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Urban Traffic Optimization and Parking Demand Analysis Utilizing Big Data

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Abstract:
With the popularization of motor vehicles, transportation convenience has brought significant improvements to people's lives and travel, but the ensuing urban road traffic congestion affects residents' daily lives. Therefore, this paper utilizes big data statistics provided by monitoring devices, including vehicle passage times, travel directions, intersections, etc. Using Excel, we identified data trends for analysis, established corresponding mathematical models, optimized constraint conditions, and employed Python software to obtain the total daily traffic volume. We also analyzed the frequency of vehicle license plate appearances and grasped the traffic volume at road intersections during different time periods and in different directions. Based on this, we optimized the traffic signal settings at intersections and estimated the number of parking spaces needed for the scenic areas during the May Day holiday. This series of measures effectively achieved the rational allocation of road resources, significantly improved residents' travel efficiency, and contributed to promoting the high-quality development of urban transportation construction.

Keywords: data analysis. big data. traffic volume. python software. mathematical model

INTRODUCTION

With the rapid economic growth in China, the improvement of people's living standards, and the acceleration of urbanization, the number of private cars has increased dramatically, leading to increasingly prominent urban traffic congestion problems that have become a significant bottleneck constraining urban development[1-2]. According to the data on highway mileage and the number of vehicles released by the National Bureau of Statistics of China, more than 60% of major cities across the country are facing severe traffic congestion issues. This not only affects residents' daily commutes but also exacerbates environmental pollution and reduces the efficiency of urban operation. According to the China Urban Transport Development Report, the traffic congestion index during peak hours in some major cities in China has exceeded 2.0, indicating that road capacity is nearing saturation.

As the number of motor vehicles increases sharply, the traffic flow on urban transportation networks grows accordingly, and traffic congestion becomes more severe. Therefore, many scholars have conducted in-depth research on urban traffic congestion issues. Mahmoud et al.[3] systematically analyzed the application prospects of big data technology in urban traffic management and highlighted the enormous potential of data-driven methods in alleviating traffic congestion. Alkinani et al.[4] focused on optimization strategies for traffic signal control and proposed effective strategies to improve road capacity by constructing mathematical models and conducting simulation experiments. Kashinath S A et al.[5] further delved into the role of Intelligent Transportation Systems (ITS) in alleviating urban traffic congestion and verified its actual effects through case studies. Meanwhile, Ma et al.[6] paid attention to the impact mechanism of urban parking management on traffic congestion and proposed an optimization plan for parking strategies based on supply-demand balance.

Although scholars both domestically and internationally have achieved numerous research results on urban traffic congestion issues[7-10], there is still a lack of systematic theoretical analysis and effective solutions specifically addressing traffic congestion problems in particular regions, such as small towns rich in tourism resources, especially the impact of tourist flow on the local transportation system. Therefore, this study aims to reveal the intrinsic relationship between tourist flow and traffic congestion by deeply analyzing vehicle monitoring information from various driving directions at a certain intersection, providing a scientific basis for formulating targeted optimization measures.

To achieve this goal, this study adopts a combined method of data analysis and mathematical modeling. Firstly, Python software is used to preprocess and statistically analyze the collected vehicle monitoring data to estimate traffic volume during various time periods and under different traffic signal phases. On this basis, an optimization model for traffic signal control is constructed, and specific improvement plans are proposed in combination with the actual situation of traffic management and control during holidays. By comparing and analyzing the traffic conditions before and after optimization, the effectiveness and feasibility of the proposed scheme are verified.

The significance of this study lies in effectively alleviating urban traffic congestion issues, improving road capacity and residents' travel efficiency by optimizing traffic signal control and formulating scientific traffic management and control measures during holidays. At the same time, this study also enriches the theoretical system of urban traffic management, provides strong decision support for practical traffic management, and has far-reaching practical and theoretical value for promoting the high-quality development of urban traffic construction.

RELATED WORK AND TECHNICAL BACKGROUND

The traffic flow is analyzed by the intersection monitoring equipment, and the following assumptions are made[11]:

(1) The hypothetical data obtained are true and reliable;

(2) Assuming that the data of the license plate number showing "no license plate" in the data is valid, the number of valid vehicles can be considered to be obscured or blurred due to the lack of license plate.

(3) Make the following symbolic assumptions, as shown in Table 1:

Table1. Symbols and Explanations Table

symbol	definition	unit	symbol	definition	unit
X_1	The intersection direction 1 traffic flow	vehicle	X_2	The intersection direction 2 traffic flow	vehicle
X_3	The intersection direction 3 traffic flow	vehicle	X_4	The intersection direction 4 traffic flow	vehicle
X	The total traffic flow in the four directions of the intersection of this intersection	vehicle	A_{ijk}	The number of left-turning cars in the direction of the $i-j$ intersection k	vehicle
B_{ijk}	The number of vehicles going straight in the direction of the $i-j$ intersection k	vehicle	C_{i-j}	The total traffic flow in the four directions of the $i-j$ intersection	vehicle
D	The width of the road	meter	S_{ij}	The distance between road i and road j	meter
v	The speed at which the vehicle travels	km/h	t	Time	hour
t_r	The length of time the red light is displayed in a traffic light cycle	hour	t_g	The signal light shows the duration of the green light in one cycle	hour

DATA COLLECTION AND PREPROCESSING

First of all, the raw data should be processed, mainly to sort out the traffic flow at the target intersection.

