Optimization of Intersection in Construction at Low Cost- A Case Study of the Intersection of Youyi Road and Luojiagang Road

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Abstract. Intersections in construction are common in China when roads in plenty of Chinese cities are under reconstruction and expansion in a large scale. As intersections are traffic hub where big traffic flows passing by, smoothness and efficiency are ought to be guaranteed in order to reduce effect caused by construction. However, plans at lower cost and more effective are appreciated because reconstructing an intersection is costly. The research analysis the current situation and raise a complete optimize plan for the crossing of Youyi Road and Luojiagang Road in order to proof there is possibility to optimize an intersection at lower cost. The research raises a feasible optimize plan for a crossing. It is feasible to cheaply optimize a crossing which still allows vehicles running while under construction.

Keywords: Intersection reconstruction, Work Zone, Low-cost Reconstruction, Webster Model.

1. Introduction

The continuous development of the city, the construction of the subway and the gradual improvement of the urban road network have brought a large number of urban road construction [1]. There are two fundamental ways to solve urban transportation problems: one is to accelerate the construction of transportation facilities; The second is to strengthen traffic management [2]. In China, during the construction process of intersections, some lanes or part of the directional entrance road have to be closed. Due to the shortage of construction funds and the limited labor force of workers, this type of intersection in construction generally has poor road conditions, used roadside facilities, temporary selection of road signals, non-motorized roads and unclearly marked sidewalks and pavement.

The intersection of Youyi Road and Luojiagang Road is selected for analysis in this research, trying to give a relatively low-cost and relatively efficient transformation plan to optimize the reconstruction and optimization of the intersection that is open to traffic while under construction.

For many intersections under construction in China, because the construction is costly, it is not possible to spend too much money on temporary control and renovation when intersection construction is progressing [3]. This article discusses how to optimize the intersection under construction with the goal of low cost and high efficiency.

In this research, a comprehensive renovation plan for signal timing, pavement facilities, and road channelization of intersections under construction is proposed. The possibility of low-cost temporary renovation of intersections under construction is discussed base on the plan.

2. Method

2.1. Situation of the intersection in the case

The intersection of Youyi Road and Luojiagang Road is one of the transportation hubs in Wuchang District of Wuhan. The traffic flow status of this intersection has a great impact on the transportation status of passengers and goods in the urban road network, the travel of households in surrounding residential areas, and the vehicles on and off the second ring road of Wuhan. When the construction of the elevated expressway began on Youyi Road where the intersection is located, the road conditions at this intersection deteriorated, the overall efficiency decreased, and many surrounding residents were dissatisfied.

Youyyi Road is the main road in Wuchang District, its traffic carrying capacity is very high, the design speed is relatively high, and the traffic composition is complex. Luojiagang Road is the ground road starts from the Second Ring Road to Huanle Road. Luojiagang road is a one-way street, and most of the vehicles passing by are vehicles on and off the Second Ring Road, which is a transportation hub between the road in Wuhan and the Second Ring Road.

However, in 2019, the rapid reconstruction project of Wuche Road to Hongmao Lane section of Youyi Road started progressing, marking the official launch of the Friendship Avenue-Zhongshan Road Rapid Reconstruction Project. This is also the Cross-city Traffic Corridor and rapid reconstruction channel in the direction of the Shunjiang River in Wuchang area, which undertakes an important function of river crossing and distribution. Therefore, the construction part of the entire Youyi Road began to be fenced, and the duration of the fence was 5 years. At the same time, because it bears a large amount of traffic flow, Youyi Road is not allowed to be closed. Therefore, Youyi Road can only be constructed by closing part of the lane, which means the intersection will enter a special stage where construction and vehicles running on the road in the same time. During this stage, the intersection is in a state where the road is partially closed, high danger, low traffic efficiency and low traffic flow.

The west side of the intersection of Youyi Road and Luojiagang Road is close to Luojiagang, and a large number of residential areas are laid out around, with large traffic demand. There are many branch roads upstream and downstream of the intersection. The second ring road runs parallel to the intersection on Luojiagang Road, with its entrance ramp downstream of the North Exit Road. Therefore, there is a large demand to enter the ramp from the north exit road in each import road.

Moreover, the intersection is under construction, and the construction will also have an impact, such as the fence around the intersection. The number of lanes on Youyi Road is reduced, and the traffic capacity is blocked. Large vehicles entering and exiting the construction area cause great interference to traffic operation. The passage space of pedestrians and non-motor vehicles is compressed. The degree of mixing of non-motor vehicles and vehicles is high, the non-mixed traffic is serious, and the safety is challenged.

