Traffic Investigation and Control of Hefei Economic Development Zone

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Abstract. According to the statistics of relevant units in Hefei City, it is conservatively estimated that the number of private cars in Hefei has reached more than 600000, and the per capita vehicle ownership rate is 8%. In the past two years, the number of new cars in Hefei has increased by 280000. However, the existing traffic system of Hefei can no longer meet the actual traffic capacity and road traffic safety. In this paper, through the traffic investigation of Hefei Economic Development Zone, we will find out the existing problems and the areas that can be effectively improved through traffic management and control. Under the condition of not affecting the normal traffic, we should investigate and control the existing facilities, improve the traffic efficiency of the existing facilities, improve the traffic environment, ensure the traffic safety and dredge the traffic.

Keywords: Traffic investigation · Signal control · Signal timing scheme

1 Introduction

With the development of the times, the economic conditions of urban residents are getting better and better, and their living standards are also constantly improving. Therefore, the car ownership of urban residents is also increasing year by year, and the residents can choose more and more ways to travel, but the following various traffic problems are also gradually highlighted. Compared with other road networks, the density of urban road network is higher. Among them, there are many road attraction points, and the traffic flow is quite large. However, widening the road will increase the cost and hinder the normal life of residents. Traffic investigation is to find out the existing problems through on-the-spot investigation on the current traffic situation, traffic facilities and traffic management in a certain area. Traffic management and control is a kind of man-made traffic control method for traffic system through relevant departments. Its object is all vehicles, pedestrians and roads on the road. On the basis of not changing the existing traffic facilities, advanced control methods are used to clear traffic congestion and ensure smooth and safe traffic.

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2 Investigation on Traffic Situation of Hefei Economic Development Zone

Based on the field investigation on the traffic situation of Hefei Economic Development Zone, it is found that the daily traffic situation of the economic development zone, especially during rush hours, is not optimistic. Through observation at the crossroads of major streets in the economic development zone, we can always see the traffic congestion most of the time. In particular, the hub intersection located in the center of the region is seriously congested, and the traffic flow in the economic development zone is large, and traffic jams often occur, resulting in tense traffic situation.

The research object of this paper is located in Hefei Economic Development Zone, which is a traffic busy area. There are 126, 148, 150, 226, 30, 508, 601, 602, 603, 605, 901 and other bus lines nearby.

2.1 Intersection Signal Timing

Due to the rapid economic development and the rapid increase of traffic flow, there are a large number of congested sections and even continuous intersections, especially at junction intersections. Therefore, residents' travel, urban public transportation and freight transportation are affected to varying degrees. After field investigation, it was found that, the intersection signal timing of Economic Development Zone fails to guide the traffic flow accurately and conveniently, resulting in congestion of some sections for more than 20 min, which seriously affects the normal transportation.

2.2 Problems in Public Transportation in Economic Development Zone

(1) Unreasonable line layout
Economic Development Zone has a number of bus lines, but the proportion of bus lines in old urban areas is far greater than that in new urban areas. The bus lines in old urban areas have been unable to meet the traffic needs of new residents and enterprise personnel, and it is difficult to provide safe, convenient and fast public transport services.

(2) The service quality is low and the riding environment is poor
According to statistical data, the full load rate of buses in economic development zones is often more than 120%. These data show that the number of passengers standing or sitting in the bus is often close to 100, which shows that residents will be very crowded when riding. In addition, if the bus speed is too slow, it will seriously waste passengers' time. As of 2014, most of the buses of Hefei public transport group have been running at a speed of no more than 16 km/h.

2.3 The Quality of Drivers is Not High

In most sections of the economic development zone, traffic congestion is more serious because some drivers rush and occupy the road. Improve the quality of drivers, learn relevant safety laws and regulations and other knowledge, develop a good sense of safety, not just improve driving skills.

3 Case Analysis

3.1 Selection of Typical Areas

In view of the traffic congestion in the economic development zone, the intersection of Jinzhai Road and busy Avenue in the economic development zone is selected as the case of traffic management to control and improve the traffic environment. Firstly, the data of lane width, traffic flow at each time, signal display and cycle of traffic lights in the economic development zone are collected, and then the data are calculated and sorted out, Finally, the effective timing is obtained and the improvement scheme is proposed.

