Research on Traffic Flow Control Based on Time Series and Green Time Allocation Model

Yanyi Wang

Internet College, Jiaxing Vocational Technical College, Jiaxing, China

371357278@qq.com

Abstract. Aiming at the problem of road traffic congestion, this paper makes an in-depth study of traffic flow by using time series model, time allocation model and queuing theory model. In this study, two main roads, Jingzhong Road and Weizhong Road, in a well-known scenic town were selected, and the differences of traffic flow in each time period were analyzed by extracting vehicle information from April 1 to May 6, 2024. On this basis, a time series model is established to estimate the traffic flow in different time periods, and the time allocation model is used to optimize the signal light configuration and improve the average speed of traffic flow. In addition, the relationship between the number of cruising vehicles and the required parking space is analyzed by using the queuing theory model, and the strategies to alleviate vehicle congestion and parking problems are put forward. The research results show that traffic congestion can be effectively alleviated through reasonable allocation of signal time and increase of temporary parking Spaces.

Keywords: Time series model, Time allocation model, Queueing theory model.

1. Introduction

With the expansion of cities and the rapid popularization of motor vehicles, road traffic congestion is a growing problem, especially in areas with well-known scenic spots. This study aims to solve this pain point through mathematical models and improve the efficiency of road traffic. We choose two main roads in a well-known scenic town as the research objects, and use the time series model [1], the time allocation model [2] and the queuing theory model [3] to conduct an in-depth discussion on road traffic control under different traffic flow conditions. By extracting and analyzing vehicle information, we expect to find an effective method to optimize the configuration of signal lights and alleviate parking problems [4]. These measures not only help to alleviate road traffic congestion and improve road traffic efficiency, but also provide useful references for urban traffic planning and management [5].

2. Pre-processing and Analysis of Traffic Flow Data

2.1. Establishment of Time Series Model

Now take the two main roads in a famous scenic spot town as reference, the situation of the two main roads in the town: Weizhong Road, from Huanxi Road to Huandong Road, about 3.5 kilometers; By Middle Road, from Huan North Road to Huan South Road, about 1.8 kilometers. There are 12 intersections on the two roads.

We divide the day into five periods: from 0 to 6; 6 to 10; 10 to 17; 17 to 20; 20 to 24. Based on the data in Annex II, model the time series for April 1 to April 30 and May 1 to May 6 respectively. Then, the vehicles in the intersection of Zhongjing Zhonglu and Weizhong Zhonglu are counted separately, and then the number of vehicles in the intersection of Zhongjing Zhonglu and Weizhong Zhonglu and the number of vehicles in the corner are counted according to the time period. Finally, the unreasonable time period data is eliminated, and then the data of each phase in different time periods are substituted into the model, and then the traffic flow of each phase in different time periods (including the four directions of going straight and turning) is estimated.

The vehicle information of the two main roads with monitoring equipment from April 1 to May and June 2024 is extracted, and the difference of vehicle flow in each time period is sorted out. Then,

the traffic lights at intersections are optimized to cope with urban congestion during different peak periods. Then the time series model [6] is established, and the relationship between the traffic flow of Jingzhong Road and Weizhong Road from April 1st to May 6th and each time period is established as a line chart, as shown in Fig. 1:

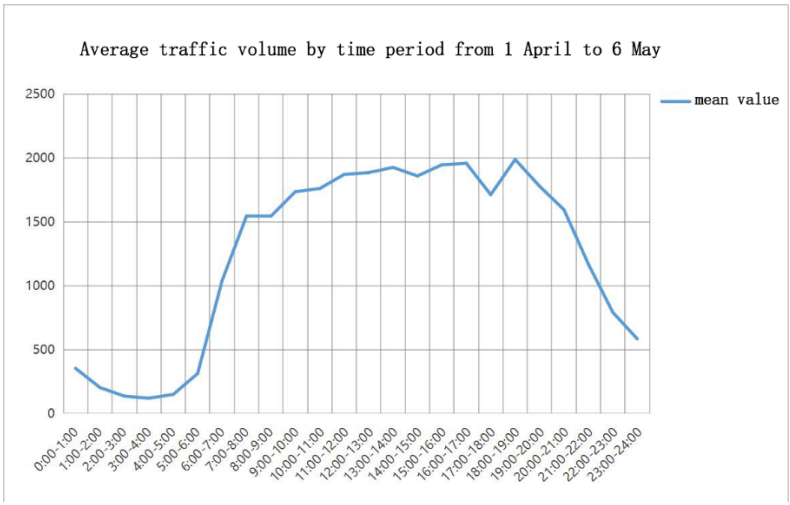


Figure 1. Average vehicle flow of Jingzhong Road and Weizhong Road in each time

According to the line chart, we can roughly understand the traffic flow of each time period of Jingzhong Road and Weizhong Road from April 1st to May 6th, and can also sum up the most intensive traffic flow from 8 to 20 o'clock. Therefore, we should conduct a more detailed analysis of the data in this time period.

