A Study of Vehicle Characteristics of Signalized Intersection based on Queuing Theory

LIAN XUE, MINGHUI WU*, HUI YAN
School of Computer and Computing Science
Zhejiang University City College
Huzhou Street 51, Hangzhou 310015
P.R. CHINA
*corresponding author email: wmhmathzju@gmail.com

Abstract: - This paper uses queuing theory to study the features of the vehicle's arriving and passing of the signalized intersection. The first part of this paper presents the background, purpose and meaning. In the second part, the arrival process and serving process are studied, especially the delay process is mainly analyzed including the dispersion vehicle headway time distribution and vehicle delay at signalized intersections is analyzed. In the third part, time series, cubic spline difference and gray prediction, RBF neural network are used to get the number of vehicles arrived outside of next 18 cycles. Based on the queuing theory, the forth part introduces a predict model on the vehicle's arrival. It predicts a certain intersections' average length, average waiting time and average length of stay in the next 18 cycles. The fifth part optimizes the intersection signal timing and gets the best signal cycle time. Scientific model and more complete analysis are founded in the paper. These methods have a good reference value to the relevant departments.

Key-words: - signalized intersection, vehicle characteristics, queuing theory, RBF neural network, forecast, timing optimization

1 Introduction

With the development of China's economics and improvement of living standards, all service industries are also increasingly to fierce competition. As the standards of enterprise management, service concept and corporate image, service quality in recent years are concerned by service parties and customers.

Traffic flow theory began in the 30's; a lot of methods are provided to solve the problem of traffic flow in the numerical calculation examples. However, with the development of new transport, it is found the original method of probability theory to some extent already does not apply to the current rapid development of the traffic situation. And the new theories which have become more sophisticated, such as Queuing Theory and fluid Mechanics Theory, are more applicable to the present traffic conditions. After Adams used the queuing theory on the pedestrian delays without the traffic lights in 1936[1], queuing theory are more widely used in traffic engineering.

The queuing process can be simulated by Queuing theory. It reflects the concept of personalized service by improving the key and details during queuing process, and relieves the customer impatience and leave people a relatively free space during queuing process. It truly reflects a "people-oriented" service concept.

In this paper, vehicles operating characteristics of a signalized intersection is analyzed based on the theory of queuing system using RBF neural network. The delay model and forecasting model are established, and the soft MATLAB is used to calculate the delay time when the vehicle is in the signalized intersection.

2 Analysis of Vehicles Delay at Signalized Intersection

2.1 Analysis of Intersection Traffic Flow

Road network is complex. One rode network is consisted of some signalized intersections and signalized intersection of roads. Suppose road network on the constitution as shown in Fig. 1:

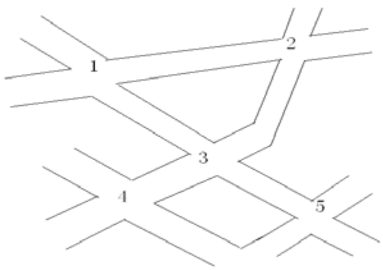

Fig.1 Intersection model

We suppose most cities and the main road intersection set is the intersection of the three phase signal control, traffic has passed for the left turn left turn phase; but the main road intersections and sub-roads intersection signal control is still two-phase Lord, turn left through the two-phase intersection traffic delays are quite serious. Traffic intersection turn left when leaving the vehicle caused by the non-follow delay is to study the intersection delay model of the part cannot be ignored, as shown in Fig.2.

