Campus Parking Planning Based on Multisource Data Analysis--Taking Mafangshan Campus of Wuhan University of Technology as an Example

Zhaoqi Huang¹, Xiaoyue Xu¹, Qingyue Luo¹ and Danhui Fang¹*

¹China Research Center for Emergency Management, Wuhan University of Technology, Wuhan, Hubei, 430000, China
²Corresponding author’s e-mail: lizdy@whut.edu.cn

Abstract. In order to solve the problems of unbalanced supply and demand of campus parking resources, chaotic parking conditions, and potential safety hazards in campus traffic, a method of campus parking system planning based on big data is proposed. Taking the Mafangshan Campus of Wuhan University of Technology as an example, from the two aspects of time dimension and spatial dimension, the paper analyzes the trend of campus parking number, vehicle’s parking time, parking density and parking space utilization rate in each area, and discards the distribution of stranded vehicles according to the vehicle collection data. Finally, according to the analysis of multi-source big data, the current situation of campus parking system is obtained, and the corresponding planning results of campus parking are obtained. Through field research and big data analysis, we can intuitively understand the distribution and utilization of the overall parking resources of the campus, and the parking planning results based on this are more practical and scientific.

1. Introduction
In recent years, the internal communication between the university and the outside world has become increasingly close, and the social vehicles entering the campus have grown rapidly. Traffic on campus has always been a problem faced by many universities in a long history. If the parking resources on campus cannot meet the parking demand, it will inevitably cause the vehicles to occupy the road at will, and even occupy the sidewalks and roadways, which will affect the normal operation of dynamic traffic and adversely affect people's work and life. It will also hinder the image of the campus [1]. In this context, campus traffic problem cannot be ignored, and scientific traffic planning is necessary.

Most campuses of foreign universities are open-ended design, which have been integrated into the surrounding urban environment, and are considered in urban planning when planning [2]. For example, the Ann Arbor Campus in Michigan will hold a campus planning seminar for the next 10 or 20 years every 10 to 20 years [3], and complete the first draft of a new round of campus planning. In addition, some scholars have also put forward corresponding suggestions for the problem of university campus traffic. Aldrete-Sanchez has integrated the various modes of transportation such as cars, public transportation, bicycles, pedestrians, etc., and recorded the systematic method for campus transportation system and urban transportation. The system is fused [4].

Parking planning is often overlooked as part of overall transportation planning. There are few targeted plans and studies on parking on campus in China and abroad, and they are often only mentioned as part of campus transportation planning. Taking the Nanning Branch of Guilin University of...
Technology as an example, Lu Yong optimized the design of campus parking space by combining landscape, architecture and greening, and measured the parking demand of various groups of people [5]. Wang Nan uses the linear programming method to design an optimization model, in this model, several parking spaces of different sizes are determined according to the size of the car model, and more parking spaces are allocated in a limited space to alleviate The contradiction between supply and demand in the parking lot [6].

With the development of computer and network technology, in the field of transportation, traditional data collection is also transforming into electronic equipment and advanced applications, which has helped the formation and development of traffic big data [7]. In the context of traffic big data, this paper takes MaFangshan Campus of Wuhan University of Technology as an example, and uses the database technology and various data analysis methods to analyze the big data collected from the time to space. The status quo, and accordingly, the campus parking area planning.

2. Data Sources

MaFangshan Campus of Wuhan University of Technology is located on both sides of the Luoshi South Road in Hongshan District, Wuhan. The total land area is 73.73 hectares. The planned colleges include the School of Materials Science and Engineering and the School of Mechanical and Electrical Engineering. It can accommodate more than 8,000 undergraduates and nearly 3,000 graduate students.

The data in this paper includes data on campus parking areas and surrounding buildings, vehicle traffic data and vehicle collection data from October 7 to 14, 2019. The campus parking area and building data are statistics on the parking area and campus building information of the MaFangshan Campus of Wuhan University of Technology. The parking areas are divided into four categories: public line parking areas, faculty-only parking areas, family-owned parking areas, and department-specific parking areas, with a total of 1,352 parking spaces. Vehicle traffic data is provided by the school security office, a total of 110,000; after processing, this article selects 43013 data for calculation. The vehicle categories are classified into four categories in this paper according to the classification criteria given by the school security department: Class A vehicles (faculty vehicles), Class B vehicles (work vehicles), Class C vehicles (construction vehicles), and temporary vehicles (not Authorized vehicle). Vehicle data collected by the research team is from October 7 to 14, 2019, five time periods per day (7:30-8:30, 9:00-10:00, 11:30-12:30, 13:30-14:30, 17:00-18:30) Data collection was carried out on all parking areas on the Mafangshan campus, totaling 44,329. The data types and contents are shown in Table 1.