There is a large residential area around the intersection, so the convenience of residents depends on the smoothness of this intersection. Although a large number of motor vehicles detour during the construction period, the traffic flow at the intersection is still very large. In addition, during the initial visit, it was also found that a large number of non-motor vehicles passed randomly in the intersection irregularly, running red lights directly along the diagonal, which is very dangerous.

In general, the problems with current intersections include high traffic flow delays, reduced capacity, and further deterioration of road surface conditions during construction.

2.2. Data used for the optimization

2.2.1 Intersection traffic data statistics

Because different data types and different types of data correspond to different intersection locations, the measured data are represented by annotating the intersection thumbnail as shown in Fig. 1.

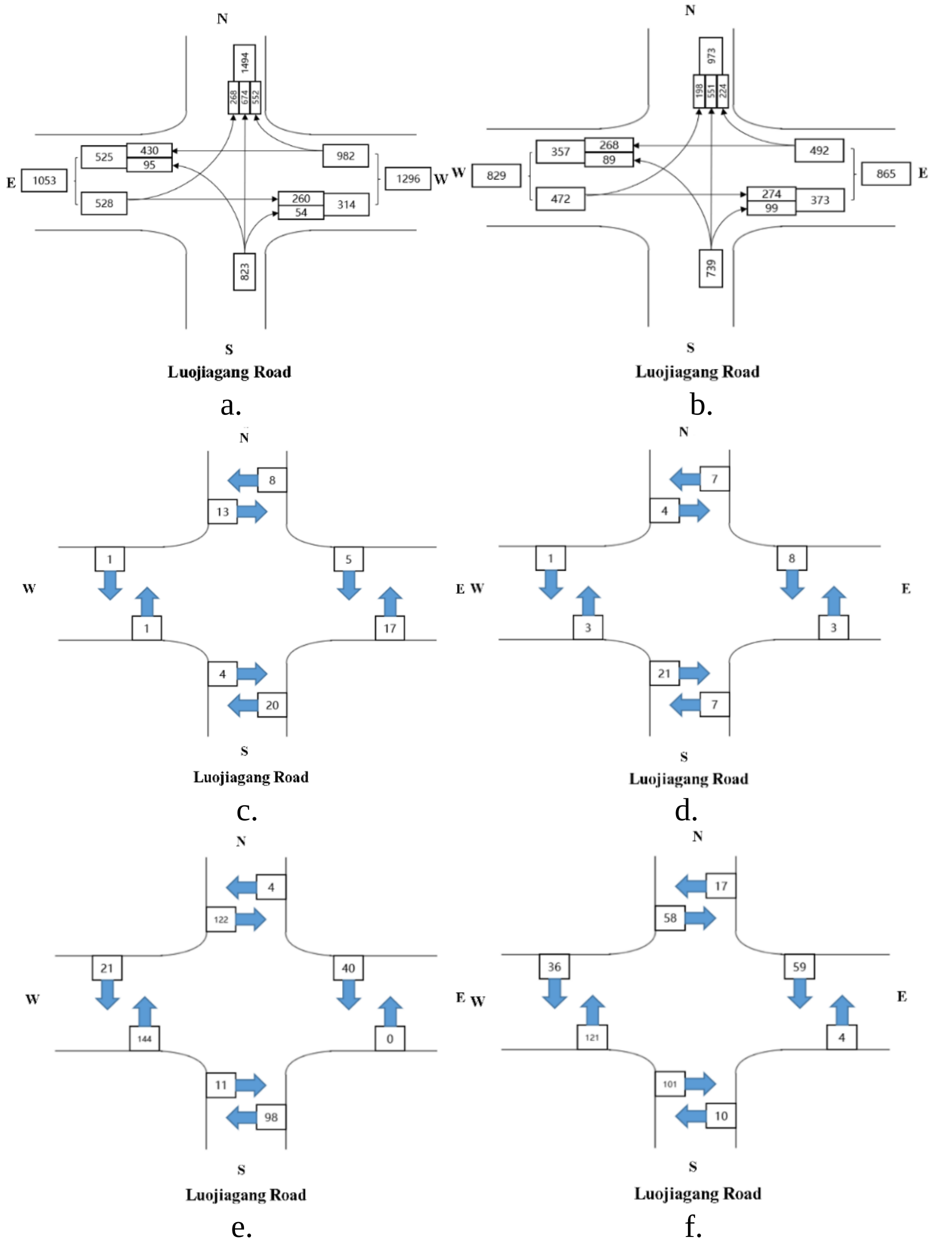

Figure 1. Flow graph of motor vehicles, non-motor vehicles and pedestrians under peak hours and flat peak hours, a, motor vehicles under peak hours, b, motor vehicles under flat hours, c, pedestrians under peak hours, d, pedestrians under flat hours, e, non-motor vehicles under peak hours, f, non-motor vehicles under flat hours