3.1.1 Channelization of Intersections

The traffic environment data of the intersection is obtained through field investigation, and the channelization design of the intersection is carried out according to the data. The geometric conditions of the intersection of Jinzhai Road and Fenghua Avenue in the Economic Development Zone are summarized in Table 1.

Firstly, the channelization scheme of the intersection is determined, as shown in Fig. 1.

3.1.2 Survey Data

(1) Signal lamp control:

See Fig. 2 for signal timing of intersection of Jinzhai Road and downtown Avenue in economic development zone.

Table 1. Geometric conditions of intersections

	Entrance lane direction	Number of lanes in different directions	Number of entrance lanes	Number of exit lanes
South import	Left	1	4	4
	straight	2		
	right	1		
Western import	Left	1	4	4
	straight	2		
	right	1		
North import	Left	1	4	4
	straight	2		
	right	1		
East import	Left	1	4	4
	straight	2		
	right	1		

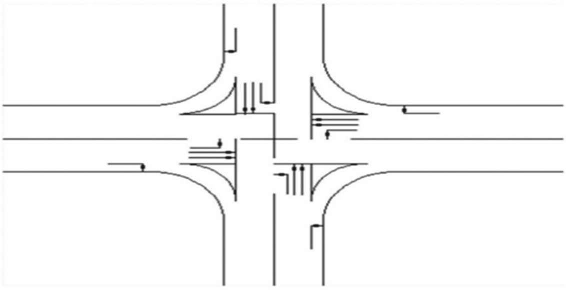

Fig. 1. Channelization scheme of intersection

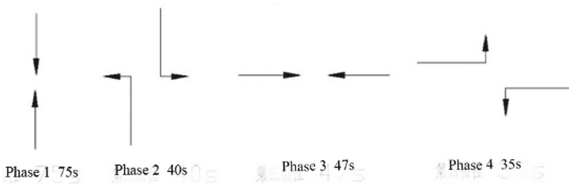

Fig. 2. Signal timing diagram of intersection

Table 2. Duration of green light in each phase

Phase stage	Green light duration g(s)	G/C
Phase 1	75	0.381
Phase 2	40	0.203
Phase 3	47	0.239
Phase 4	35	0.177

According to the traffic flow on the road, the intersection signal can be divided into four phases. After observing the intersection, the period of recording the signal is 205 s, in which the yellow light flashes for 3 s. When switching between phases, insert a yellow light. See Table 2 for the duration of green light at each phase of intersection:

(2) Traffic flow survey

Location: Intersection of Jinzhai Road and Fanhua Avenue, Hefei Economic Development Zone

Time: 11:30 to 12:30 noon

By selecting the representative 1 h traffic data during the peak period as the main basis of traffic flow. See Table 3 for summary statistics of collected data:

Table 3. Traffic volume at each entrance

		traffic	total
South import	Left	129	1690
	straight	1094	
	right	468	
Western import	Left	325	960
	straight	494	
	right	142	
North import	Left	80	1588
	straight	1070	
	right	439	
East import	Left	241	747
	straight	362	
	right	144	

3.2 Basic Method and Phase Establishment

3.2.1 Basic Methods

The method used in this paper is the Weber method proposed by B.M. Cobbe and F.V. Webester in 1950. This timing method is suitable for the existing traffic facilities environment, aiming at the shortest delay time of vehicles passing through the intersection, and then revising the optimization results according to the current situation of the intersection as the limiting condition. Finally, the best signal timing design scheme suitable for the intersection is sorted out to improve the traffic problem [1].

3.2.2 Phase Scheme

According to the survey data, draw up the phase connection and design a reasonable scheme for the initial phase. Through the on-the-spot investigation of the intersection, because the main phases all choose the way of lagging the left turn phase, according to relevant theories, it is determined that the left turn and straight through will be drawn up as the connection form between the two main phases in the new scheme. This connection form is compatible with the intersection. This intersection can perfectly meet the current traffic demand. The complete initial phase scheme of is shown in Fig. 3, using 4 phases.