Due to the huge amount of data provided by the device, up to 8844996 pieces of data. In order to ensure the integrity of the data, the Python software is selected to analyze the data, and the total number of traffic flows of the four phases of the intersection is counted, and then the Excel table is used for visual display, as shown in Figure1.

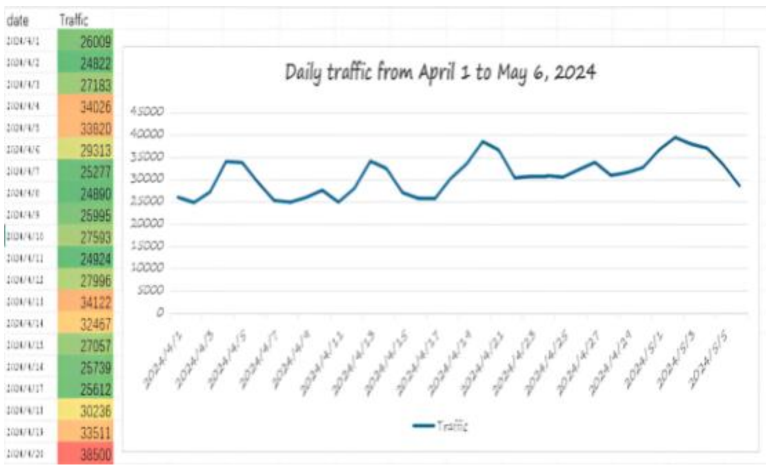


Figure 1. Daily traffic from April 1 to May 6, 2024

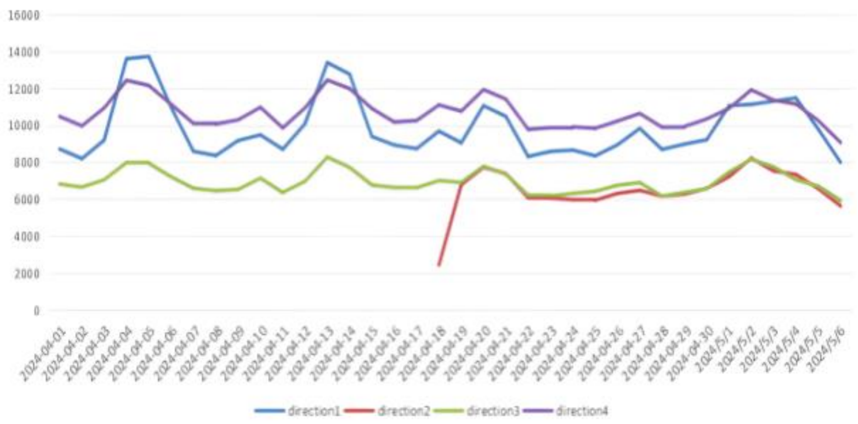


Figure 2. Traffic flow in four directions

Observing the trend of the line chart in Figure 1, it is found that the line shows obvious periodic changes, and the change of single-day traffic volume in the 36 days from April 1 to May 6, 2024 has increased, decreased, and then increased .... This also coincides with weekdays, weekends, and holidays. However, the traffic flow data after April 18 has a clear upward trend compared with before April 18, in order to discuss this change, we use python to count the daily traffic flow in the four directions of this intersection, and use Excel to draw a line chart of the traffic flow in the four directions, as shown in Figure 2.

Observing the trend of Figure 2, it is easy to find that the monitoring data of direction 2 of the target intersection from April 1 to April 17 is missing. It is guessed that the intersection is from west to east due to road construction and other reasons, and there is no record of monitoring. Re-analysis of the data on April 18 is also significantly lower than that of the later date, as can be seen from Figure 3, there was only a traffic flow record at 16:03 on April 18, guessing that the monitoring began to resume normal work at this moment.

V1	V2	V3
2	2024-04-18T16:03:13.000	AFA84A7K
2	2024-04-18T16:03:18.000	AE9M4X8
2	2024-04-18T16:03:21.000	AFJADED
2	2024-04-18T16:03:21.000	AF58AHB
2	2024-04-18T16:03:28.000	AFH877S
2	2024-04-18T16:03:30.000	ABAX9E7M
2	2024-04-18T16:03:37.000	EG9UBX7
2	2024-04-18T16:03:37.000	EF46L8Y
2	2024-04-18T16:03:45.000	AF4A9Z9
2	2024-04-18T16:04:00.000	AB8NBA8K
2	2024-04-18T16:04:04.000	AF4I6E3
2	2024-04-18T16:04:09.000	FDH69KD
2	2024-04-18T16:04:11.000	AFL471D
2	2024-04-18T16:04:14.000	AF2A9VE
2	2024-04-18T16:05:41.000	AF4E5D7K
2	2024-04-18T16:05:43.000	AF33ZE6
2	2024-04-18T16:05:43.000	EC9C7BDK
2	2024-04-18T16:05:46.000	EVAED56
2	2024-04-18T16:05:47.000	[illegible]

Figure 3. Direction 2's monitoring start data

For this purpose, we selected data from April 19 to May 6 and analyzed weekdays, weekends, and holidays separately in combination with the above periodicity.