2.2.2 The current signal timing measurement results of the intersection

By analyzing traffic lights and traffic flow, this study investigates the current signal timing scheme at intersections as shown in Table 1. The current signal timing scheme is a three-phase timing scheme: the east entrance is released first, the signal of east entrance is straight, and the right turn is released at the same time for 43 seconds. After that, the east entrance is prohibited, and the signal of south entrance becomes left, straight and right. At the end, the east and south imports are prohibited, and the west imports are released.

Table 1. Diagram of the current peak signal timing scheme at the intersection

Phases		Cycle	Green Time	Yellow Time	All-red Time
Phase 1		120	43	3	0
Phase 2		120	34	3	0
Phase 3		20	43	3	0

2.3. Modeling

Similar studies have compared different algorithms for signal timing optimization at single-point intersections in cities. The Webster model used in this optimization scheme is a relatively common model. The Webster model is the best choice for the intersection in this case, after considering all factors. Although the relevant research has found that other schemes such as genetic algorithms and annealing algorithms can greatly improve congestion when the traffic flow is very large and the traffic delay has a great impact on the traffic state [4]. However, the intersection in this case is under construction and its traffic flow has not reached saturation, so there is no need for a lot of tedious calculations and adjustments of the genetic annealing algorithm for large traffic flows. For intersections with medium traffic flow, Webster algorithm is used to basically optimize them like this scheme, which has a small amount of calculation, good optimization effect, and is still maximized in terms of overall benefits.

In recent research, Webster models are relatively rare, but Webster, as the most classic model in the world, uses more examples of the same type, and it is a model that has undergone the test of time. It is also relatively reliable to use it [5].

In a study conducted by Sun Chao et al., a new method was proposed and compared with the traditional model, the Webster model. It is found that the new model can increase the number of passing vehicles and reduce the waiting time under unsaturated conditions, and the Webster model will fail under supersaturated conditions [6].

In a more recent study, based on understanding the timing of traditional Webster and summarizing its limitations, the researchers proposed a multi-objective optimization model for signal cycle duration. It mainly analyzes the pros and cons of the traditional Webster model. [7] The signal timing optimization of single-point signal intersection is a relatively mature field, and recent research results have developed in a more specialized direction, for example, Zhang Tianci's research only studied the regulation and optimization of single-point intersection in emergency situations [8].

Li Ning et al. considered slow traffic based on existing knowledge and studied and analyzed the traffic organization at the intersection [9]. Some researchers have improved and optimized the signal intersection regulation in combination with the latest networked autonomous driving [10].

Through video analysis of the peak and plain hours of the intersection, the author counts the traffic flow of motor vehicles on the three inlets of the intersection, the traffic flow of non-motor vehicles in the four directions, and the traffic flow at the three inlets of pedestrians. At the same time, the statistics of the current signal timing of the intersection are carried out through field research, and the geometric size and structure of the intersection are measured in the field.

According to the traffic flow data of motor vehicles in three directions, the traffic flow straight equivalent calculation and flow rate ratio analysis are carried out. Then the Webster model (the formula is shown below) is used to calculate the delay and service level, which is used to evaluate the current intersection signal timing and the evaluation of the proposed signal timing scheme. The following formula is the formula used to calculate the signal timing in all schemes, including the calculation formula of saturation flow rate, the calculation of saturation, and the calculation of the traffic capacity of the inlet lane.

$$S_i = S_o \cdot N \cdot \prod f_i \tag{1}$$

S_L: Lane group saturation flow rate, pcu/h; S_0: The inlet lane enters the basic saturation flow rate; N: The basic saturation flow rate contained in lane group I; f_i: Various correction coefficients of the imported lane

$$CAP_i = S_i \lambda_i \tag{2}$$

CAP_i: Entry i Lane Capacity; S_i: Inlet Lane i saturation flow rate, λ_i: Inlet Lane green signal ratio

$$CAP = \sum_i CAP_i \tag{3}$$

CAP: Entry Lane capacity

3. Results

3.1. Analysis of the current situation

In order to systematically assign solutions to problems, problems are divided into construction ones and planning ones according to the root cause and the limited time for solving them. But the above division is specifically for the idea of transformation of this intersection. It is worth to mention that not all intersections have these problems, and the divide manner is improper to be generalized to other intersections.