3.3 Signal Timing Scheme

3.3.1 Green Light Interval Time and Loss Time

(1) Yellow light time [2]

$$Y = t_r + (S_{85}/2a) \quad (1)$$

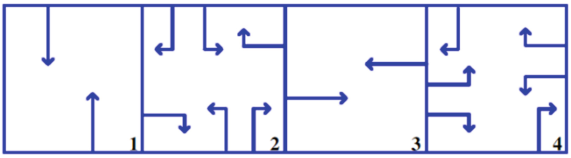

Fig. 3. Phase diagram of each lane

Table 4. Yellow light time calculation table

	Reaction time (s)	Deceleration (m/s^2)	Average vehicle speed v(m/s)	Yellow light time (s)
South import	1	3	11	2.8
Western import	1	3	11	2.8
North import	1	3	6	2
East import	1	3	8	2.33

Type:

Y——yellow light time (s);

t_r-the driver's reaction time (s), which is generally 1.0 s;

S_{85}——85% speed (m/s) of the vehicle at the entrance road, which can be equal to the average speed when substituted;

a——deceleration (m/s^2), which can be 3 m/s^2.

See Table 4 for the calculation of yellow light time:

In the same area, for the convenience of each phase, the yellow light time can be 2 s, which can make the yellow light time more reasonable.

(2) All-red time [3]

$$AR = (w + l)/S_{15} \tag{2}$$

Type:

AR——all-red time (s);

w——the width of intersection clearance, and the interval (m) from the stop line to the center line of the extreme conflict lane;

l-body length (m), generally 6.1 m;

S_{15}——the vehicle speed at the entrance is multiplied by 0.15 (m/s), and the average vehicle speed can be used for substitution.

First, determine two basic parameters: the length L of the car body and the emptying width W, and then calculate the full red time. L Theoretically, it should be calculated by measuring the content of large cars in traffic flow. Because this number has little influence on the determination of all-red time, 6.1 m is taken as the body length in this paper. The measured width of the intersection is about 15 m, the average speed measured by speedometer is 33.3 km/h (about 9.25 m/s). Substitute the above values to get AR = (6.1 + 15)/9.25 = 2.28 s. After rounding, it is concluded that the full red time is 2 s.

(3) Phase loss time

According to the above calculation, the green light interval time I and phase loss time tL of the new timing scheme are both 4s, and the total cycle loss time L = 4 * 4 = 16 s.

3.3.2 Key Traffic Flow and Key Phase

It can be seen from Table 5 that there are four key traffic flows in total, of which two are left-turn traffic flows and straight-through traffic flows at the south entrance, and two are straight-through traffic flows and left-turn traffic flows at the west entrance respectively. The four key traffic volumes are as follows: the left-turn traffic volume at the south entrance is 129 vph/ln, the straight traffic volume at the south entrance is 547 vph/ln, the straight traffic volume at the west entrance is 247 vph/ln and the left-turn traffic volume at the west entrance is 240 vph/ln. Total traffic volume of all key lanes Vc = 129 + 547 + 247 + 240 = 1163 vph.

Table 5. Calculation table of key traffic flow and key phase

		South import			Western import			North import			East import		
		Left	Straight	Right	Left	Straight	Right	Left	Straight	Right	Left	Straight	Right
Traffic		129	1094	468	325	494	142	80	1070	439	240	362	144
Number of entrance lanes		1	2	1	1	2	1	1	2	1	1	2	1
Lane traffic volume		129	547	468	325	247	142	80	535	439	240	181	144
Critical lane traffic volume	Phase 1		547										
	Phase 2	129											
	Phase 3					247							
	Phase 4										240		
Critical lane traffic volume		129	547			247					240		

3.3.3 Length of Signal Cycle

Calculate the best signal period duration [4]:

$$C_0 = (1.5L + 5)/(1 - Y) \tag{3}$$

Type:
C_0——initial period duration (s);
L——sum of signal cycle loss time of all phases (s);
Y——the total flow ratio of key phases and lanes.

Before calculating the period length, it is necessary to obtain the signal period loss time of all phases, and calculate the value of Y by counting the obtained key phase flow. Here, a key parameter is used, that is, the actual saturated flow of a single lane. According to the research conclusion of HCM2000, S = 1600 vph is generally selected. The applicable flow limit ratio can be $Y_c = 0.9$, and the sum of available flow ratios Y = 1163/1600 = 0.728 < 0.9. Then, $C_0 = (1.5*16 + 5)/(1–0.728) = 107$ s.

