of Jiefang Road and Zhihuai Road3.2.2 Traffic volume survey at the intersection

(1)Investigation on the Traffic Volume of the Motor Vehicle

The traffic volume data of the motor vehicle was investigated by means of manual investigation. The investigation time was between 7:10 and 8:30, and the traffic flow of the intersection between the Liberated Road and the Huaihe Road was investigated.

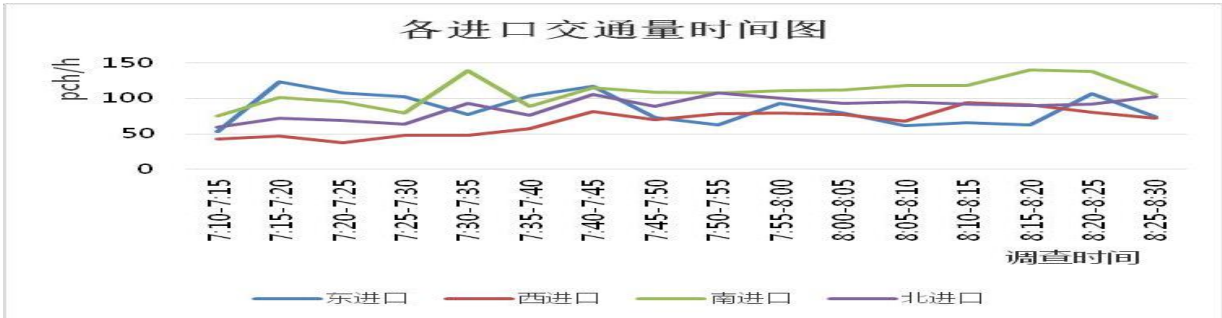

Fig. 3 Distribution time profile of each inlet flow

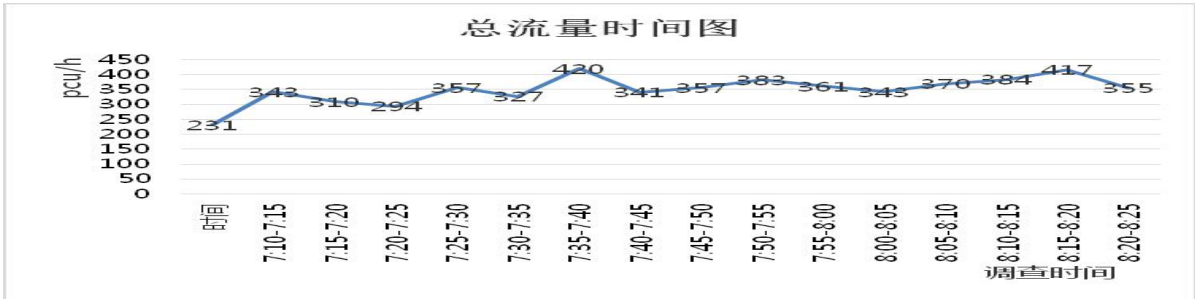

Fig. 4 Time distribution map of total motor vehicle flow at intersections

(2)investigation of non-motor vehicle traffic volume

The traffic volume of the non-motor vehicle is composed of electric vehicle and bicycle, and the traffic volume of the electric vehicle and the bicycle at the intersection of the Liberated Road and the Huaihe Road is counted by manual statistics.