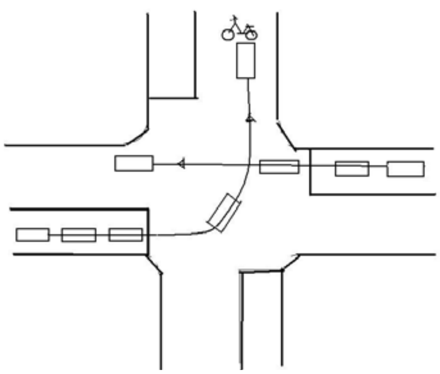

Fig.2 Schematic diagram of the intersection turn left to traffic delays

When the lights turned green, the original waiting in traffic behind the stop line began to move forward, the vehicle crossed the stop line to stream, its flow rate from zero to saturation flow quickly. Since then, the follow-up traffic flow across the stop line will remain with the saturation flow rate equal to, until the stop line of vehicles behind the accumulation of all clearance is completed, or has not yet finished but the green time of release has been closed. Seconds in the first green light turned on, flow rate is changing rapidly from the original stationary vehicle began to accelerate, the speed gradually from zero to normal driving speed. During this period, the number of vehicle through the intersection (stop line) of the traffic volume is less than that in the saturation flow rate. Just in the red light into green light, the vehicle does not immediately cross the stop line, but a few seconds of the stagnation, start the vehicle from the start to the speed needed to achieve the desired period of time, during this time, the front apparent than when the distance between the vehicles lined up behind the big headway, so the time has not been fully utilized, there is loss of running time, that is the loss starting time. Similarly, the green light yellow light after the end of time or the green light flashes, the part of the vehicle due to braking measures have been taken to halt, and the other part of the vehicle has not yet stopped, but has started to slow and the flow through the intersection then to maintain the original level of saturation flow gradually down. So, vehicles do not make full use of time, with the loss of running time.

The phase of the process through their vehicle along the lines mentioned, but the circumstances have to be analyzed, different phase of the Drive or the intersection number of the process is different.

2.2 Vehicles to reach the signal characteristics of the mouth

In the existing references, usually in traffic Daoshi section is assumed to be Poisson distributed. The density function is:

$$P_k(t)=\frac{(\lambda t)^k}{k!}e^{-\lambda t}, k=0,1,2\cdots,\lambda>0 \qquad (1)$$

Within period of time assume that the number of customers reaching sections $[0,t]$ is $N(t)$, for fixed t, $N(t)$ is a random variable. When t is changed, $N(t)$ began to change and form a random data stream, that is, Poisson. The Poisson distribution as a vehicle for Poisson arrival with the following three advantages:

(1) Stationary: $\{N(t),t\geq 0\}$ has a smooth increment, and for any $t\geq 0$ and $s\geq 0$, the number of vehicles appear in $(t_0,t+t_0]$ has nothing to do with the interval length Δt, has nothing to do with the first test time t_0.

(2) Independent increments: $\{N(t),t\geq 0\}$ independent increments, that is taken for any one time n: $0<t_1<t_2<\cdots<t_n$, $N(t_1)-N(0), N(t_2)-N(t_1),\cdots, N(t_n)-N(t_{n-1})$ are independent random variables, meaning that in

every time period, the number of vehicles arriving are independent of each other.

(3) Sparsity: when Δt is small enough, there is

$$P\{N(\Delta t)=1\}=\lambda\Delta t+o(\Delta t), \quad (2)$$

$$P\{N(\Delta t)\geq 2\}=o(\Delta t) \quad (3)$$

That is sufficiently small time interval to achieve more than two or two very small probability of a vehicle.

Vehicles that meet the above sections can be regarded as Poisson distribution, and when the vehicles reach the intersection by intersection stop line to reach a certain phase distribution should be Poisson distribution.

Stop delay can be divided into the following three cases [4].

Case 1: When the vehicle before arriving at the stop line at red lights has become, the vehicles arrived at the stop line to wait;

Case 2: When faced with green light and the vehicle in front has started, the vehicle moved on;

Case 3: When the green light but there are some vehicles experience does not start, still had to wait;

Combination of three conditions can delay the time of parking the vehicle as is the $M/M^k/1/\infty$ system stay.

Average team leader:

$$\bar{N}=\frac{r-1}{2}+\frac{1}{s_0-1} \quad (4)$$

Average waiting queue length:

$$\bar{N}'=\bar{N}-rp$$
$$=\frac{r-1}{2}+\frac{1}{s_0-1}-rp \quad (5)$$

Desk busy probability (this is the service desk intensity):

$$\sum_{n=r}^{\infty}P_n=\rho \quad (6)$$

Average length of stay:

$$\bar{T}=\frac{r-1}{2\lambda}+\frac{1}{ru(s_0-1)}+\frac{1}{u} \quad (7)$$

3 The Short-Term Traffic Flow Prediction

3.1 Based on Time Series

Intersection of external vehicles to arrive on the forecast of operating characteristics of the vehicle plays an important role in prediction, so the establishment of an appropriate prediction model to forecast is an important part. Intersection of a section now known in 18 cycles (60 seconds per cycle) and external traffic flow data, such as shown in Table 1:

Table 1 Intersection external traffic flow data table

Cycle	External traffic flow (Cars)	Cycle	External traffic flow (Cars)	Cycle	External traffic flow (Cars)
1	28	9	23	17	27
2	36	10	37	18	39
3	35	11	34	19	40
4	25	12	29	20	23
5	28	13	26	21	29
6	33	14	32	22	36
7	37	15	35	23	34
8	30	16	32	24	30

There are trend analysis and seasonality analysis for the number of vehicles reached signalized intersection during 18 cycles. If the long term trend, a time series, it was a long-term trend, you can use the trend of the sequence to be legitimate, if less Trend describes the parameters of time series prediction is the trend of change over time, can be transformed into a " smooth "time-series [8].

