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Analysis and Simulation of Signalized Intersection Delay Model

Lian Xue[1, a*]

[1]School of Computer and Computing Science，Zhejiang University City College Hangzhou, 310015, P.R. China

[a]xuel@zucc.edu.cn

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Abstract. Signalized intersection delay is an important evaluation index of the signalized intersection capacity and level of service. This paper presents a signalized intersection delay model for signalized intersection. The model uses time series and queuing theory. It discusses the operation characteristics of the process of arrival and leaving and optimizes the intersection signal timing and gets the best signal cycle time. A scientific model and a more complete analysis are founded in the paper. These methods have a good reference value to the relevant departments.

Introduction

With the development of China's economic and raise 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 receives a double concern by service and customers.

Traffic flow theory [1] began in the 30's; literature [2] and [3] provided a Poisson 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[4] and fluid Mechanics Theory[5], are more applicable to the present traffic conditions[6][7]. After Adams used the queuing theory on the pedestrian delays without the traffic lights in 1936, queuing theory are more widely used in traffic engineering.

Queuing theory can simulate the queuing process. It can reflect the concept of personalized service by improving the key and details during queuing process, relieve 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. It uses MINITAB and MATLAB7.0 to calculate the delay time when the vehicle is in the signalized intersection and other vehicles running Eigen value.

The Short-term Traffic Flow Prediction of Basing 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:

The signalized intersection of 18 cycles to reach the number of vehicles outside for trend analysis and seasonality analysis. 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].

Table 1 Intersection external traffic flow data table

Cycle	External traffic flow (Cars)	Cycle	External traffic flow (Cars)	Cycle	External traffic flow (Cars)
1	25	9	21	17	25
2	33	10	35	18	39
3	36	11	36	19	42
4	20	12	29	20	23
5	23	13	20	21	28
6	30	14	32	22	36
7	35	15	33	23	33
8	22	16	32	24	31

Observing the timing diagram, it is founded 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]:

$$Y_t = Trend + Seasonal + Error \tag{1}$$

For the variable seasonal variations, should be used to describe the multiplicative decomposition model. Multiplicative model [10]:

$$Y_t = Trend \times Seasonal \times Error \tag{2}$$

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

Table 2 Prediction Results Table additive

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

Traffic Signal Model

Forecast the arrival rate of vehicles in the traffic signal intersection and queue length and the corresponding delays is very important for the implementation of traffic signal control and management. In this paper, stochastic service system theory is used to forecast the vehicle's arrival rate in the signalized intersection, queue length and delay time.

See the signalized intersection i as a service, the arrival of all vehicles at signalized intersection i as the arrival of customers (Vehicles which reach the stop line of each signalized intersection are subject to Poisson distribution, there are four directions of the stop line in a signalized intersection, and Poisson stream confluence is still Poisson stream. So vehicles which reach the stop line of signalized intersection i are subject to Poisson distribution). There are signals to control in Signalized intersection i, different phase followed by the flow of traffic through intersections, vehicles which reach the stop line of signalized intersection i are subject to Poisson distribution. But from a complete cycle, there will always be a green light in a certain phase at any time, that is to say the intersection is a continuous service for the customer (vehicle). The time of service from the help deist for the vehicles can be seen as a negative exponential distribution with independent, thus signalized intersection i can be seen as a $M/M/1$ system.

So the system mentioned above is called $M/M/1$ queuing system and in this system, customers receive services.

Average waiting time

$$\bar{W} = \frac{\rho}{u(1-\rho)} \tag{3}$$

The average length of stay

$$\bar{T} = \frac{\rho}{\mu(1-\rho)} + \frac{1}{\mu} \tag{4}$$

Average length of the ranks

$$\bar{N}_1 = \frac{\rho}{1-\rho} \tag{5}$$

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

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 3:

Table 3 Forecast Results table of $\bar{N}, \bar{W}, \bar{T}$ (time series analysis)

Cycle	$\bar{N}$ **(Cars)**	$\bar{W}$ **(Second)**	$\bar{T}$ **(Second)**	**Cycle**	$\bar{N}$ **(Cars)**	$\bar{W}$ **(Second)**	$\bar{T}$ **(Second)**
25	5	3.488	4.287	34	3	2.031	2.727
26	3	1.703	2.29	35	2	1.42	2.13
27	2	1.301	2.01	36	4	3.051	3.6
28	4	2.657	3.32	37	6	4.22	5.01
29	6	4.302	5.11	38	3	2.11	2.71
30	3	1.81	2.39	39	2	1.446	2.13
31	2	1.43	2.02	40	5	3.48	4.27
32	4	3.00	3.5	41	8	5.301	5
33	6	4.302	5.11	42	3	2.21	3

Signal Timing Optimization

The intersection of heavy urban transportation, generally setting the lights to regulate traffic. Capacities of a signalized intersection design and signal control are closely linked. Select optimal solution to maximize the traffic capacity of intersections, reduce delays, to solve bottleneck problems. Signalized intersection is the best cycle times for each light interval between the best. Is calculated as follows :

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

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 $K = 0$.

Conclusions

This paper studies the arrival of vehicles through the intersection operation and the characteristics of them in signalized Intersections. Then on the basis of that, make use of time series and queuing theory to establish delay model and forecast of vehicles in signalized Intersections. This research gives a solid theoretical foundation of enhancing the efficiency of road, reducing vehicle delay, and be adapt to the rapid development of transport, etc, and also provide an effective method to enhance the capacity of public services.

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