For working days, we selected the hourly traffic flow in four directions from April 22 (Monday) to April 25 (Thursday) for analysis, as shown in Figure 4.

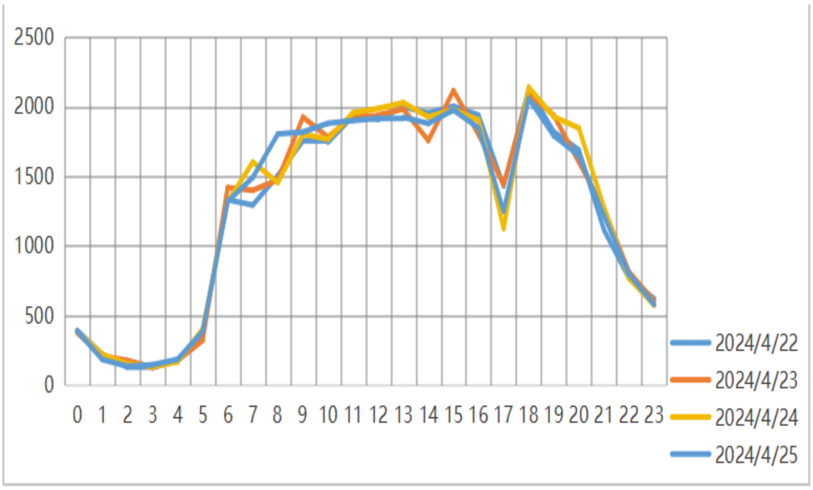


Figure 4. April 22nd - April 25th, the unit hourly traffic volume in four directions in a single day

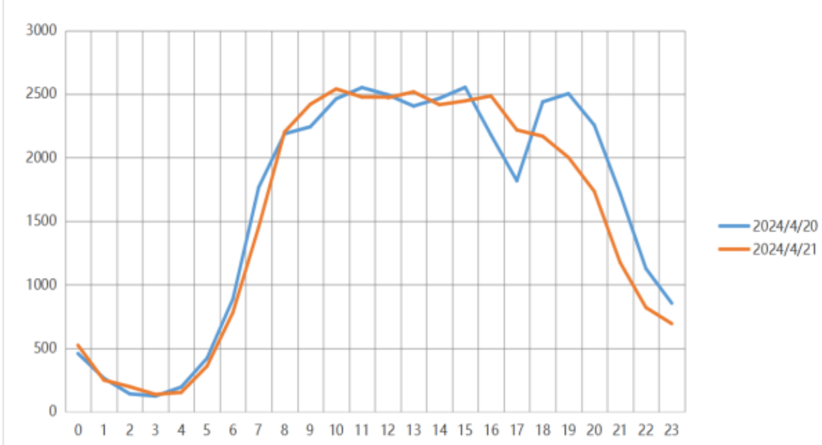


Figure 5. April 20th - April 21st, the unit hourly traffic volume in four directions in a single day

For weekends, we selected the unit hour traffic volume in four directions from April 20 (Saturday) to April 21 (Sunday) for analysis, as shown in Figure 5.

For holidays, we selected the unit hour traffic volume in four directions from May 1 to May 4 (May Day holiday) for analysis, as shown in Figure 6.

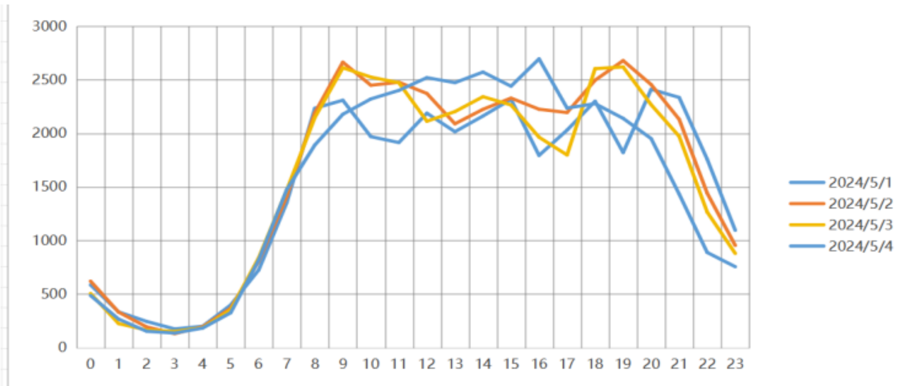


Figure 6. May 1st - May 4th, the unit hourly traffic volume in four directions in a single day