The data in Table 1 are on a simple time series graph drawing, shown in Fig. 3:

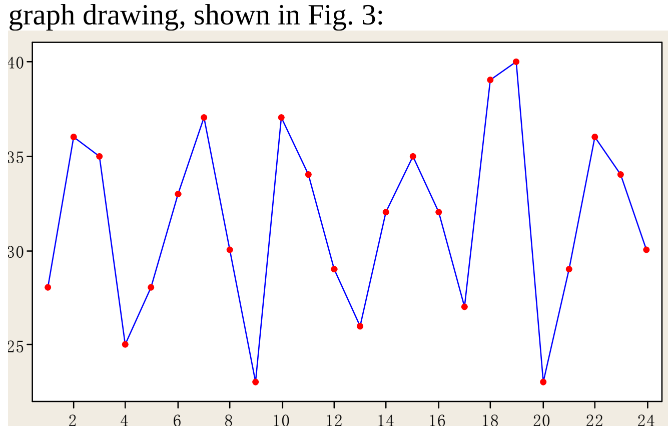

Fig.3 the external traffic flow at signalized intersection timing diagram

Observed no significant growth trend found in Figure 1, and then to the seasonal analysis of the sequence. Again observe the timing diagram, found that the sequence may exist, "seasonal" features actual quotes here because of the seasonal timing is not presented in the real season, but a cyclical change. Seasonal changes in sub-up of two types: regular seasonal changes and seasonal variations changes.
For the regular seasonal changes, the best model to describe the use of additive decomposition. Additive model [9]:

$$Y_t = Trend + Seasonal + Error \quad (8)$$

For the variable seasonal variations, should be used to describe the multiplicative decomposition model. Multiplicative model [9]:

$$Y_t = Trend \times Seasonal \times Error \quad (9)$$

Additive model used here to predict the timing, forecasting the next 18 cycles of external traffic flow, the results shown in Table 2, prediction map shown in Fig.4.

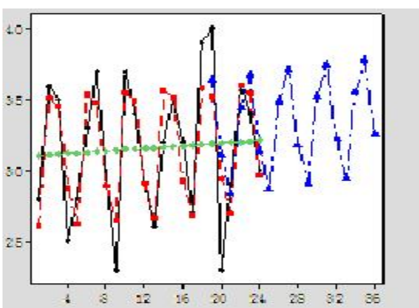

Fig.4 Intersection of external traffic flow forecast chart (additive model)

Table 2 Prediction Results Table additive

Cycle	Forecast(Cars)	Cycle	Forecast(Cars)
25	36	34	32
26	31	35	29
27	28	36	35
28	34	37	37
29	37	38	32
30	31	39	29
31	29	40	36
32	35	41	38
33	37	42	33

3.2 Cubic Spline Prediction

Cubic spline interpolation [7] (referred to as Spline interpolation) through a series of data points form a smooth curve, mathematical equations by solving the three moments obtained curve function group process. Spline function is to satisfy the engineering practice for the type value line request of smoothness, it is not only simple but also has a continuous second derivative, which for the study of nature offers a good theoretical basis. In general, spline interpolation required data distribution is relatively uniform, so that the interpolation result is the ideal and the actual intersection in the signal measured in the data are measured over adjacent cycles to meet this requirement. Spline interpolation function is applicable not only, but also for extrapolation, interpolation can automatically extend the range of a future trend of short-term forecast. Predicted results as shown in Table 3:

Table 3 cubic spline prediction table

Cycle	Forecast (Cars)	Cycle	Forecast (Cars)	Cycle	Forecast (Cars)
25	33	31	35	37	28
26	37	32	24	38	34
27	30	33	30	39	34
28	25	34	37	40	28
29	31	35	31	41	32
30	36	36	27	42	43

3.3 GM (1,1) prediction

Grey forecasting system through the identification of factors that the similarity between the trends, namely, correlation analysis, and generated by processing the raw data to find changes in the law system, the formation of regular use of strong data, the establishment of differential equations model for the future of things to predict trends and conditions [8].