3.3.4 Green Signal Ratio and Green Time Allocation

The effective green light time must be allocated reasonably after strictly calculating the proportion of each key traffic flow according to the principle of equal saturation [7]. The calculation formula of green signal ratio [8] is as follows [5]:

$$\lambda_i = \frac{V_{ci}}{V_{cs}} \frac{(C - L)}{C} = \frac{V_{ci}}{V_{cs}} \frac{G_e}{C} \tag{4}$$

Type:
V_{ci}-the critical traffic volume (vph) of a critical traffic flow;
V_{cs}-the sum of all key traffic volumes (vph), which is calculated as 1163 vph according to the above;
G_e——the total effective green time of the cycle (s).

Therefore, the total effective green light time of the intersection cycle is: G_e = 107–16 = 91 s (Table 6).

3.3.5 Final Timing Scheme

According to the calculation results, after reading the relevant data and combining with the actual situation, the appropriate timing scheme is determined. The scheme is divided

Table 6. Calculation table of green light time and green signal ratio

Key traffic flow	Critical traffic volume (vph)	effective green time	Green letter ratio
Turn left to the south	129	11	0.1
Go straight south	547	43	0.4
Go straight west.	247	19	0.18
Turn left east.	241	22	0.21
total	1164	95	0.89

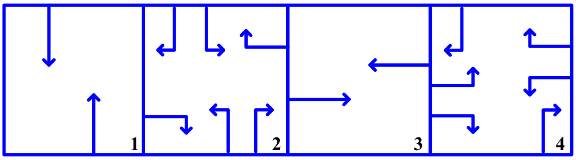

Fig. 4. Phase diagram of each lane

Table 7. Green light duration of each phase

Phase stage	Green light duration g(s)	G/C
Phase 1	43	0.40
Phase 2	11	0.10
Phase 3	19	0.18
Phase 4	22	0.21

Table 8. Time table of traffic flow green light

traffic	Green light duration (s)	G/C
North South left turn	11	0.10
Straight north and South	43	0.40
North South right turn	19	0.18
Turn left from east to west	22	0.21
East West Straight	54	0.50
Turn east and West right	41	0.39

into four phases. According to the reasonable arrangement, the North-South main phase and the East-West main phase will use the left turn protection phase at the same time (Fig. 4).

According to the scheme, there are four phases in total. The total period of the signal is 107 s, and the waiting time of yellow light and full red time are both 2S. Then the Yellow time and full red time are inserted between the switching of each phase. The green time of each phase of intersection is shown in Table 7.

The summary of green light duration of traffic flow at intersections is shown in Table 8.

4 Improvement Plan

Through the traffic investigation and analysis of the economic development zone, it is found that there are some deficiencies in the current traffic situation and system of the economic development zone. In view of these deficiencies in the traffic status and system of the economic development zone, combined with the specific situation of the economic development zone, three improvement suggestions are put forward: traffic signal optimization, traffic management improvement and public transport development.

4.1 Traffic Signal Optimization

In the urban traffic network, the traffic at the intersection is very complex, and it is also a very important structure, and it is also the place where vehicle congestion is most likely to occur. It can be seen that by reasonably organizing and managing the traffic at the intersection, the traffic capacity can be improved and the traffic safety can be guaranteed without changing the original facilities.

After the investigation of each intersection in the survey area, it is found that traffic congestion is common at these intersections. Signal control has more or less problems. According to the existing traffic management and control theory, it is generally believed that the delay caused by the intersection is much higher than that of the road section. Therefore, it is necessary to reasonably improve the safety and smooth traffic of intersections, It can optimize the urban road network structure adjustment and achieve reasonable traffic control.

By using the signal control method in this case, reasonable control of the existing traffic facilities can greatly reduce the road congestion and effectively improve the traffic status of the economic development zone.