Observing Figures 4, 5 and 6, it was found that the changes of the polyline were similar, and it was decided to split the 24-hour day into the following five time periods:

00:00-05:00 is the night time, and the traffic flow is less;

05:00-09:00 is the morning rush hour, the traffic volume rises to the morning peak, and reaches the peak at about 7:00;

09:00-16:00 is a stable period, and the traffic flow is relatively stable;

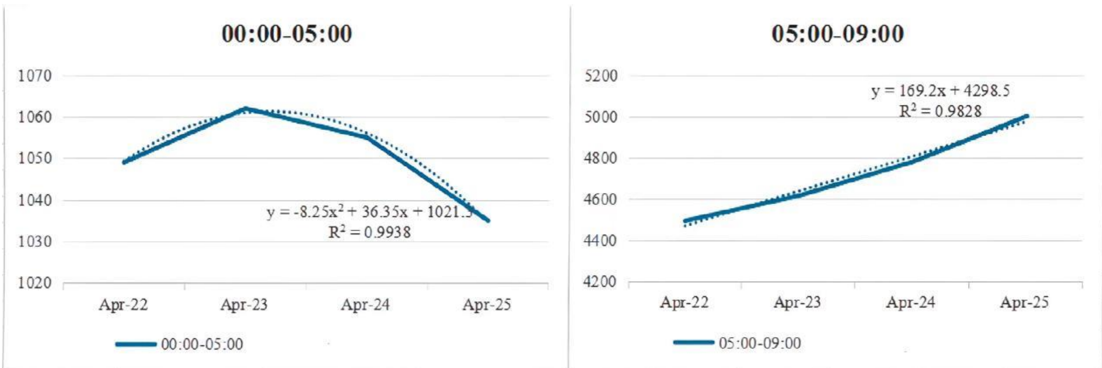
16:00-20:00 is the evening peak hour, the traffic volume starts to rise from 16:00, and decreases sharply after 20:00;

20:00-00:00 is the evening period, and the traffic gradually decreases.

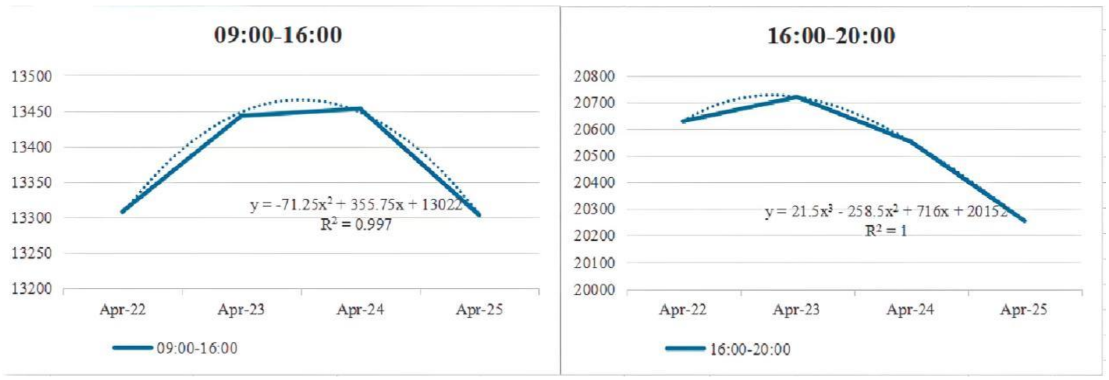
According to the working day, April 22 (Monday) - April 25 (Thursday) data overlap is high, using the traffic flow of each period of these four days, as shown in Table 2, draw a line chart of the traffic flow change of the five periods of these days, according to the line chart, draw the trend line, show the function relationship of the trend line, and all, as shown in Figure 7, shows the high reliability of the trend line, can predict the traffic flow of these five periods on the working day. Using the same method, it is possible to predict traffic flow on weekends and holidays in a similar way[12-13].

Table 2. Traffic flow at each time from April 22nd to April 25th

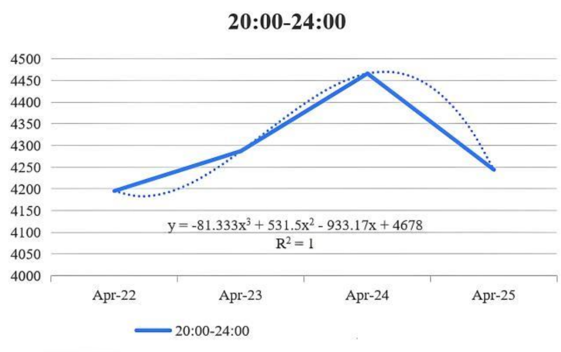
Time	22-Apr-24	23-Apr-24	24-Apr-24	25-Apr-24
00:00-05:00	1049	1062	1055	1035
05:00-09:00	4492	4614	4779	5001
09:00-16:00	13308	13443	13453	13303
16:00-20:00	20631	20722	20554	20256
20:00-24:00	4195	4287	4466	4244