Grey prediction theory for incomplete information or incomplete application of the actual situation with a good [9], which model has the full use of "little data" to predict the benefits. Table 1 shows the data only 24, are "little data" scope. This article is signalized intersections using models to predict traffic flow outside.

The basic steps of Model are:
Step 1: to make a cumulative sequence of data

$$x^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots x^{(0)}(M)\} \quad (10)$$

Generated by:

$$x^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots x^{(1)}(M)\} \quad (11)$$

Where: $x^{(1)}(i) = \sum_{k=1}^{i} x^{(0)}(k)$ 。

Step 2:Construct matrix B and constant accumulation vector YN that is

$$B=\begin{pmatrix} -\frac{1}{2}(x^{(1)}(1)+x^{(2)}(2)) & 1 \\ -\frac{1}{2}(x^{(1)}(2)+x^{(2)}(3)) & 1 \\ \cdots\cdots\cdots\cdots\cdots\cdots & \\ -\frac{1}{2}(x^{(1)}(M-1)+x^{(2)}(M)) & 1 \end{pmatrix} \quad (12)$$

$$Y_M = [x_1^{(0)}(2), x_1^{(0)}(3), \cdots, x_1^{(0)}(M)]^T \quad (13)$$

Step 3: The parameters of a least squares solutions of gray $\hat{a}$

$$\hat{a}=\begin{bmatrix} a \\ u \end{bmatrix} = (B^T B)^{-1} B^T Y_M \quad (14)$$

Step 4：The gray parameters into the function of time:

$$\hat{x}^{(1)}(t+1)=(x^{(0)}(1)-\frac{u}{a})e^{-at}+\frac{u}{a} \quad (15)$$

Step 5: The reduction of the derivative of the $\hat{x}^{(1)}$:

$$\hat{x}^{(0)}(t+1)=-a(x^{(0)}(1)-\frac{u}{a})e^{-at} \quad (16)$$

Step 6: Calculate the difference $\varepsilon^{(0)}(t)$ between $x^{(0)}(t)$ and $\hat{x}^{(0)}(t)$, and a relative error $e(t)$:

$$\varepsilon^{(1)}(t)=x^{(0)}(t)-\hat{x}^{(0)}(t) \quad (17)$$

$$e(t)=\varepsilon^{(0)}(t)/x^{(0)}(t) \quad (18)$$

Step 7: The model predicted.
Predicted results as shown in Table 4:

Table 4 GM (1,1) Forecast Results Table

Cycle	Forecast (Cars)	Cycle	Forecast (Cars)	Cycle	Forecast (Cars)
25	30	31	32	37	34
26	30	32	32	38	33
27	31	33	33	39	34
28	31	34	33	40	35
29	31	35	34	41	35
30	32	36	34	42	34

3.4 RBF artificial neural network forecasting method

Short-term traffic prediction algorithm more. Macro-model is mainly dynamic traffic assignment model, the onlookers model a variety of econometric models (regression, autoregressive, moving average, filter, etc.), non-parameter theoretical model, neural network model, in addition to wavelet method and other methods of control theory combined model. Here the use of RBF artificial neural network.

RBF network has the ability to identify complex nonlinear systems, more suitable for short-term traffic forecasts. Predicted results as shown in Table 5 with Fig. 5:

Table 5 RBF prediction table

Cycle	Forecast (Cars)	Cycle	Forecast (Cars)	Cycle	Forecast (Cars)
25	27	31	36	37	33
26	35	32	30	38	32
27	38	33	22	39	36
28	27	34	38	40	31
29	28	35	33	41	24
30	32	36	29	42	41

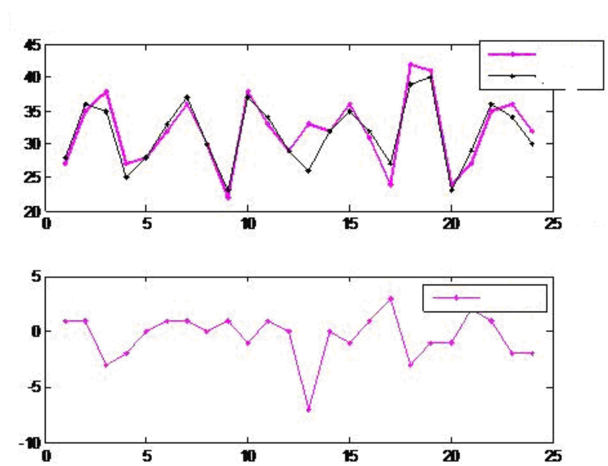

Fig. 5 RBF prediction error map

4. Signalized Intersection Operational Characteristics of Vehicles Forecast

4.1 Transport network on the constitution

Constitute a more complex road network, refer to Fig.1 and Fig.2. This article will use the *Jackson* network to simulate a relatively simple traffic network.