| Table1 Basic data table |
|-------------------------|
| type of data            | Data content                                |
| parking area & building data | Parking area name  | Type      | Building type | Building name | Parking acreage | Parking space |
| Faculty-only 6          | Public marking  | Teaching  | Kindergarten | 260 m²       | 35             |
| ...                     | ...           | ...       | ...          | ...          | ...            |
| Vehicle traffic data    | License plate | Pass type | Access area  | Entry time    | Departure time | Parking time  |
| EAU****                 | Class A vehicle | Mafangshan Campus | 2019/10/14 | 10:08 | 2019/10/14 | 11:03 | 55min |
| EA1****                | Temporary vehicle | Mafangshan Campus | 2019/10/14 | 10:54 | 2019/10/14 | 11:03 | 9min |
| ...                     | ...           | ...       | ...          | ...          | ...            |
| Vehicle collection data | Vehicle category | Upload time | License plate | longitude | latitude | Parking area |
| Class A Vehicle        | 10/6/2019 21:41:02 | EAU**** | 114.352111851 | 11672 | 30.520067 | 65791581 | faculty-only 6 |
| ...                     | ...           | ...       | ...          | ...          | ...            |
3. Analysis of the current situation of campus parking

The analysis can be divided into two dimensions. First, from the time dimension, use the Vehicle collection data to count the number of parking changes with time in the campus, and then through the license plate association, calculate the parking time of each vehicle from the vehicle traffic data, and select the stranded vehicles through the result. Then from the spatial dimension, classify each parking area into the corresponding buildings around it, take the buildings as the analysis object, calculate the parking density and parking space utilization rate of all the parking areas contained in each building, and draw the distribution map of stranded vehicles according to Vehicle collection data. Finally, the two dimensions of the analysis are combined to get a more comprehensive campus parking situation. The analysis flow of campus parking status is shown in Figure 1.

Figure 1 Flow chart of campus parking status analysis

3.1 Dimension analysis of campus parking time

3.1.1 Trend analysis of parking quantity on campus. It can reflect the overall parking demand of the campus from a macro perspective. With the help of the curve obtained, the peak period of campus parking demand is determined, and get the detailed overall parking status of campus.

Take the Mafangshan Campus of Wuhan University of Technology as an example. First, pre-process the collected data to screen and calculate the number of parking at a certain time on a certain day in the campus (i=1, 2, ..., m; j=1, 2, ..., n), get the campus parking quantity matrix:

$$Q = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1j} \\ q_{21} & q_{22} & \cdots & q_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ q_{i1} & q_{i2} & \cdots & q_{ij} \end{bmatrix}$$

Therefore, the average number of parking per day is:

$$\overline{N_j} = \frac{1}{n} \sum_{i=1}^{n} q_{ij}$$

Table 2 and Table 3 show the trend of the number of parking lots drawn based on the data collected during the eight days of the survey period. The results show that the vehicle is always the most on campus from 9:00 to 10:00, whether it is a working day or a weekend. On the whole, the number of parking on weekdays is significantly greater than that of weekends.

Table 2 Weekday parking quantity trend table

Table 3 Weekend parking quantity trend table

A comprehensive analysis of the trend analysis of parking quantity shows that most of the vehicles occupying campus parking resources at the Mafangshan Campus of Wuhan University of Technology
are class A vehicles, and the parking supply in the campus is far from meeting the parking demand during peak hours. In addition, before 7:30 and after 18:30, the number of vehicles is maintained at more than 600, indicating that some vehicles are always on the campus and occupy parking resources.

3.1.2 Analysis of the distribution of campus parking time. In order to better study the turnover of parking spaces, the distribution characteristics of the parking time of each vehicle in the campus are studied from the dynamic point of view. The vehicle collection data and vehicle traffic data are cross compared according to the "license plate " field, and the vehicles with access records are screened out, and the "parking time" field in the vehicle traffic data is obtained, and sorted in ascending order. Taking 1H, 4h, 10h, 24h, 72h as the analysis period, the distribution diagram of vehicle stopping time was obtained. According to statistics, 38.6% of the vehicles have a parking time within 15 minutes, which may be vehicles passing through the campus. Therefore, in order to observe the distribution law of other periods more intuitively, it is necessary to remove the vehicles whose parking time is less than 15 minutes. The distribution of parking time after removal is shown in Table 4.