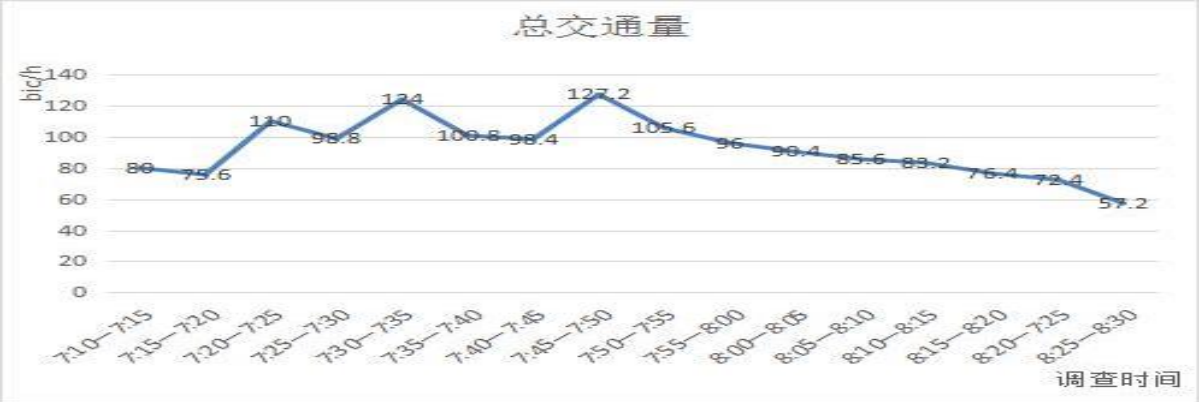

Fig. 5 Time distribution map of total non-motor vehicle flow at intersections

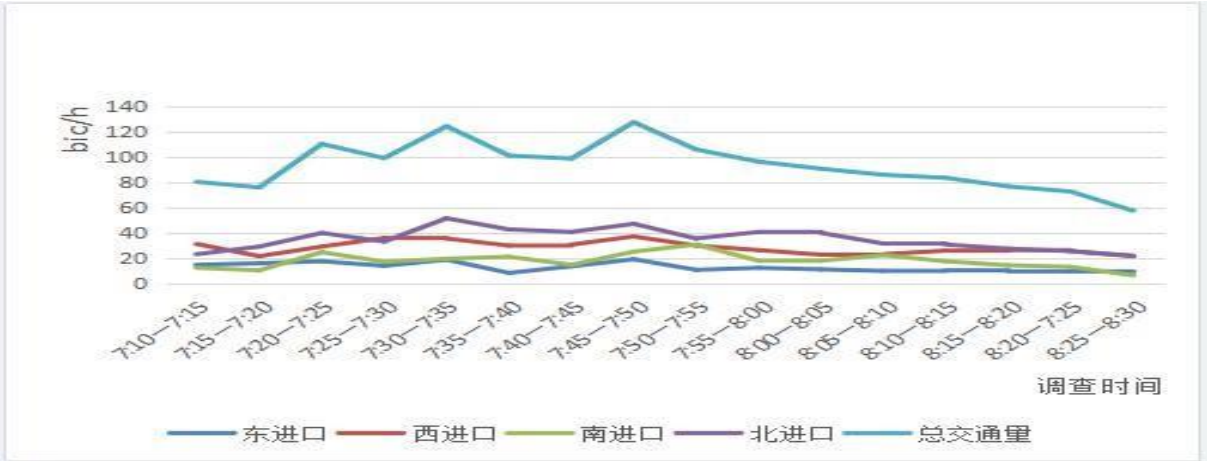

Fig. 6 Distribution time profile of each inlet flow

(3)pedestrian traffic survey

The pedestrian traffic volume survey is mainly to calculate the service level of the sidewalk at the intersection. Therefore, the number of pedestrians passing through the crosswalk in the east, west, north and south directions at the intersection of Jiefang Road and Zhihuai Road is counted. The specific table is as follows: table 4.

Table 4. Statistics of the number of crosswalk lines at the intersection

time	east	west	south	north	Number of
7:10-7:15	45	50	41	43	179
7:20-7:25	52	47	38	33	170
7:30-7:35	47	39	44	42	172
7:40-7:45	49	46	37	46	178
7:50-7:55	44	38	39	39	160
8:00-8:05	39	37	41	41	158
8:10-8:15	56	49	56	37	198
8:20-8:25	38	35	47	43	163
amount to	370	341	343	324	1378

3.3 investigation on Service level Indexes of non-motorized vehicles at intersections

3.3.1 The speed at which a non-motor vehicle passes through an intersection.

Refer to Table 5 for raw data of bicycle passing time and Table 6 for electric vehicle passing through intersection.