Theorem 1 (*Jackson* Theorem [10]): Let queuing network is composed of n nodes, node i get the total average number of Λ_i (λ_i and from outside to reach the number of other nodes to reach all nodes i and arrival rate), and meet the following conditions:

(1) does not backspace node is $M/M/m$ queuing system components, node i there are m_i desks, working independently of each desk, the average working time is $\frac{1}{U_i}$;

(2) customers from outside the network to reach the first i nodes of flow parameters of the Poisson flow λ_i;

(3) End node i in customer service to reach node j with probability P_{ij} or $1-\sum_{j\neq i}^{n} p_{ij}$ from the network system;

So:

(1) Λ_i satisfy the equations

$$\Lambda_i = \lambda_i + \sum_{j\neq i}^{n} p_{ji}\Lambda_j, (j=1,2,\cdots,n)$$

(2) Node i is the $M/M/m_i$ system, the number reached by Λ_i calculation.

Concern is that visually illustrates the theorem: n nodes in the Markov network, as

(1) Arrive from outside the network node is a Poisson stream of customers;

(2) $M/M/m$ system, the input stream is a Poisson stream, the output stream is also Poisson, Poisson sub-stream is also Poisson, then each node of the stream flows are Poisson;

(3) Poisson is the convergence of Poisson;

(Note: This result has been specific in describing the second part), therefore, merging into the i nodes of the river should be Poisson.

i signalized intersection to a desk as to reach the signalized intersection i of all vehicles as a customer arrives, the knowledge is known by the second chapter: the signal to reach the intersection stop line of vehicles, each Poisson distribution, the direction of a signalized intersection with four stop line, but also the convergence of Poisson remains to get the vehicles at signalized intersection i is Poisson distributed. Although the signal lights control intersections i different phase on the light is green, that is when the signal intersection uninterrupted customer (vehicle) services. The vehicle's service desk can be seen as a negative exponential distribution with independent, thus signalized intersection A can be seen as a $M/M/1$ system.

4.2 The method of calculating vehicle operating characteristics

Located only a desk, help desk services, according to a first line rules, the customer arrival stream is Poisson parameter for the λ stream, the service time U obey a negative exponential distribution parameters, claimed that the system $M/M/1$ queuing system, and customer acceptance of services in the system

Average waiting time

$$\bar{W} = \frac{\rho}{u(1-\rho)} \tag{19}$$

The average length of stay

$$\bar{T} = \frac{\rho}{\mu(1-\rho)} + \frac{1}{\mu} \tag{20}$$

Average length of the ranks

$$\bar{N}_1 = \frac{\rho}{1-\rho} \tag{21}$$

And $\rho = \frac{\lambda}{U}$ is the service's intensity

4.3 The forecast of $\bar{N}, \bar{W}, \bar{T}$

Under the observation, the average service rate of the signal intersection is $\mu = 43$, that is, the intersection per cycle (a period of 60 seconds per week) that can pass through 43 cars.

In accordance with the time series obtained outside the next 18 cycles the number of vehicles predicted to reach the average captain intersection $\bar{N}$, the average waiting time $\bar{W}$, the average length of stay $\bar{T}$. The results are as follows Table 6, Table 7, Table 8 and Table 9:

Table 6 Forecast Results table of $\bar{N},\bar{W},\bar{T}$ (time series analysis)

Cycle	$\bar{N}$ (Cars)	$\bar{W}$ (Second)	$\bar{T}$ (Second)
25	5	3.588	4.287
26	3	1.803	2.499
27	2	1.302	2.001
28	4	2.637	3.333
29	6	4.302	5.001
30	3	1.803	2.499
31	2	1.446	2.142
32	4	3.051	3.75
33	6	4.302	5.001
34	3	2.031	2.727
35	2	1.446	2.142
36	4	3.051	3.75
37	6	4.302	5.001
38	3	2.031	2.727
39	2	1.446	2.142
40	5	3.588	4.287
41	8	5.301	6
42	3	2.301	3