Table 4 Parking time distribution table

| Parking Time | Class A vehicle | Class B vehicle | Class C vehicle |
|--------------|----------------|----------------|----------------|
| 1H-4h        | 20%            | 30%            | 50%            |
| 10h          | 15%            | 25%            | 60%            |
| 24h          | 10%            | 20%            | 70%            |
| More than 72h| 5%             | 10%            | 85%            |

It can be seen from Table 3 that the total number of vehicles of four types of vehicles with a parking time of 1h-4h is the largest, and the number of class A vehicles is always the largest in any time period, which shows that the main demand of campus parking is for teachers to go to work and park; there are still 556 vehicles with a parking time of more than 72h, so it can be inferred that there are vehicles that have not been moved for a long time in the campus. If this part of vehicles are removed, a large number of them can be released public parking resources.

3.2 Dimension analysis of campus parking space

3.2.1 Analysis of parking demand around campus buildings. Now, taking the buildings of Mafangshan Campus of Wuhan University of Technology as the research object, this paper analyses the current situation of parking supply and demand beside the buildings on campus. Each parking area is allocated to each building in the campus according to the geographical location, and the utilization rate and density of each building are calculated. First, according to the data collected by vehicle collection data and campus parking area data, a PivotTable is established to get a building (n = 1, 2, n) daily average number of parking spaces, total number of parking spaces and total area of surrounding parking areas. Among them, the daily average parking quantity is calculated from the vehicle collection data:

$$P_N = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} q_{ij}^N$$

Then, the utilization ratio and density of parking space beside each building are obtained as follows:

$$UR_N = \frac{P_N}{S_N}$$
$$D_N = \frac{P_N}{A_N}$$

Similarly, eight days (five time periods) of data from the survey are selected for analysis, and the utilization rate and density of parking space beside the building are obtained as shown in Table 5.

Table 5 Utilization rate and density of parking space beside buildings

| Buildings                                | Daily average peak parking quantity | Utilization rate | Density |
|------------------------------------------|------------------------------------|-----------------|---------|
| Materials Science Experiment Centre      | 58                                 | 223%            | 0.20    |
Through the multi-source analysis of Table 4 and campus parking survey data, we can know the parking status beside each building. 30% of the buildings can no longer meet their maximum demand; 50% of the buildings are densely parked, which has a great potential safety hazard; the utilization ratio of parking spaces beside different buildings is quite different, and the distribution of parking resources is uneven.

3.2.2 Analysis on the distribution of stranded vehicles in Campus. During the investigation, it is found that there are many long-term stranded and immobile vehicles in the campus, which occupy a lot of limited parking resources in the campus. Therefore, vehicles that have been parked for more than 5 days on campus and have not been moved on campus are defined as stranded vehicles. Firstly, the "license plate" field is used as the external code to compare the vehicles that exist in the vehicle collection data but not in the vehicle traffic data. Then, the "parking area" field of the obtained vehicles is used as the main code to determine whether the vehicle has moved in the campus. A total of 495 stranded vehicles are obtained by combining the vehicles that have not been moved with the vehicles that have been screened out for more than 5 days through the "parking time" field of vehicle traffic data. Finally, according to the coordinates of each vehicle in the vehicle collection data, the distribution diagram of stranded vehicles as shown in Figure 2 is obtained.

![Figure 2 Stranded vehicles distribution](image)

From Figure 2, it can be seen that the number of stranded vehicles is large and scattered, mainly distributed in the parking area of teachers and staff and the residential area of their families, which occupy a large amount of parking resources in the campus, resulting in the public resources cannot be used to a greater extent. And the parking demand survey accuracy is not high due to the existence of stranded vehicles, which cannot represent the accurate parking demand in the campus.
4. Analysis of the current situation of campus parking

4.1 Dimension analysis of campus parking space

In view of the uneven distribution of parking resources on campus, the problem that Class A vehicles and temporary vehicles seize parking resources and the detention vehicles occupy public parking areas for a long time, the author proposed a solution.