Table 5. Time for bicycles to pass through intersections

order number	east	west	south	north
1	16.53s	12.32s	18.37s	16.79s
2	19.23s	13.41s	12.83s	17.58s
3	17.92s	14.67s	16.79s	14.36s
4	15.78s	21.75s	17.25s	13.27s
5	14.89s	17.89s	17.61s	14.13s
Average value of imports	16.87s	16.01s	16.57s	15.23s
Phase average value	16.4 4s		15.9s	
Overall average value		16.17s		

Table 6. Time of electric vehicle passing through intersection

order number	east	west	south	north
1	13.96s	12.78s	8.49s	12.10s
2	14.44s	14.66s	7.21s	14.79s
3	13.81s	15.90s	13.13s	14.14s
4	14.21s	13.87s	11.58s	13.41s
5	13.90s	13.68s	12.36s	9.81s
Average value of imports	14.06s	14.18s	10.55s	12.85s
Phase average value	14.12s		11.7s	
Overall average value			12.91s	

3.3.2 occupied road area

According to the approximate calculation formula of bicycle occupation area: $s=1.9+0.14v+0.0079v^2$[2] The calculated bicycle occupation area is 2.33 in the east-west direction,1.94 in the north-south direction,and the average road area at the intersection is 2.12.

3.3.3 load degree

The load degree is equal to the ratio of peak hour traffic volume to road section capacity. Through the investigation of the morning peak traffic flow of 6:50-8:50 at the intersection, the peak hour traffic volume is obtained. The planned capacity of each lane at a intersection shall be calculated on the basis of 1000 vehicles/h, and the planned capacity of each lane on a special bicycle road shall be multiplied by 1.1≤1.2 in accordance with the above provisions.

3.4 Investigation on Service level Indexes of intersection sidewalk

3.4.1 per-capita occupied area

The area of the sidewalk was measured first, and then the number of pedestrians passing through the sidewalk in a signal cycle was investigated. The per-capita occupied area was obtained by comparing the sidewalk area to the uplink number.The data in five cycles were investigated,and the average value was taken.The number of pedestrians passing through the sidewalk at each entrance during a signal

cycle is shown in Table 7. Table 7 Number of pedestrians passing through the sidewalk at each entrance in a signal cycle

Table 7. Comparison between the length of pedestrian crosswalk and the walking distance during the

signal cycle	east	west	south	north
1	43	45	46	41
2	51	47	38	46
3	46	51	43	39
4	38	39	51	50
5	49	41	39	47

3.4.2 Longitudinal per-capita,horizontal spacing

By measuring the length of pedestrian crosswalk in each direction at the intersection of Jiefang Road and Zhihuai Road and counting the number of pedestrians passing through crosswalk, the per-capita longitudinal spacing and per-capita transverse spacing during the peak period are calculated respectively.

3.4.3 Walking speed

A comparison of the length of the crosswalk with the walking distance during the pedestrian green light cycle is shown in Table 8.

Table 8. Green light cycle of pedestrians

Entrance lane	east	west	south	north
Pedestrian crosswalk green light time(s)	20	30	20	30
Young people walk at speed			1.194m/s	
Green time maximum distance(m)	25.074	23.88	25.074	23.88
Actual length of crosswalk(m)	43	43	37	37

3.5 The Evaluation of the Service Level of the Intersections and the Analysis of the Existing Problems

(1). Speed analysis and evaluation of non-motorized vehicles passing through intersections

Through the investigation, it is found that the distance between the east and west imports is 44 m, and the distance between the north and south imports is 38 m.Therefore, the cycling speed of non-motor vehicles passing through intersections can be obtained through Table 8 and Table 9,as shown in the following table.