4.2 Improve Traffic Management

Economic Development Zone must carry out the construction of reasonable traffic management, so as to improve the level of traffic management. Specific suggestions are as follows:

First, optimize the traffic flow organization. Traffic organization optimization is an efficient management method. By using the current road space facilities according to time-sharing, road, vehicle type and flow direction, traffic organization can be optimized in a time-saving and labor-saving way, and the running state of road traffic is no longer chaotic and always orderly and efficient. Actually, in a sense, traffic organization optimization is actually a process of road traffic pressure transfer. Once the reasonable traffic organization optimization measures are successfully implemented, the intersection with serious congestion can be transferred to the relatively unobstructed intersection in the traffic organization, and the traffic pressure of each intersection in the same road network can be released in a short time. Traffic flow is evenly and reasonably distributed in the whole road network.

Second, implement the traffic demand management strategy. With the development of road traffic management, the original traffic management can't meet the current urban traffic demand. With the concept of traffic demand management put forward, traffic management began to turn to manage its source, that is, road traffic demand. It is determined that the solution to the traffic congestion problem can only be realized through the joint management of supply and demand.

4.3 Develop Public Transportation

So far, due to the rapid increase in the number of urban residents and motor vehicles in Hefei, the problem of urban road traffic congestion is becoming more and more serious. With the increase of population, the development of Hefei public transport system is difficult to meet the traffic demand at this stage, and the service quality and operation efficiency cannot be improved. Giving priority to the development of public transport in Hefei has become an important method to solve the complex traffic problems in Hefei, which can provide a good foundation for the healthy development of urban economy and people's livelihood [6].

According to the data of relevant departments, there are only more than 3000 public transport vehicles in use in Hefei city. There are less than 150 commonly used bus lines. The total length of the total line is less than 2000 km, and the daily average number of passengers is 1.7 million.

According to the rough estimation of relevant departments, the bus travel sharing rate of Hefei is only slightly more than 20%, but according to the proposal of "transit city", the minimum requirement of bus travel sharing rate is at least 40%.

In large cities with rapid economic development, the use of public transport by residents can reduce the utilization rate of private vehicles and greatly change the operation of urban roads. The reduction of the use of private vehicles can greatly reduce the energy consumption of vehicles and the environmental pollution caused by the use of vehicles. On the contrary, once the level of urban public transport is low, it will reduce the living standard of the whole city residents, delay the good economic development of the modern city, and also bring environmental pollution and other problems.

5 Conclusion

Through the traffic investigation of economic development zones, we can know that most of the road systems in economic development zones are mesh structures. The main feature of this kind of system structure is the high density of road network, in which the number of road network nodes-intersections is very large. Up to now, the intersection is still an important part of the urban road system. In many cities, it is precisely because of the serious traffic interference at intersections that the traffic capacity at intersections is extremely reduced. Once the capacity of intersections is too low, it will eventually lead to traffic problems such as traffic chaos, traffic jams and frequent road traffic accidents.

In order to improve the safety of intersections, it is necessary to inspect the current situation of each intersection and surrounding roads, buildings, etc., and strictly measure the size and direction of required traffic, even including the basic parameters of pedestrians and other aspects. Then analyze the data objectively, qualitatively and quantitatively to find out the existing problems in economic development zones. Then put forward reasonable improvement plans for economic development zones, so as to improve the interference and conflict between traffic flows in all directions, so that vehicles and pedestrians can pass through intersections safely, conveniently and quickly.

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Study on urban road traffic risk based on coupling characteristics of mixed traffic and adverse climate and environment factors (Grant NO. PTZD2020017) Study on short term fatigue recovery characteristics of Expressway drivers (Grant NO. zsys20002).

References

1. Liu X, Sun L (2010) Design and optimization of signal control scheme for urban road intersections. J Xinjiang Agric Univ 5(33):457–459
2. Wu B, Li Y (2009) Traffic management and control, vol 1. People's Communications Press, Beijing, pp 150–151
3. Liu Y (2013) Optimal design of signal timing at the intersection of Luoyu Road and Guanggu Avenue in Wuhan. Hebei Commun Vocat Tech News 9, 10(3):64–66
4. Sun X (2011) Analysis of timing method of single-point adaptive control of traffic signal. J Fujian Radio TV Univ No. 4 (No. 88) 88
5. Wu D (2014) The signal optimization design of Xiongchu Street intersection in Wuhan. J Hebei Commun Vocat Tech Coll 3, 11, No. 173–75
6. Yuan Z (2007) Road traffic management and control. People's Communications Press, Beijing, pp 56–60