Construction problems will gradually disappear through the demolition of the construction fence, the end of construction, effective management during construction and other factors related to time. It can be considered that the problem is temporary, brought about by the construction. These problems will gradually disappear when the construction is over. They may cause a huge impact in a short time, but become easier to solve after the construction.

Planning problems can be solved by completing renovations during planning. There may be problems with the design of the intersection itself, and it is difficult to eliminate these problems from the root cause without adjusting the planning plan such as the relevant facilities and related management methods of the intersection.

In addition to the above problems, this paper also analyzes the current traffic flow situation, including the delay calculation and the calculation of the traffic capacity of the current control scheme in order to compare different capacities of raised plans.

3.2. Construction Problems

3.2.1 Roads are Temporarily Closed

Overall traffic efficiency is greatly reduced. At the northeast entrance, the road has seen a reduction in lanes due to fencing and a backward shift of traffic lights. At the same time, the shape of the fence in the middle of the road is unreasonable, resulting in a temporary "pedestrian safety island". A large number of pedestrians are stranded in front of this fence, crossing the sidewalk in one direction move forward, waiting for signal lights in the open space directly in front of the fence between the entrance road and the exit road, and directly affecting the movement of motor vehicles on the road. The reduction of lanes directly leads to a significant reduction in road capacity and an increased likelihood of pedestrians jaywalking.

3.2.2 Heavy Locomotives

A large number of heavy locomotives pass through the intersection, resulting in decline of traffic smoothness, road surface service life deduction and other problems. When the traffic flow rate increases, the overall delay and accident rate of traffic flow will increase [1]. The intersection is in the construction stage, resulting in a large number of construction vehicles such as heavy trucks, mixer trucks passing through the intersection. That will cause a high vehicle rate, the increase in overall delay of the traffic flow, the decrease of efficiency, etc. The large vehicle rate is an important factor affecting the traffic safety accident rate, so the large increase in large vehicles will also directly cause an increase in accidents.

3.3. Problems

3.3.1 Road Sign and Marking

The lane and stop line are hard to recognize. The signs before construction have not been cleaned up, overlapping with the newly painted signs, which is confusing. The sidewalk at the southeast exit has been subjected to heavy construction equipment for a long time, resulting in almost invisibility. Conversely, the sidewalk line in the southwest is not removed, but almost no pedestrians pass through it. At this entrance the zebra crossing becomes a decoration and the zebra crossing is too wide.

3.3.2 Signal Lights

The arrangement of signal lights does not conform to the law of driver recognition. The new and old traffic lights attract the attention of drivers at the same time, increasing the identification time and reaction time. For example, the northeast entrance in the fig.2. The lower left corner is the old signal lights. Because the construction visual distance is not enough and the line in unclear, the old signal lights are proposed to be removed. The signal lights in the upper right corner is temporarily placed for the use of the control of the crossing. When the drivers drive from the lower left corner to the upper right corner, they will first be attracted by the traffic light in front of them and ignore the road state. At the same time the vehicle is about to pass through the pedestrian gathering place caused by the fence. The pedestrians are very easy to jaywalk in such a narrow lane at the construction site. At this time, they may ignore the surrounding environment, resulting in a traffic scene where drivers and pedestrians are relatively inattentive to each other, and this scene is bound to be more likely to cause accidents.

Figure 2. The signal lights are not arranged reasonably

3.3.3 Pavement Space Design

Observation found that the existing problems with the design of the pavement space are listed. Firstly, the pavement layout is messy, also there is no dedicated lane for pedestrians and non-motor vehicles. The pedestrian passage is part of the outermost lane exposed after the fence, as shown in fig.3. Pedestrians and non-motor vehicles directly mixed on this narrow space. The width of the road is about 90cm, which does not meet the requirements of pedestrians and non-motor vehicles mixed width. The pedestrian walking area is directly adjacent to the motor vehicle lane, which poses a great threat to the safety of pedestrians.