Table 7 Forecast Results table of $\bar{N},\bar{W},\bar{T}$ (cubic spline forecast)

Cycle	$\bar{N}$ (Cars)	$\bar{W}$ (Second)	$\bar{T}$ (Second)
25	3	2.301	3
26	6	4.302	5.001
27	2	1.611	2.307
28	1	0.969	1.668
29	3	1.803	2.499
30	5	3.588	4.287
31	4	3.051	3.75
32	1	0.882	1.578
33	2	1.611	2.307
34	6	4.302	5.001
35	3	1.803	2.499
36	2	1.176	1.875
37	2	1.302	2.001
38	4	2.637	3.333
39	4	2.637	3.333
40	2	1.302	2.001
41	3	2.031	2.727
42	4	29.301	3

Table 8 Forecast Results table of $\bar{N},\bar{W},\bar{T}$ (forecast of $GM(1,1)$)

Cycle	$\bar{N}$ (Cars)	$\bar{W}$ (Second)	$\bar{T}$ (Second)
25	2	1.61	2.3077
26	2	1.61	2.3077
27	3	1.8023	2.5
28	3	1.8023	2.5
29	3	1.8023	2.5
30	3	2.0296	2.7273
31	3	2.0296	2.7273
32	3	2.0296	2.7273
33	3	2.3023	3
34	3	2.3023	3
35	4	2.6357	3.3333
36	4	2.6357	3.3333
37	4	2.6357	3.3333
38	3	2.3023	3
39	4	2.6357	3.3333
40	4	3.0523	3.75
41	4	3.0523	3.75
42	4	2.6357	3.3333

Table 9 Forecast Results table of $\bar{N},\bar{W},\bar{T}$ (*RBF* artificial neural network)

Cycle	$\bar{N}$ (Cars)	$\bar{W}$ (Second)	$\bar{T}$ (Second)
25	2	1.1773	1.875
26	4	3.0523	3.75
27	8	5.3023	6
28	2	1.1773	1.875
29	2	1.3023	2
30	3	2.0296	2.7273
31	5	3.588	4.2857
32	2	1.61	2.3077
33	1	0.7309	1.4286
34	8	5.3023	6
35	3	2.3023	3

36	2	1.4452	2.1429
37	3	2.3023	3
38	3	2.0296	2.7273
39	5	3.588	4.2857
40	3	1.8023	2.5
41	1	0.8813	1.5789
42	2	4.3023	5

Other operating characteristics of vehicles at signalized intersection can be obtained under this method.

5 Signal Timing Optimization

5.1 Signal phase of the traffic capacity and the saturation

Signal phase and the saturation capacity is calculated as follows:

$$C = S\cdot(g/c) \tag{22}$$

Where C is the phase capacity (vel/h); g/c is the phase can be the effective split, that with ς , that is $\varsigma = g/c$;

In order to facilitate capacity price and the actual traffic volume, the definition of a phase that actually reached the flow of traffic volume q and the ratio of S phase saturated flow is called flow ratio y the capacity q and C as the ratio of the saturation phase degree of x , that is:

$$x = q/c = qc/S_g = y/\varsigma \tag{23}$$

Usually flow ratio y as a constant, which reflects the actual demand for access to splits ς as controllable parameters, which represents the available capacity. Saturation x $x<1$ reflects the intersection of these two "supply" relationship Parameters. In order to provide sufficient capacity, must meet the following formula: $C>q$ or $x<1$. That is:

$$S_g > qc \tag{24}$$

$$\varsigma > y \tag{25}$$

Obviously increase the effective split as long as you can increase the capacity of the phase, or reduce its saturation. Although this approach can make the phase capacity increase, this will make the conflict phase of its capacity decrease. It is necessary to each phase of the cross 13 as a whole to consider the intersection of the total capacity and saturation.

5.2 Intersection with the saturation of the total capacity

Intersection capacity is an intersection for each direction (or phase) all the traffic can provide the maximum allowable throughput. If an intersection has sufficient capacity, then for each phase can be an inequality (25). All key intersections will be a consolidation phase in the inequality, we can get the entire intersection should be the total capacity to meet the relation:

$$\sum_{i=1}^{n}\varsigma_i > \sum_{i=1}^{n} y_i \tag{26}$$

where $i = 1, 2, \cdots, n$, that is the first key phase $1, 2, \cdots, n$.