a. 00:00-05:00 traffic flow trend line b. 05:00-09:00 traffic flow trend line



c. 09:00-16:00 traffic flow trend line d. 16:00-20:00 traffic flow trend line



e. 20:00-24:00 traffic flow trend line

Figure 7. The overall chart of traffic flow trend line

This is because there are both straight ahead, left turns, and right turns in all directions, as well as the total amount of traffic that suddenly disappears or appears

$$X = X_1 + X_2 + X_3 + X_4 + \Delta X \tag{1}$$

Using python programming, the traffic flow of turning and going straight in the four directions of the intersection is further estimated, and the output of python software is shown as follows.

From 0 to 5 o'clock, the output results of straight, left and right turn traffic flow in all directions:

```
begin_hour:0, end_hour:5, total traffic:13512
—direction:1, total traffic:3790
——direction:1 straight_cnt:802, left_and-return_cnt:201, right_cnt:777
—direction:2, total traffic:2275
——direction:2 straight_cnt:340, left_and-return_cnt:95, right_cnt:51
—direction:3, total traffic:3589
——direction:3 straight_cnt:1010, left_and-return_cnt:26, right_cnt:94
—direction:4, total traffic:3858
——direction:4 straight_cnt:936, left_and-return_cnt:559, right_cnt:276
```

5-9 o'clock in all directions straight ahead, left turn, right turn traffic flow output results:

```
begin_hour:5, end_hour:9, total traffic:62503
—direction:1, total traffic:16324
——direction:1 straight_cnt:3374, left_and-return_cnt:635, right_cnt:4149
—direction:2, total traffic:7138
——direction:2 straight_cnt:760, left_and-return_cnt:415, right_cnt:201
—direction:3, total traffic:21280
——direction:3 straight_cnt:6244, left_and-return_cnt:179, right_cnt:231
—direction:4, total traffic:17761
——direction:4 straight_cnt:4188, left_and-return_cnt:1437, right_cnt:1230
```

9-16 o'clock in all directions straight ahead, left turn, right turn traffic output results:

```
begin_hour:9, end_hour:16, total traffic:173959
    —direction:1, total traffic:44319
    ——direction:1 straight_cnt:9711, left_and-return_cnt:3541, right_cnt:9966
    —direction:2, total traffic:25953
    ——direction:2 straight_cnt:2232, left_and-return_cnt:1395, right_cnt:852
    —direction:3, total traffic:53045
    ——direction:3 straight_cnt:16260, left_and-return_cnt:288, right_cnt:1327
    —direction:4, total traffic:50642
    ——direction:4 straight_cnt:12359, left_and-return_cnt:6080, right_cnt:3827
```

16-20 o'clock in all directions straight ahead, left turn, right turn traffic flow output results:

```
begin_hour:16, end_hour:20, total traffic:100177
—direction:1, total traffic:25675
——direction:1 straight_cnt:5479, left_and-return_cnt:1653, right_cnt:4789
—direction:2, total traffic:17331
——direction:2 straight_cnt:2141, left_and-return_cnt:992, right_cnt:390
—direction:3, total traffic:26806
——direction:3 straight_cnt:7573, left_and-return_cnt:225, right_cnt:631
—direction:4, total traffic:30365
——direction:4 straight_cnt:6900, left_and-return_cnt:4204, right_cnt:2535
```

20-24 o'clock in all directions straight ahead, left turn, right turn traffic output results:

```
begin_hour:20, end_hour:24, total traffic:58074
—direction:1, total traffic:16497
——direction:1 straight_cnt:4048, left_and-return_cnt:1367, right_cnt:2961
—direction:2, total traffic:11414
——direction:2 straight_cnt:2044, left_and-return_cnt:560, right_cnt:250
—direction:3, total traffic:12639
——direction:3 straight_cnt:3438, left_and-return_cnt:66, right_cnt:429
—direction:4, total traffic:17524
——direction:4 straight_cnt:4659, left_and-return_cnt:2558, right_cnt:1574
```

MATHEMATICAL MODEL ESTABLISHMENT AND TRAFFIC FLOW OPTIMIZATION

In view of the above passenger flow prediction, the reasonable optimization of the signal light at the intersection can make the vehicles on the road travel more smoothly, and its signal light control scheme must also be formulated according to the traffic conditions at the intersection.

In reality, we believe that the straight and right-turning vehicles do not affect each other, but the left-turning vehicles are mutually influencing the opposite straight vehicles, and the traffic signal timing scheme at the intersection is to adjust the signal cycle to arrive safely.