Figure 3. Narrow temporary pedestrian area

3.3.4 Line-of-sight

At present, the line-of-sight problem found is that the fence in all directions of the intersection does not meet the visual distance requirements that can be seen by the intersection entrance road. The fence completely blocks the non-motor vehicles and motor vehicles on the intersecting road, and the possibility of safety accidents is very large. The figure below shows the driver's visual status when the driver is about 10 meters away from the stop line at the entrance of the intersection at the southeast entrance. It can be seen that although to avoids poor visual distance in the future, the part of the fence near the middle of the intersection is hollowed out, the driver of the entrance road with poor hollowing effect is still almost unable to see pedestrians and non-motor vehicles at the southwest entrance. In this case, it is very easy to have such a situation: non-motor vehicles or pedestrians suddenly driving out of the shelter are not noticed by the driver of the straight motor vehicle due to visual distance, causing the driver of the motor vehicle to quickly press the brakes, resulting in serious personal injury or property damage as shown in fig.4.

Figure 4. Simulation of the driving angle of the car at the southeast entrance

3.3.5 Calculation and Analysis of the Capacity of the Current Program

Firstly, the current option of the intersection was calculated in order to compare with the options raised by the author. The results are summarized in Table 2.

Table 2. Straight equivalent calculation of the current scheme of the intersection

Entrance	Lane group	Flow	Straight equivalent coefficient	Direct equivalent	Lane Group Straight Travel Equivalent	Average Single-lane Straight-line Equivalent
South Entrance	Left	95	1	95	834	278
	Straight	674	1	674		
	Right	54	1.21	65		
East Entrance	Straight	430	1	430	1098	366
	Right	552	1.21	668		
West Entrance	Left	268	1.05	281	281	281
	Straight	260	1	260	260	130

Secondly, the signal flow ratio has to be analysis. The results are summarized in Table 3. It can be seen from the results that Y=0.56, which is much less than 0.9. This indicates that the current state of traffic flow at the intersection of Youyi Road and Luojiagang Road has not re[hed[ts design capacity, the overall traffic flow is relatively smooth, and the average delay during peak hours may not be long.

Table 3. Analysis of Intersection Signal Flow Rate Ratio

Phase		Flow	y	Y
φ1		366	0.252	0.56<0.9
φ2		278	0.168	
φ3		281 130	0.170	

Because it is difficult to evaluate whether the current traffic capacity of the intersection is saturated and to estimate the degree of saturation value of the existing state, the traffic capacity is calculated to facilitate comparison of the results of the signal timing scheme proposed in this scheme and the scheme in use, as shown in Table 4.

Table 4. Three Scheme comparing

Direction	Lane	Saturation Flow Rate	Green Ratio	Lane Capacity	Entrance Lane Capacity
South Entrance	Straight Right	1485	0.264	392	1365
	Straight	1866	0.264	493	
	Straight Left	1820	0.264	480	
East Entrance	Right	1450	0.333	483	1594
	Straight Right	1649	0.333	550	
	Straight	1683	0.333	561	
West Entrance	Left	1771	0.333	590	1666
	Straight 1	1614	0.333	538	
	Straight 2	1614	0.333	538	

The lane group saturation is generally low, so the Webster model is used for delay calculation. The calculations are shown in Table 5, and the result is an average delay of 43.928s and an intersection service level of D.

Table 5. Calculation results of Webster modle

Entrance	Lane	Equilibrium Delay	Random Additional Delay	Total Delay	Lane occupancy	Entrance Average Delay
South Entrance	Straight Right	39.881	3.995	43.876	185	51.087
	Straight	44.585	14.12	58.705	404	
	Straight Left	40.126	3.542	43.668	235	
East Entrance	Right	37.549	8.49	46.039	342	42.855
	Straight Right	36.134	5.145	41.279	280	
	Straight	34.912	3.625	38.537	150	
West Entrance	Left	33.809	2.513	36.322	268	34.326
	Straight 1	31.206	1.063	32.269	130	
	Straight 2	31.206	1.063	32.269	130	
Average Delay		43.928		Capacity		D

4. Intersection Optimization and Transformation Plan

4.1. Marking and Pavement Facility Issues

4.1.1 Crosswalk Settings

Erase the original non-functioning zebra crossing in the southwest, adjust the position of the vehicle stop line and the pedestrian crossing, so that the zebra crossing is located before the vehicle stop line, and supplement and improve other zebra crossings that still need to be used. Improve crosswalk visibility. Crosswalks use retroreflective road markings (highly visible, reflective pavement surface markings) to increase crosswalk visibility at night. The rest of the lane lines, the stop lines of the two cars, etc. should be improved.