In equation (26), the inequality on the left that is equal to the total intersection of the effective split, with $\varsigma_{\text{总}}$ the total that its specific meaning is all the "critical phase" the sum of the effective green time and the ratio of Signal Time:

$$\varsigma_{\text{总}} = \sum_{i=1}^{n}\varsigma_i \tag{27}$$

Type (27) inequality on the right for the entire intersection overall flow ratio, with Y , is all the "critical phase" flow ratio of the sum:

$$Y = \sum_{i=1}^{n} y_i \tag{28}$$

The evolution of the equation can be obtained from the following forms:

$$\varsigma_{\text{总}} = (c-L)/c \tag{29}$$

where $c - L = \sum g$, that is, the total sum of all effective green time of key phases $A-F$.

Intersection of the total level of saturation is the saturation phase reached the maximum saturation value, rather than the sum of the phase saturation. Practical limits of saturation are between 0.8 and 0.9. There are better operating conditions in intersection. Under certain specific conditions, such as the heavy traffic condition, while the intersection of the surrounding environment terms and conditions are poor, to reduce the intersection of infrastructure investment, we can use a higher limit such as 0.95

Intersection level of service reflects the generally delayed. Signalized intersection level of service manual determine, according to capacity for the $A-F$ class.

5.3 Importing Road saturation flow calculation

Import Road saturation flow is calculated:

$$s(r,f,\delta_n,G,\omega_1)=\frac{2080-140\delta_n G+100(\omega_1-3.25)}{1+\frac{1.5f}{r}} \quad (30)$$

The formula: r is the turning vehicle turning radius; f is the proportion of turning vehicles; δ_n that Drive the location, aside drive to take 1 and Non-aside Drive take 0; G as the slope, taken 1 when it is uphill, taken 0 when it is downhill; ω_1 as lane width, taken $\omega_1 = 3.0m$.

5.4 Signals the loss of time

In a signal cycle, the direction of vehicles cannot be any time, is the signal loss of time, including the loss of the green interval and start time. Starting time loss which, according to the UK to examine for the 1.35s.

5.5 The best cycle length

In heavy urban traffic intersection, we generally set the lights to regulate traffic. Signal intersection capacity and signal control design are closely linked. Select optimal solution to maximize the capacity of intersection to reduce delays, to solve the bottleneck problems. Signalized intersection is the best cycle times for each light interval between the best. Calculated as follows [11]:

$$C_0 = \frac{(1.4+k)L+6}{Y-1} \quad (31)$$

Where: L is the total lost time per cycle(s); Y is the maximum sum of phase flow ratio; K is the parking compensation parameters, according to different optimized requirements, required the most hours of fuel, taken $K = 0.4$; when it is the minimum consumption, taken $K = 0.2$, when it is the minimum delay, taken $K = 0$. The results in Table 10:

Table 10 Signal with the optimal cycle length (Unit: seconds)

Minimum fuel consumption	Minimum consumption	Minimum delay
75.343	70.252	65.315

6 Conclusion

This paper studies the intersection of signal reaches the vehicle through the intersection and running characteristics, based on the use of this theory were established by queuing vehicles at signalized intersection delay models and prediction models, and the cycle of the signal optimization analysis.

The innovation of paper is that in delays of parking, the use of model to describe the way of the vehicles reaching and releasing. (Most of the previous model to model, which is based on the idea of Intersection Channelization above, this is not realistic, because no drainage of signalized intersection); then forecast of signal to reach this population of vehicles of different multiple operating characteristic index cycle is given, while in some of the existing literature, basically a single cycle of a single indicator is forecasted. And integrated transport network of this paper to consider, within the road network for the same time, all I can give the signal characteristic value. Finally, on the road capacity and saturation analysis, combined with ARRB Amendment Act [11], obtained under the different requirements of the best signal cycle timing to achieve the optimization of intersections.

Queuing theory has a more mature theory, this is only a model with a more basic vehicle operation at signalized intersections were analyzed follow-up study in depth can continue to use more complex queuing system, perfected the whole analysis process . In addition, this is only the lights of the cycle are optimized, in real life, Affect the operation of an efficient traffic network there are many factors, such as road width, number of lanes, etc., which are worth to explore

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