Table 9. the speed of riding through the intersection

	bicycle	electrombile
East-west average velocity	2.68m/s	3.12m/s
Average velocity in the north and south direction	2.39m/s	3.25m/s
Average speed through intersection	2.54m/s	3.19m/s

Results Analysis:according to the standard of"Code for Design of Urban Road Engineering",it can be seen that the cycling speed of the intersection is the third grade service level.

(2). Analysis and evaluation of bicycle occupation area.

As can be seen from the above table, the average cycling speed of bicycle at the intersection is 2.54 m/s,so it is found that the area of bicycle occupying road in the east and west direction of the intersection is 2.33,the area of bicycle in the north and south direction is 1.94,and the average area of the intersection is 2.12 m/s. According to the standard of"Code for Design of Urban Road

Engineering", it can be seen that the cycling speed of the intersection is the third grade service level, and the occupied road area is the third grade service level.

(3). Load degree analysis and evaluation

the traffic data of the non-motor vehicle at the intersection knows that the peak hour period of the intersection is7:10-8:10,Therefore, the traffic volume of non-motor vehicle rush hour is 1275.6. Intersection load =1275.6/1000=1.2756>0.9.According to the standard of Urban Road Engineering Design Code, the load degree is four levels of service level.

3.5.1 Analysis and Evaluation of pavement Service level at intersections

(1). Analysis and evaluation of per-capita occupied area

Combined with the number of pedestrians passing through the sidewalk during a signal cycle, the per-capita occupation area is shown in the table below.

Table 10. Per-capita channel area

signal cycle	east	west		south	north
1	5.0	4.7		4.0	4.5
2	4.2	4.5		4.8	4.0
3	4.6	4.2		4.3	4.7
4	5.6	5.5		3.6	3.7
5	4.3	5.2		4.7	3.9
average value	4.7	4.8		4.3	4.1
average value			4.5		

Results analysis: According to the standard provisions of, the per capita occupation area of the intersection of Jiefang Road and Zhihuai Road is the first level of service.

(2). Analysis and evaluation of vertical and transverse spacing per capita

According to the crosswalk length of each direction in the peak hour section of the intersection and the number of lines passing through the crosswalk, the average longitudinal and lateral spacing of the intersection is shown in the following table.

Table 11. Per-capita longitudinal spacing

East and West Import crosswalk long43m			north and south import crosswalk long37 m		
number of people		Per-capita longitudinal spacing		number of people	Per -capita longitudinal spacing
East import	7	0.71m	South import	9	0.55m
West import	9	0.55m	North import	8	0.62m

Results analysis: The service level of per capita longitudinal spacing at the intersection is the third level of service. The per capita horizontal distance service level is the fourth level of service level.

(3). Analysis and evaluation of walking speed

According to the survey, the length of crosswalk between east and west imports is 43m,and that between north and south entrances is 37m.

Results analysis: According to the calculated data, young people walk the fastest when passing through the sidewalk, with an average walking speed of 1.1035m/s,followed by children with an average walking speed of 1.0385m/s,and the elderly are the slowest with an average speed of 0.964m/s. According to the standard of"Code for Design of Urban Road Engineering",the walking speed of the intersection of Jiefang Road and Zhihuai Road is the third grade service level.

3.5.2 Analysis of slow traffic system problems

(1). Analysis of pedestrian and non-motor vehicle problems

In the process of investigation, it is found that the interference of pedestrians to non-motor vehicles is very serious, and the pedestrian and non-motor vehicles can not go their own way.

(2). Analysis of pedestrian and motor vehicle problems

At the intersection of the Liberated Road and the Huaihe Road, the right turn is not controlled by the signal,so the conflict point is generated between the pedestrian and the right-turning vehicle.