4.1.2 Lane signal Settings

The southwest exit of Youyi Road, when installed on the overpass body, shall not be lower than the clearance of the bridge body. The other two outlets are cantilevered.

4.1.3 Pedestrian Crossing Signal Settings

Because the current signal lights are misleading, the signal lights that have been abandoned due to construction should be removed. Because the current line-of-sight conditions are not good, placing signal lights in normal positions may cause line-of-sight problems. Even if drivers drive normally, they still can't see the signal lights within the stopping sight range. So consider installing new signal lights in all four directions of the intersection to avoid line-of-sight problems.

4.1.4 Traffic Sign Adjustment

There are two styles of inverted triangle traffic signs: white inverted triangle signs on the road floor, set at intersections, to remind vehicles to slow down and pay attention to pedestrians ahead. A more appropriate suggestion is to add a red inverted triangle sign to the entrance road of Luojiagang Road to remind vehicles to avoid vehicles on Youyi Road. Because the traffic flow of the south import is large, it is best for fewer vehicles on Luojiagang Road to avoid the traffic coming from the south entrance of Youyi Road. At the same time, signs are set up to indicate motorized and non-motorized lanes.

4.2. Pedestrian and Non-motorized Vehicle Crossings

The first thing to deal with is the problem of pedestrian crossings, and the proposal is to widen the crosswalk line and implement two-way pedestrian traffic. Set up a right-turn guide line on the entrance road of Luojiagang Road to reduce the turning radius of right-turning motor vehicles. By reducing the turning radius of right-turning motor vehicles and forcing the speed reduction to alleviate the collision between people and vehicles, it not only achieves the effect of vehicle slowing down and avoiding pedestrians, but also increases the passage space of pedestrians and non-motor vehicles, and shortens the crossing time of pedestrians.

The second is non-motorized vehicle crossing improvements. For this, the two renovation suggestions are: move the non-motor vehicle parking line forward. According to the characteristics of bicycles and electric vehicles starting quickly, cyclists are eager to pass through the intersection, non-motor vehicles drive into the intersection first, which can avoid non-motor vehicles and motor vehicles crossing the street at the same time. Non-motorized lane markings are set up next to zebra crossings for electric vehicles and bicycles. When pedestrians and non-motorized vehicles cross the road, they can go their separate ways and pass in an orderly manner.

Finally, is the improvement of non-motorized crossings. This plan proposes to add non-motorized left turns (secondary crossings) and waiting areas (red areas in fig.), with red lines marking waiting areas at the corners of each intersection. A "Left Turn Non-Motor Vehicle Second Crossing" sign is set up on the guardrail, which indicates the driving route. That means, non-motor vehicles that need to turn left, drive in from the dedicated non-motorized lane, first follow the guidance of the green light of the crosswalk, go straight to the waiting area on the opposite side, and then look at the green light of the crosswalk on the other side to go straight across the road, at this time, the driver need to wait for the secondary signal light to pass. Such a scheme can avoid non-motor vehicles turning left with motor vehicles along, as shown in fig.5.

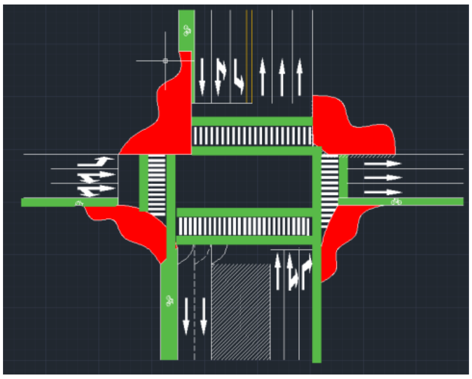

Figure 5. Renderings of the Completion of the Intersection Renovation

4.3. Channelization Design Improvements

4.3.1 Entrance

Due to the excessive number of right-turning vehicles, the east entrance of Youyi Road increased the right-turn lane by widening the entrance road, the length of the widening section was 70 meters, the length of the widening gradient section was taken by 30 meters. The straight right lane was changed to a straight lane. Set a pre-U-turn in the central divider.

For Youyi Road West Entrance Road, move the pedestrian crossing back to increase the area of the intersection. Due to the excessive number of left-turning vehicles, a left-turn waiting area is added at the front of the lane to improve the traffic efficiency of left-turning vehicles.

The corner fence of the south entrance of Luojiagang Road and the west entrance of Youyi Road will be reduced to provide a waiting area for pedestrians to cross the street and the necessary driving distance for two vehicles.