2.2. Model Analysis and Solution

The data from 1 April to 30 April were analysed and plotted to estimate the traffic flow in each phase (including four directions of straight and turning) in different time periods, and we divided the traffic flow in different time periods into four parts, as shown in Table 1:

Table 1. Traffic flow

Direction 1	Direction 2	Direction 3	Direction 4
East to west	West to East	From south to north	From north to South

Comparing the traffic flow during Qingming Festival and normal time, there is no big change, so we put the traffic flow during Qingming Festival and the usual traffic flow together. In order to facilitate the statistics and observation of the changing trend of traffic flow and time from April 1 to April 30, exce1 was used for data integration, and then a time series model was established for solving. We divide the day into 5 time periods for statistics (0-6; 6-10; 10-17; 17-20; 20-24), and then re-count the traffic flow of the above different times according to the time period, and make a rectangular chart:

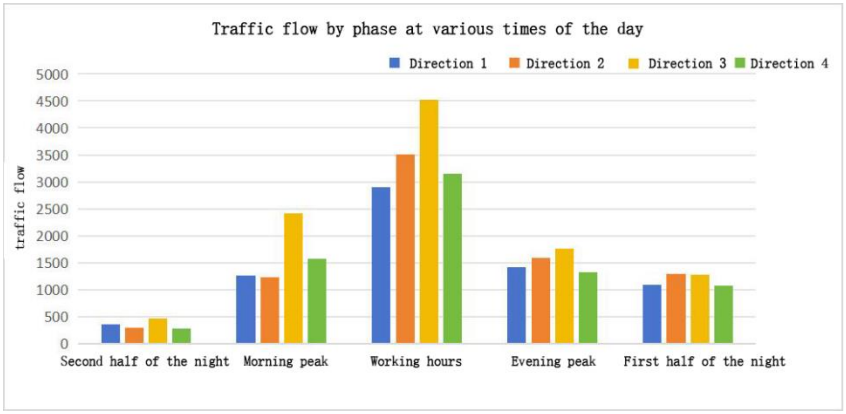


Figure 2. Traffic flow at different periods and phases in a day

As shown in Fig. 2, the figure reflects the obvious change of traffic flow in morning peak and evening peak. It can be observed that there is relatively more traffic flow in direction 3.

Using the same method above, we use exce1 to integrate the data of the changing trend of traffic flow and time from May 1 to May 6, and then establish a time series model for solving. Finally, the obtained results are presented in a rectangular graph:

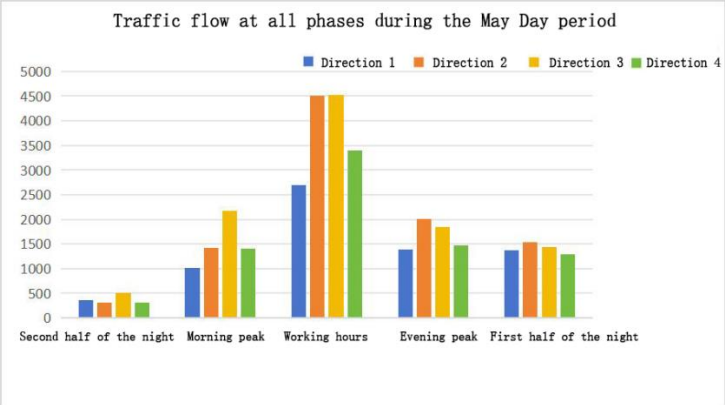


Figure 3. Traffic flow at different periods and phases during May Day

As shown in Fig. 3, through the data during the May Day period, we can see that the traffic flow in direction 2 increases significantly, which depends on the increase in the number of people in the scenic spot during the May Day holiday. By comparing the above two sets of data, we can see that the traffic flow from west to east during the May Day holiday increased significantly compared with the usual traffic flow. Due to the existence of this special period, we excluded the special traffic flow data during the May Day holiday in the calculation process to ensure the accuracy of the data.