After that, the traffic flow data of this intersection and adjacent intersection should be cleaned out, the intersection of an intersection should be set as the target intersection first, and the traffic flow data of its adjacent intersection and the data of the target intersection should be compared, and which of them is repeated, that is, the turning vehicle, and the rest is the vehicle going straight ahead, and then the traffic flow of other lanes can be calculated by this method, and the traffic flow of the other lanes can also be known, and the traffic flow of its lane going straight and turning can be known.

Suppose the intersection is a two-lane intersection in both directions as shown in Figure 8.

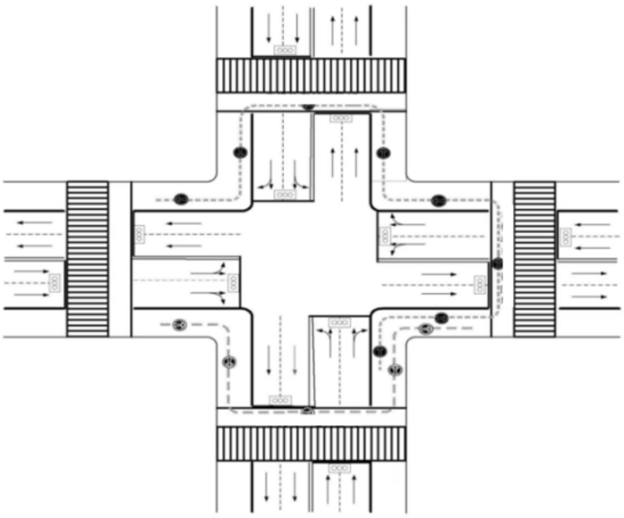


Figure 8. A two-lane intersection in both directions

Let's assume that the number of vehicles turning left at each intersection at this intersection is A_{ijk} ,

The number of vehicles going straight is B_{ijk} ,The width of the intersection is D ,The speed of a vehicle going straight is v ,

The red light is displayed for a period of time t_r ,The duration of the green light display in a traffic light is in a cycle t_g .

Then the time for vehicles going straight to pass through the intersection is as follows $\frac{B_{ij}}{v}$, The time for left-turning vehicles to pass through the intersection is $\frac{A_{ij}}{v}$,

That is, the ratio of the time it takes for a vehicle going straight to pass through the intersection to the time for a left-turning vehicle to pass through the intersection

$$\frac{A_{ij}}{B_{ij}} = \frac{t_g}{t_r} \tag{2}$$

So the green light duration is: $t_g = \frac{t_r \cdot A_{ij}}{B_{ij}}$,The duration of the red light is $t_r = \frac{t_g \cdot B_{ij}}{A_{ij}}$

Therefore, the length of a traffic light cycle is:

$$t_r + t_g = \frac{t_g \cdot B_{ij}}{A_{ij}} + \frac{t_r \cdot A_{ij}}{B_{ij}} \tag{3}$$

Using the model and combining with Python software, the optimal duration of a cycle of traffic lights is shown in Figure 9.

```
from scipy.optimize import fsolve
def f(t_g, S, L, T):
    n=len(S)
    total=0
    for i in range(n):
        total +=S[i]/L[i]-t_g/(T-t_g)
    return total
S=[23414, 7517, 34525, 29042]
L=[7397, 3457, 784, 14838]
L_total=100
T=60
t_g=fsolve(f, x0=30, args=(S, L, T))
print("Traffic time:", t_g[0])
```

Figure 9. The optimal length of a traffic light cycle

```
In [4]: df_data[(df_data['V4']=='jz-wxRoad')&(df_data['V3']=='none')&(df_data['date']>='2024-05-01')&(df_data
Out[4]:
```

	V1	V2	V3	V4	time	date
6077551	4	2024-05-02T20:38:00.000	none	jz-wzRoad	20	2024-05-02
6077589	4	2024-05-05T14:47:43.000	none	jz-wzRoad	14	2024-05-05
6183938	1	2024-05-02T22:05:56.000	none	jz-wzRoad	22	2024-05-02
6183939	1	2024-05-03T10:48:54.000	none	jz-wzRoad	10	2024-05-03
6183940	1	2024-05-03T11:12:28.000	none	jz-wzRoad	11	2024-05-03
...	...	...	...	...	...	...
6186281	2	2024-05-04T03:15:16.000	none	jz-wzRoad	3	2024-05-04
6186283	4	2024-05-04T17:20:07.000	none	jz-wzRoad	17	2024-05-04
6186285	4	2024-05-05T23:45:38.000	none	jz-wzRoad	23	2024-05-05
6186286	4	2024-05-05T22:54:12.000	none	jz-wzRoad	22	2024-05-05
6186288	4	2024-05-04T12:13:57.000	none	jz-wzRoad	12	2024-05-04

2025 rows × 6 columns

Figure 10. The number of vehicles with "no license plates".

Suppose that the signal light at this intersection has a left turn light, and the left-turning vehicle needs to wait for the straight lane indicator to turn red, and the left turn light is green before turning left.

Then, if $\frac{3.6(S_{ij}+D)}{v} > 55.6$, then the duration of a traffic light is $\frac{3.6(S_{ij}+D)}{v}$.