4.3.2 Exit Lane

On the north exit of Luojiagang Road, due to the right-turn lane set up at the east entrance of Youyi Road, the exit lane widens a right-turn exit lane. The corner of each intersection is marked with red waiting area, and the guardrail is set up with a "left turn non-motor vehicle secondary crossing" sign, which indicates the driving route, that is, non-motor vehicles that need to turn left, in the dedicated non-motorized lane, first look at the green light of the crosswalk to go straight to the opposite waiting area, and then look at the green light of the crosswalk on the other side to go straight across the road, you need to wait for the secondary signal light to pass, to avoid the original left turn mixed with motor vehicles. Channelized traffic situation can be seen in fig.6.

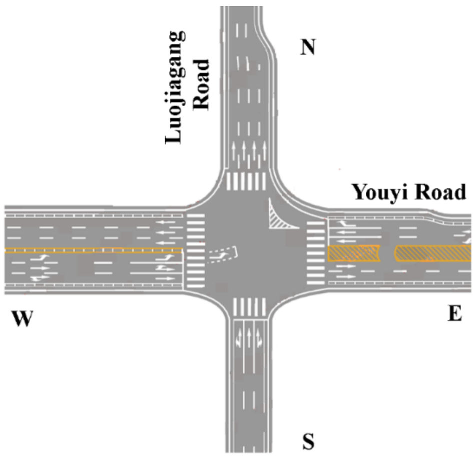

Figure 6. Channelized traffic

4.4. Signal Timing Scheme

4.4.1 Option I

First, in order to carry out subsequent calculations, the phase sequence diagram and control chart of Option I are drawn. The straight equivalent of the lane group is marked according to the straight-going equivalent calculation results. Then the key traffic flow and flow values of each phase are determined, showing in Table 6.

After calculating, the calculated parameters are listed as below: yellow time $A_{1,2,3}$=3s, full red time $r_{1,2,3}$=3s, green interval time $I_{1,2,3,4}$=6s, loss time of each phase $L_{1,2,3}$=6s, total signal loss time L=18s, signal period =72s.

Table 6. Phase Sequence and Control Charts of Option I

Phase		Ring
φ1		0.222
φ2		0.168
φ3		0.170

Secondly, draw the signal phase display diagram. The first option can be used to improve the overall traffic efficiency of the intersection, and the signal are shown in fig.7.

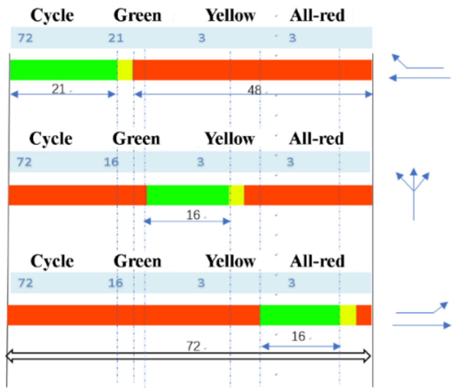

Figure 7. Phase Display Diagram of Option I

The design purpose of option I is to reduce signal cycles, reduce pedestrian waiting time and reduce queuing time at each entrance. Then the capacity of option I is calculated as the follow table. It is clear that capacity of all the entrances has increased, showing in Table 7.

Table 7. Capacity-based calculation of Option I

Direction	Lane	Saturation Flow Rate	Green Ratio	Lane Capacity	Entrance Lane Capacity
South Entrance	Straight Right	1485	0.222	330	1148
	Straight	1866	0.222	414	
	Straight Left	1820	0.222	404	
East Entrance	Right	1450	0.291	422	1392
	Straight Right	1649	0.291	480	
	Straight	1683	0.291	490	
West Entrance	Left	1771	0.222	393	1163
	Straight 1	1614	0.222	385	
	Straight 2	1614	0.222	385	

The delays and service levels are also calculated as below, in table 8.