(3). Analysis of non-motor vehicles and motor vehicle problems

There are also some problems between non-motor vehicles and motor vehicles. Due to the long time of red light in the east and west direction, people's safety consciousness is slackened,resulting in random wear of non-motor vehicles in the past, but there will still be right-turn vehicles, and the hidden danger of safety is great.

(4). Analysis of intersection problem

Jiefang Road crosswalk passes through more bicycles and battery cars, and the green light time is relatively short. The traffic volume of Jiefang Road to the south and north is large, and the traffic flow of Zhihuai Road is slightly smaller. Jiefang Road and Zhihuai Road intersection pedestrians are relatively few,electric vehicles,a large number of bicycles. Zhihuai Road East entrance right turn lane and non-motorized lane mixed, east exit only two lanes, no motorized lane.

4. The Optimum Design of the Traffic System of the Slow-line Traffic in the Jiefang Road and the Control of the Huaihe Road

4.1 Design of optimization scheme for slow traffic system

(1). non-motorized secondary crossing

Considering the large number of non-motor vehicles at the intersection of Jiefang Road and Zhihuai Road, the interference between left-turn non-motor vehicles and motor vehicles is great, and there is a conflict between left-turn non-motor vehicles and straight-line motor traffic. Therefore, at the intersection of non-motor vehicles to take the way of secondary crossing.

(2). Bicycle parking line in advance.

Due to the large number of non-motor vehicles at the intersection of Jiefang Road and Zhihuai Road, the non-motor vehicle parking line can be advanced to the parking line of the motor vehicle according to the characteristics of fast start of non-motor vehicles and the urgent psychology of the rider on the intersection. This avoids both non-motor vehicle mainstream and motor vehicle flows crossing the street at the same time, conflict and interference. The formula for the specific non-motor vehicle parking line to the front distance L of the motor vehicle parking line is[3]:

$$L = \frac{Q \times P}{B} + \Delta L$$

Q—the number of non-motor vehicles arriving in the red light time; P—Parking density of non-motor vehicles;

B—Width of entrance road at intersection;

ΔL—The width required for non-motor vehicles to enter the parking area;

Through the calculation of the distance between the two stop lines, the traffic flow at the intersection and the geometric size of the intersection, it is concluded that the north-south import non-motorized parking line should be about 12 m ahead of schedule, and the east-west import parking line should be about 10 m ahead of schedule.

(3). non-motor vehicle multi-phase release method

Non-motor vehicle multi-phase release refers to the non-motor vehicle according to the phase of the motor vehicle, that is, the so-called spatial separation release method, non-motor vehicles and motor vehicles according to the same signal light, when the motor vehicle is a left turn signal,the left turn non-motor vehicle running route is a small roundabout(that is, do not need to go straight first and then turn left),pass through the intersection at one time.

(4). There are only two lanes for the East exit of the Huainan Road, which is not only the motor lane, but the mixed line of the non-motor vehicle and the motor vehicle is serious. The pedestrian and the non-motor vehicle are also serious, so the pedestrian and the non-motor vehicle are added on the existing non-motor vehicle to separate the solid line, and the width of the non-motor vehicle lane can be compensated by compressing the green belt.

(5). According to(CJJ37-2012),the width of pedestrian crossings shall be determined according to the number of pedestrians crossing the street and the signal control scheme, and the width of pedestrian crossings of the main road shall not be less than 5m.Therefore,according to the actual conditions of the intersection of Jiefang Road and Zhihuai Road, the width of the pedestrian crossing is set as 6.0m.

(6). the optimized intersection plan is as follows.