Finally, the above results are integrated by clustering to obtain the clustering value for the traffic flow of each phase (including the four directions of straight and turning) at different times, as shown in Table 2:

Table 2. Traffic flow in all directions

Time	Direction 1	Direction 2	Direction 3	Direction 4
The second half of the night $(0-6)$	351	300	474	280
Morning rush $(6-10)$	1268	1231	2419	1570
Hours of work $(10-17)$	2901	3501	4517	3155
Evening rush hour $(17-20)$	1412	1585	1759	1321
First half of the night $(20-24)$	1098	1288	1276	1076

3. Study on Green Light Time Allocation Model

3.1. Green Light Time Allocation Model Establishment

The green time allocation model of traffic lights based on traffic flow data is established to analyze the green time of traffic lights [7], and then according to the green time of traffic lights will change with the change of total traffic flow data, the following formula is used to calculate the change of total traffic flow of each phase in this period:

$$\mathrm{F(i)}=\sum_{j=1}^{4} f_{i,j} \tag{1}$$

Where F is the total traffic flow on each phase, f is the traffic flow on each day on each phase, i is the phase and j is the period.

Since the phase, time period and total traffic flow are related to the change of green time, the following formula is used to find the green time of each phase:

$$T_{i,j} = \frac{f_{i,j}}{\sum_{k-1}^{4} f_{i,k}} * t \tag{2}$$

Where t is the traffic light time cycle, k is the time period, and T is the green time.

Since the non-integer data cannot be applied to the actual situation, use the following formula to round the green light time:

$$T_{i,j} = \text{round}\left(\frac{f_{i,j}}{\sum_{k-1}^{4} f_{i,k}} * t \right) \tag{3}$$

To ensure that the green time for each phase does not exceed the total cycle time minus 1, the following formula is used to adjust the green time to not exceed the cycle:

$$T_{i,j} = \min\left(\frac{f_{i,j}}{\sum_{k-1}^{4} f_{i,k}} * (t-1), t-1 \right) \tag{4}$$

3.2. Model Analysis and Solution

The green time allocation model for traffic flow data is a problem of finding the optimal solution of green time, which can be solved by annealing algorithm, genetic algorithm, etc. However, it is too complicated for the research problem, so we use linear programming to solve the problem. However, these algorithms are too complicated for the research problem, so we use linear programming to solve the problem. Compared with other algorithms, the linear programming solution is simpler and easier to understand, and it is also easier to get the final result, the following is the solution process of our model:

Substituting the data for each phase at each time into the formula for the total traffic flow yields the results shown in Table 3:

Table 3. Total vehicle flow value

Time	Second half of the night (0-6)	Morning rush (6-10)	Hours of work (10-17)	Evening peak (17-20)	The first half of the night (20-24)
Total traffic volume	1405	6488	14074	6077	4738

Through reviewing the information we know that the general time period of each traffic light is 90 s, we will assume that the period of each phase of the traffic light change is 90 s, and then the total traffic flow data, phases, and time periods are substituted into the formula to find the running time of the green light time of each phase, and then through python for coding and solving as well as optimisation to get the results in Table 4:

Table 4. Green light duration

Time period/Phase	Half way 1	Half way	Halfway 3	Halfway 4
The second half of the night $(0-6)$	10	9	15	10
Morning rush $(6-10)$	36	35	69	35
Hours of work $(10-17)$	32	40	50	31
Evening rush hour $(17-20)$	16	18	19	18
First half of the night $(20-24)$	12	15	15	12

When the green time of each phase and period is as described in the table above, the average speed of traffic flow on the two main roads is the largest, and the street light time is: the second half of the

night - (phase 1, phase 2, phase 3, phase 4) the green time is (10, 9, 15, 10); When the morning peak - (phase 1, phase 2, phase 3, phase 4) green time is (36, 35, 69, 35); When the working time - (phase 1, phase 2, phase 3, phase 4) green time is (32, 40, 50, 31); Evening peak - (phase 1, phase 2, phase 3, phase 4) green time is (16, 18, 19, 18); Current midnight - (phase 1, phase 2, phase 3, phase 4) green time is (12, 15, 15, 12).

4. Traffic Flow Control Measures and Effect Analysis

4.1. Establishment of Control Model

The queuing theory model is established to analyze and solve the number of cruise vehicles and the required parking Spaces. Then according to some parameters in the queuing theory model and the required data, we list the following formula [8]:

$$\mathrm{L}_q = \frac{\lambda^2}{\mu(\mu-\lambda)} \tag{5}$$

This formula is mainly used to solve the average queue length of vehicles at this intersection, where L_q is the average queue length, λ is to determine the arrival rate, μ is to determine the service rate;

$$W_q = \frac{L_q}{\lambda} \tag{6}$$

This formula mainly through the average queue length obtained above to determine the vehicle need to wait for the average time, where W_q the average time;

$$\mathrm{C} = \frac{\lambda^2}{\mu(\mu-\lambda)} + \frac{\lambda}{\mu} \tag{7}$$

This is the key formula of this model, which is used to find the number of parking Spaces required, where C is the number of parking Spaces.