If $\frac{3.6(S_{ij}+D)}{v} \leq 55.6$, then the duration of a traffic light is 55.6s.

The accurate prediction of parking demand is the premise of reasonable arrangement of temporary parking spaces, if the error between the prediction value of parking demand and the actual demand is large, there will be waste of human and material resources, or lead to traffic jam in the parking section. Therefore, the error between the forecast data and the actual demand is minimized to improve resource utilization[14-15].

EXPERIMENT AND RESULT ANALYSIS

Using Python software, the data was processed, and after analysis, there were 2025 pieces of data for vehicles without license plates, as shown in Figure 10.

The total traffic flow from May 1 to May 5 is 184367 as shown in Table 3, and $\frac{2025}{184367} \approx 0.01$ can be seen, so for the requisition of temporary parking spaces, the number of vehicles without license plates can be ignored.

Table 3. Traffic flow in four directions from May 1st to May 5th

Date	2024-5-1	2024-5-2	2024-5-3	2024-5-4	2024-5-5
Direction 1	11059	11132	11308	11478	9793
Direction 2	7218	8220	7527	7336	6567
Direction 3	7468	8158	7744	7046	6712
Direction 4	10918	11916	11360	11152	10255
Sum	36663	39426	37939	37012	33327
Total	184367				

Considering that the entry and exit of the cruise vehicle in and out of the scenic spot is recorded by the monitoring equipment at least twice, then the vehicle with more than or equal to 4 license plates per hour is the cruise car to be stopped.

The total number of cars that appeared 4 times or more in each hour at the same intersection from May 1 to May 5 was calculated by using Python software, as shown in Figure 11.

```
In [27]: def get_xunyou_car(df):
             for hour in sorted(df['hour'].unique()):
                 df_single_hour = df[df['hour']==hour]

             #     df_single_hour = df_data[df_data['hour']==1]
                 df_chepai_cnt = df_single_hour.groupby(['V3','V4']).agg({'V3': 'count'})
                 df_chepai_cnt['V3'] = df_chepai_cnt.index.get_level_values(0)
                 df_chepai_cnt = df_chepai_cnt.rename(columns={'V3':'The number of times the license plate appears'})
                 df_chepai_cnt

                 print('hour:',hour,',Total number of cars:',len(df_chepai_cnt['License plate number column'].unique()),',T

             #     df_single_hour = pd.merge(df_single_hour, df_chepai_cnt, left_on=['License plate number'],right_on=['Licen
             #     df_single_hour = df_single_hour[df_single_hour['The number of times the license plate appears']>1]
```

Figure 11. Procedure for the number of cars that appear 4 times or more per hour at the same intersection from May 1st to May 5th

Combined with the changes in the hourly traffic flow in four directions in five days from May 1 to May 5 (May Day holiday) in Figure 6, assuming that the opening hours of the scenic spot are 9:00-18:00, assuming that all leave the scenic spot before 18 o'clock, we consider the number of vehicles that appear 4 times or more during the opening hours of the scenic spot .

Let M be the average number of vehicles waiting to be parked and parade per hour in a single day, and N be the number of temporarily requisitioned parking spaces. T is the average parking time of the cruising vehicle,Based on the total number of cruise cars waiting to be parked for five days between 9:00 and 18:00 in Figure 12, we estimate the average number of cruise cars to be parked per day, as shown in Table 4.

Table 4. 9:00-18:00 The number of cruise cars to be parked in five days and the average number of cruise cars to be parked every day

Time	Five-day vehicles to be paraded	Average
9	1018	203.6
10	902	180.4
11	1006	201.2
12	768	153.6
13	741	148.2
14	578	115.6
15	669	133.8
16	881	176.2
17	957	191.4

In order to determine the number of temporary parking spaces required to be requisitioned, at least satisfy:

$$N = \frac{MT}{18-9} \tag{4}$$

Assuming that the maximum number of vehicles paraded on all roads in the area is 204 within 9 hours of the opening of the scenic area, and the average parking time per vehicle is 2 hours, it is calculated that at least 46 parking spaces will need to be temporarily requisitioned.

The proportion of cruising vehicles to the total traffic flow is calculated as shown in Figure 13 and Figure 14 compared to the number of traffic during the May Day holiday and on the weekend before the May Day holiday.