Table 8. Delay calculation table of Option I

Entrance	Lane	Equilibrium Delay	Random Additional Delay	Total Delay	Lane occupancy	Entrance Average Delay
South Entrance	Straight Right	22.5	6.64	29.24	185	51.087
	Straight	27.8	4.51	32.31	404	
	Straight Left	22.97	5.97	28.94	235	
East Entrance	Right	23	21.19	44.19	342	42.855
	Straight Right	20.77	5.11	25.88	280	
	Straight	21.98	1.61	23.59	150	
West Entrance	Left	25.66	9.23	34.89	268	34.326
	Straight 1	23.68	2.36	26.04	130	
	Straight 2	23.68	2.36	26.04	130	
Average Delay		31.6772		Capacity		C

4.4.2 Option II

As in the first scenario, draw the phase sequence diagram and control chart for scenario 2 to calculate the relevant parameters for comparison, in table 9. The Parameters are listed below: yellow time, $A_{1,2,3}$ = 3s; full red time, $r_{1,2,3}$= 3s, green interval time, $I_{1,2,3,4}$ = 6s; loss time of each phase, $L_{1,2,3}$ = 6s; total signal loss time L=18s, signal period = 72s.

Table 9. Phase Sequence and Control Charts of Option II

Phase		Ring 1	Ring 2
φ1		0.13	0.08
φ2		0.17	
φ3		0.168	

The complete signal timing is shown through fig. 8.

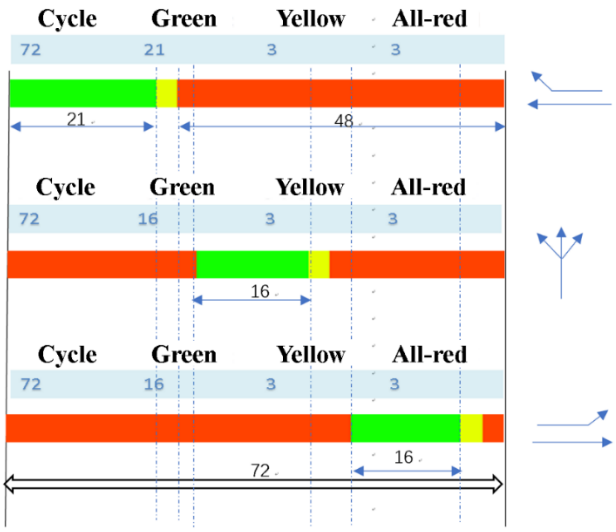

Figure 8. Phase Display Diagram of Option II

Then the capacity of option II is calculated as the follow table. It is clear that capacity of east entrances has increased, however the capacity of south and west entrance remains unchanged, as shown in Table 10.

Table 10. Capacity-based calculation of Option II

Direction	Lane	Saturation Flow Rate	Green Ratio	Lane Capacity	Entrance Lane Capacity
South Entrance	Straight Right	1485	0.25	371	1293
	Straight	1866	0.25	467	
	Straight Left	1820	0.25	455	
East Entrance	Right	1450	1	1450	2120
	Straight Right	1649	0.2	330	
	Straight	1683	0.2	340	
West Entrance	Left	1771	0.25	443	1895
	Straight 1	1614	0.45	726	
	Straight 2	1614	0.45	726	

Calculating the delay and service level, it can be found that the advantage of option 2 is that it reduces the average delay and outperforms the results of option 1. But it has no obvious effect on the flow control in the direction other than the east entrance, showing in Table 11.

Table 11. Delay calculation table of Option II

Entrance	Lane	Equilibrium Delay	Random Additional Delay	Total Delay	Lane occupancy
South Entrance	Straight Right	19.26	4.677	23.94	185
	Straight	21.53	18.85	40.38	404
	Straight Left	19.37	4.146	23.52	235
East Entrance	Right	0	0	0	342
	Straight Right	22.07	22.87	44.94	280
	Straight	22.01	4.11	26.12	150
West Entrance	Left	19.88	6.01	25.89	268
	Straight 1	9.86	0.51	10.37	130
	Straight 2	9.86	0.51	10.37	130
Average Delay		29.407		Capacity	C

In comparison, it is not difficult to see that the signal timing scheme has played its due role, and the problem of large delays in imported vehicles in the south has been greatly solved. The remaining entrances have less traffic and less overall delays, so there is no need for much adjustment.

5. Summary

Data analysis and discussion in accordance with related studies and methods related to other studies are traffic statistics and processing analysis in each direction of intersection, the analysis scheme of intersection signal timing is flow rate ratio analysis, the Webster model is used to calculate the intersection traffic capacity and delay status. For the safety of the researchers, there is no more nuanced data on the road geometry conditions at this intersection, which may lead to the final road channelization and non-motorized lane modification results being less accurate. The traffic flow at the intersection of Youyi Avenue and Luojiagang Road is very small, far from reaching the design capacity of the intersection, so the signal timing scheme of this scheme may not be able to be used under high traffic, and the construction intersection scheme under high flow is still not a good conclusion.

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