In summary, the queuing theory model of this paper is as follows:

$$\begin{gathered} \mathrm{L}_q = \frac{\lambda^2}{\mu(\mu-\lambda)} \\ W_q = \frac{L_q}{\lambda} \\ \mathrm{C} = \frac{\lambda^2}{\mu(\mu-\lambda)} + \frac{\lambda}{\mu} \end{gathered} \tag{8}$$

4.2. Analysis of Control Measures

The queuing theory model is a statistical study on the arrival and service time of service objects, so as to obtain the statistical rules of waiting time, queue length, busy period and other quantitative indicators. In this model, we take the vehicles cruising in each time period as the middle of the parking space that needs to be temporarily borrowed, and determine the parking space that needs to be borrowed by calculating the number of vehicles cruising in each time period.

At first, we sorted out the data between May 1st and May 6th by screening the data in Annex II, and then solved it by programming software. We adopted:

$$\mathrm{C} = \frac{\lambda^2}{\mu(\mu-\lambda)} + \frac{\lambda}{\mu} \tag{9}$$

The utilization rate is 10.42 and the number of vehicles on parade is 125.

Where is the arrival rate of vehicles, that is, the maximum number of vehicles per hour in the parade. Later, we obtained the service rate of the general scenic spot by consulting information and other ways. When the service rate is less than the arrival rate, it means that the cruise car cannot find the parking space normally. Only when the service rate is equal to the arrival rate, so that all the vehicles in the parade can find parking Spaces instead of cruising. As we know from the above solution that the maximum number of vehicles in the parade is 125, the scenic spot needs to rent 125 parking Spaces to meet the needs of the 125 vehicles in the parade in each hour. And then almost every hour after the number of cruise vehicles will be less than 125, so in the end we can know that the need for a temporary parking space of 125.

In this model, to solve this problem, we have two solutions, one is to increase the service rate and the other is to reduce the arrival rate, but in this problem, Since the number of tourists who come to the scenic spot cannot be changed by itself, we can only solve the problem by increasing the service rate. In order to find a parking space for more than 125 cruise vehicles, the scenic spot needs to temporarily requester 125 parking Spaces to meet the demand.

5. Conclusion

By using time series model, time allocation model and queuing theory model, this paper studies the traffic flow deeply, and puts forward some effective strategies to optimize the allocation of signal lights and alleviate the parking problem. The research results show that traffic congestion can be effectively alleviated through reasonable allocation of signal light time and increase of temporary parking Spaces. These research results are of great significance for improving road traffic efficiency and urban traffic environment. In the future, we will continue to deepen research and explore more effective methods of traffic control.

References

[1] Chen J, Chen Y, Bao Q. Pricing and Replenishment Strategies for Vegetable Commodities Based on Time Series Models [J]. Academic Journal of Computing & Information Science, 2023, 6 (13).

[2] Bokal D, Steinbacher M. Phases of psychologically optimal learning experience: task-based time allocation model [J]. Central European Journal of Operations Research, 2019, 27 (3): 863-885.

[3] Mas, Lluis, Vilaplana, et al. A queuing theory model for fog computing [J]. The Journal of Supercomputing, 202, 78 (8): 1-18.

[4] Ayoub L, Cesar J SP, Noureddine L, et al. Study of Energy Dissipation and Satisfaction Rates in Mixed Traffic Flow with Lights: A Two-Lane Cellular Automaton Approach [J]. E3S Web of Conferences, 2,024,582.

[5] L. M N, Miguel L V. Scenario archetypes in urban transport planning: Insights from the implementation of LRT systems [J]. Transport Policy, 202, 118152-164.

[6] Yu J, Wang H, Chen M, et al. A novel method to select time-varying multivariate time series models for the surveillance of infectious diseases [J]. BMC infectious diseases, 2019, 24 (1): 832.

[7] Cherchye L, Rock D B, Vermeulen F. A simple identification strategy for Gary Becker's time allocation [J]. Economics Letters, 2015, 137187-190.

[8] Comparison of Queuing Performance Using Queuing Theory Model and Fuzzy Queuing Model at Check-in Counter in Airport [J]. Mathematics and Statistics, 2019, 7 (4).