First, remove the stranded vehicles data from the vehicle collection data. According to the cleaned data, 9:00-10:00 is the peak period of campus parking. The average number of parking vehicles during this period is 1399, plus about 359 vehicles that were not collected due to parking in non-compliant areas. It is concluded that at least 1758 parking spaces need to be planned to meet the parking needs of the Mafangshan campus. Therefore, in order to achieve the balance of supply and demand of parking resources, the author re-planned the parking resource allocation table as shown in Table 6.

| Buildings                  | Planned Parking Space | Suggested Parking Space (Short-term) |
|----------------------------|-----------------------|-------------------------------------|
| Silicate Society Branch    | 151                   | 140                                 |
| Finance Department         | 173                   | 87 (26)                             |
| East School Hospital       | 0                     | 97 (29)                             |
| Development and Reform Office | 11               | 56 (16)                             |
| International Education Institute | 14           | 23                                   |
| First Teaching Building    | 28                    | 76                                   |
| Fengwei Canteen            | 15                    | 25                                   |
| Employment Building        | 40                    | 74 (22)                             |
| West School Hospital       | 6                     | 10 (3)                              |
| Comprehensive Administrative Office | 16           | 46 (13)                             |
| West-East Teaching Building| 86                    | 83                                   |
| Material Compound Laboratory| 89                  | 63                                   |
| Personnel Office           | 27                    | 34 (10)                             |
| West Library               | 45                    | 50                                   |
| Materials Science Experiment Centre | 18       | 52                                   |
| Conference Centre          | 36                    | 60 (18)                             |
| West Canteen               | 0                     | 30                                   |
| **Total**                 | **1352**              | **1758**                            |

4.2 Management measures: Although the parking resources of the Mafangshan campus have been re-integrated and planned, the owners will inevitably violate some regulations in the implementation process. School security office can formulate specific measures to assist management.

First, a camera can be set at the exit of the parking area of the stranded vehicles and the short-term parking place to record the parking time. Then, intelligently screen the license plate data recorded by the traffic camera to extract the illegal vehicle information. Although the machine screening is faster and more accurate than the manual screening, due to the actual situation, it is impossible to set up the camera to record the vehicle information in all parking areas, so irregular manual inspection is required.
Finally, for vehicles that violate the rules, notify the owner in time and give a warning. If the number of violations reaches the upper limit, a stricter ban can be adopted.

5. Conclusion
The university carries a large number of faculty and student groups, as well as staff with contacts and temporary vehicles. The supply and demand of parking resources are unbalanced and management is difficult. Therefore, scientific and reasonable overall transportation planning is urgently needed. Taking the Mafangshan Campus of Wuhan University of Technology as an example, this paper analyzes the status of campus parking by multi-source analysis of more than 100,000 vehicle traffic data and vehicle collection data, finds out the existing problems, and proposes a set of parking area planning solutions for campus. The program is suitable for universities with limited parking resources and huge parking demand, and provides a reference for building a safe, orderly and comfortable modern campus transportation system.

Acknowledgments
This paper is based on the Wuhan University of Technology Independent Innovation Research Fund Project. Thanks to all the students who provided help during the survey, to the staff of the Security Office who supported and assisted the survey team in collecting data, and to Professor Fang, who gave pointers when the survey team encountered difficulties. I believe that with the joint efforts of everyone, the Mafangshan Campus of Wuhan University of Technology will eventually get a beautiful and clean parking environment.

References
[1] Wang T, Ma D.X, Xu H.X. Research on School Parking Problem and Countermeasures——Taking Anhui University of Engineering as an Example J. Science and Technology Information(36):19-20.
[2] Zhou Z.Y, Chen J, Xie H. Study on the Planning Strategy of the New Campus Traffic System on University Campus——Taking Huazhong Normal University as an Example J. Central China Architecture, 2016(1):88-91.
[3] MAYERFW.A Setting for Excellence: The Story of the Planning and Development of the Ann Arbor Campus of the University of Michigan M. Ann Arbor: University of Michigan Press, 2015.
[4] ALDRETE- SANCHEZR, SHELTONJ, CHEURL. Integrating the Transportation System with a University Campus Transportation Master Plan: A Case Study J. Optimization Methods & Software, 2010,25(25):553-571.
[5] Lu Y. Analysis of the Status Quo of University Campus Parking and Optimization of Parking Space Layout——Taking Guilin University of Technology Nanning Branch as an Example J. Chinese and Foreign Architecture, 2018(8).
[6] Wang N, Guo R. Analysis of the Planning and Design of Campus Parking Lot——Taking the North Campus of Inner Mongolia University as an Example J. Manager, 2018, 542(10):100.
[7] Lu H.P,Sun Z.Y,Qu W.C.A Review of Big Data and Its Application in Urban Intelligent Transportation Systems J. Journal of Transportation Systems Engineering and, 2015,15(5):45-52.