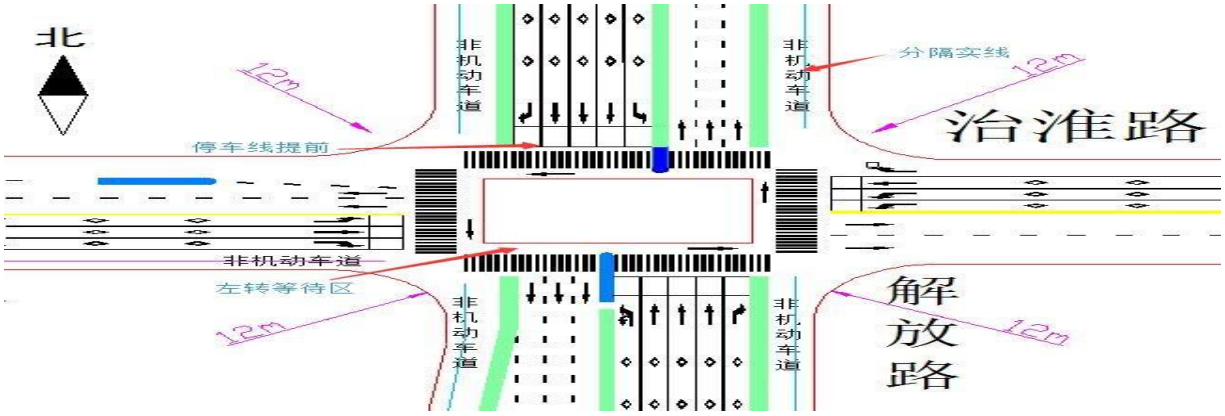

Fig. 7 Optimization Map of intersection between Jiefang Road and Zhihuai Road

4.2 Analysis of service level after implementation of optimization scheme

(1). After the implementation of the optimization scheme, the area of the crosswalk in the east and we st direction of the intersection is 258㎡,and the area of the crosswalk in the north and south directio n is 222㎡.Before optimization, the per-capita road occupation area of the north import is 4.5m^2/per son, and the per-capita occupation area after optimization is expected to reach 5.4 ㎡ /person, and the per-capita occupation area of the optimized intersection is increased by 0.9㎡/person compared with that before optimization.

(2). after optimization, the longitudinal distance between east and west imports is 0.77 m, and that bet ween north and south imports is 0.71 m. Compared with before optimization,the transverse distance between east and west import lines is increased by 0.14 m, and the transverse distance between north and south import lines is increased by 0.12 m.

(3). The average speed of bike passing through the intersection after optimization is 3.05m/s, the aver age speed of bicycle passing through north-south direction is 2.60m/s, and the average speed of bicy cle passing through the intersection is 2.83m/s.Compared with the optimization, the average speed of bicycle passing through the intersection is increased by 0.29m/s. After optimization,the average sp eed of the electric vehicle passing through the east-west direction is 3.07m/s, the average speed of th e electric vehicle passing through the north-south direction is 3.51m/s, and the average speed of the electric vehicle passing through the intersection is 3.29 m/s, compared with before optimization,the average speed of bicycle passing through the intersection increased by 0.10 m/s.

5. Conclusion

(1). The main contents of this paper are as follows: (1) this paper explains the necessity of the study of slow traffic service level from the aspects of research background,purpose and significance,and exp ounds that Bengbu City has not yet formed a perfect slow traffic system, which lays a foundation for the later study of the service level of slow traffic at the intersection of Jiefang Road and Zhihuai Ro ad.

(2). through the analysis of the present situation of slow traffic research at home and abroad,the devel opment state of slow traffic service level at home and abroad is clarified, and through the comparativ e study of the two,the advantages and defects of domestic and foreign research are analyzed.

(3). combined with the basic data obtained from the investigation,the non-motor vehicle and pedestri an service level of the intersection is calculated and analyzed, and the present service level of the slo w traffic at the intersection of Jiefang Road and Zhihuai Road is obtained.

(4). through the analysis of the slow traffic system problem of the intersection and the design of the s ervice level optimization scheme of the intersection, the existing problems and hidden dangers of the intersection can be effectively improved.

(5). To manage and control the intersection reasonably, so that each traffic participant can develop good habits and can effectively improve the traffic capacity and service level of the intersection.

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