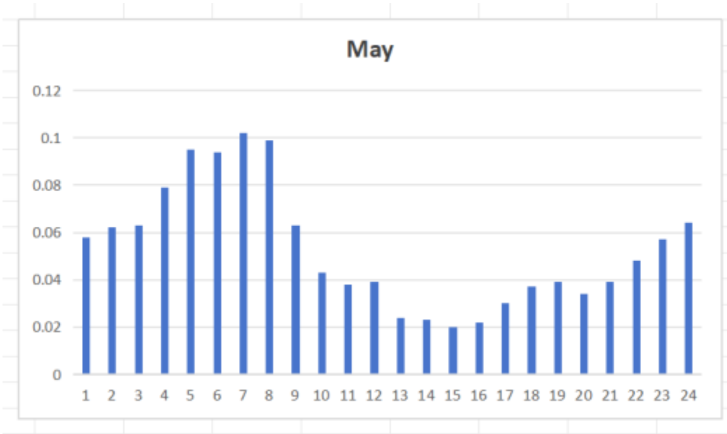


Figure 13. Proportion of cruising vehicles to total traffic in May

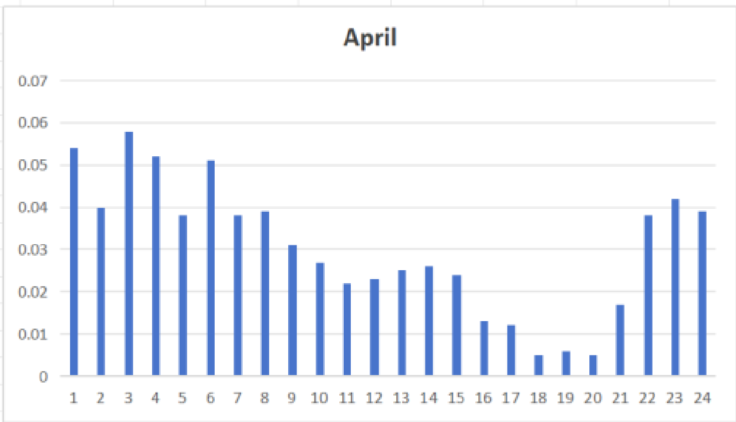


Figure 14. Proportion of cruising vehicles to total traffic in April

As can be seen from Figures 13 and 14, compared with the weekend rest days in May, although the ratio of parade vehicles to total vehicles during May Golden Week is higher than that of parade vehicles on weekends in April, from the analysis of time periods, from 9 o'clock,

Due to the opening of the scenic spot, the ratio of parade vehicles waiting to be parked in Figure 11 has dropped sharply, because the traffic control was implemented during the May Day holiday, which greatly reduced the number of parade vehicles waiting to be parked, and greatly improved the traffic capacity of the road section attached to the scenic spot.Through the analysis of the two graphs of Figure 5 and Figure 6, it is found that in the period of 9:00-18:00, the number of vehicles in the same intersection, the May Day Golden Week is more, compared with the weekend without control, the curve decreases significantly, although there are ups and downs, but it is still much lower than the value during the period without control, so the temporary traffic control of the May Day Golden Week is significant, and can reduce the traffic pressure at the intersection near the scenic spot.

CONCLUSION

Based on the mathematical model constructed from the monitoring records of a certain intersection, we have achieved certain research results. This model is not only powerful but also has wide application potential. It can accurately predict passenger flow, providing strong data support for urban traffic management. On this basis, we have reasonably optimized the traffic lights, effectively improving the traffic efficiency at the intersection. At the same time, the model also proposes scientific and reasonable suggestions for the challenging issue of holiday traffic control, providing a solid basis for decision-making by urban traffic management departments.

The advantage of this model lies in its high degree of versatility and scalability. Whether it is for urban roads in different cities, traffic flow prediction on weekdays and holidays, or optimization of traffic signals, these can all be achieved by adjusting the sampled data. This flexible application method greatly reduces the cost and difficulty of model application, enabling it to play an excellent role in various complex traffic scenarios. In addition, the application scope of the model is not limited to urban road traffic; it can also be extended to other popular scenic spots, providing strong support for scenic spots to formulate plans for temporary parking space allocation, effectively alleviating the problem of difficult parking in scenic spots.

Despite the significant achievements of this model, there are still some shortcomings. Firstly, the prediction accuracy of the model is to some extent influenced by the quality and quantity of the sampled data. Inaccurate or insufficient sampled data may affect the model's prediction performance. Secondly, the model may not make completely accurate predictions and suggestions when dealing with emergencies or special situations. This requires further refinement of the model's algorithms and mechanisms in future research to enhance its ability to handle complex scenarios. Lastly, although the model has a wide range of applications, it may still need fine-tuning based on actual conditions in specific application scenarios to better meet the demands of different situations.

Looking ahead, this mathematical model has broad development prospects. As urban traffic management continues to become more intelligent and refined, the application of the model will become more extensive and in-depth. To further improve the model's prediction accuracy and application effectiveness, we suggest making improvements and refinements in the following aspects: strengthening the collection and processing of sampled data to improve the quality and quantity of the data, providing more accurate baseline data for the model's predictions; deeply studying the impact of emergencies and special situations on traffic flow, refining the model's algorithms and mechanisms to enhance its ability to handle complex scenarios; fine-tuning and optimizing the model based on the actual needs of different application scenarios to better adapt it to the demands of various traffic situations; and actively exploring the model's application potential in other fields, such as urban traffic planning and intelligent transportation system construction, to provide strong support for the comprehensive development of urban traffic management.

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