Evaluation on Optimization of Traffic Organization of Xiangfang Wanda Parking Lot

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Abstract—With the rapid growth of per capita car ownership, urban parking demand has increased sharply, and the contradiction between parking supply and demand has become increasingly prominent. Part of the reason for this problem is that under the conditions of the existing transportation facilities, the functions of parking facilities are not adequate Play. This paper takes the Xiangfang Wanda underground parking lot in Harbin City as the research object. Through questionnaires and observation records, the parking lot is investigated and analyzed. The parking lot is optimized by qualitative and quantitative methods, and finally based on fuzzy synthesis. Evaluation.

1. INTRODUCTION

As an important infrastructure in the city center, parking facilities are of great significance to the construction and development of the city. With the rapid development of my country's urban economy, the number of motor vehicles continues to increase, and the construction of parking facilities in the central area can no longer keep up with the pace of social and economic development. At present, my country's urban transportation is relatively backward compared with foreign developed countries. The difficulty of parking in urban centers in China is concentrated in the construction and management of urban parking lots. The parking space is severely lacking, and the existing parking facilities cannot meet the parking needs well; there is a lack of scientific rationality in planning and layout, and parking information is not available. Matching leads to oversaturation of vehicles in the parking hotspot area, while no or fewer vehicles are parked in the rest of the parking area, resulting in a waste of resources; in the construction of the parking lot due to backward design concepts, design specifications, and aging parking facilities, etc. Factors have caused the parking lot to be increasingly congested; and the lack of information technology support in operation and management is also an important reason for the difficulty of parking. The parking lot lacks a clear and continuous guidance sign system and berth usage information, so that unfamiliar drivers cannot determine the location and usage of parking facilities in the area, causing unnecessary detours to find parking spaces. Therefore, it is necessary to optimize the traffic organization of the parking lot, which will play a very positive role in alleviating traffic congestion and parking difficulties.

At present, many scholars at home and abroad have done research on the optimization design of parking facilities traffic organization. Wang Yan et al. [1] proposed a mathematical programming model to optimize the layout of public parking lots. Under the constraints of the total investment budget, all users of the objective function The shortest walking distance. Fan Yifang et al. [2] analyzed the current situation of parking lot resource allocation in big cities, and explained the reasons for the imbalance of parking lot resource allocation, tried to build a parking lot resource-parking charging model, and optimized the allocation of parking lot resources from the perspective of urban space. Yang Jie et al. [3]
analyzed the causes of problems in the construction of underground parking garages, and optimized the layout of underground garages from the architectural design stage. Zhang Wenhui et al. [4] compiled and analyzed the main factors affecting the demand and supply of parking spaces based on the survey data, and established an on-street parking demand model based on the capacity of the regional road network, the comprehensive reduction coefficient of road network usage, and the proportion of each parking behavior. Forecast and revise the demand for on-street parking spaces. Tan Yunlong et al. [5] took a super-large underground parking lot of CCCC as an example, and discussed the organization of entrances and exits of large parking garages and the layout of the garage. Chi Cheng et al. [6] discussed the traffic design of the underground parking lot of the commercial plaza, and provided some conceptual support for the traffic design of the underground parking lot. Fu Ying [7] formulated a complete internal and external traffic organization plan for the parking spaces of the Expo Park to ensure the safety, convenience and efficiency of passenger flow. Sun Hongxia [8] analyzed the main reasons for the congestion at the entrance and exit of Beijing Huiju parking lot and insufficient parking spaces and unbalanced parking, and proposed a four-level parking guidance system to guide vehicles in real time and optimize the parking layout. Yi Lei et al. [9] analyzed the existing problems of traffic organization in the underground parking lot of Xi'an North Railway Station, and proposed a traffic organization optimization plan of "one-way main channel + two-way parking channel" according to the characteristics of pedestrian and vehicle traffic flow. Jin Lili [10] analyzed the layout and characteristics of the major parking lots around the Hengyang East Railway Station, pointed out the problems of the parking lots and the defects in the traffic organization, and proposed the organization optimization design plan of the parking lot, which increased the number of parking spaces and made the layout more reasonable and the traffic flow smoother. OuXinqua et al. [11] improved the transportation system by using spatial grammar combined with parking guidance and information system (PGIS) in transportation organization to solve the problem of shared parking. ZhangPing et al. [12] used scoring standards to determine the level of the underground parking system, and defined the number of vehicles entering and leaving the system during peak hours. According to the layout mode of the underground parking system and the internal traffic flow analysis of the vehicle entering and leaving the system, the underground parking system in the system was considered. The setting of vehicle passages and underground parking lots determines the internal traffic organization of underground parking lots.

In the above research, the problem is mainly considered from the perspectives of qualitative traffic organization and quantitative construction of optimization functions. This article takes the Xiangfang Wanda underground parking lot in Harbin City as the research object, and conducts related surveys and surveys on its parking lot through the method of questionnaires and observation records. Analyze, optimize the traffic organization of the parking lot through qualitative and quantitative methods, and finally evaluate it based on fuzzy synthesis.

2. ANALYSIS OF PARKING LOT STATUS

Harbin Xiangfang Wanda is located at the intersection of Hengshan Road and Ganshui Road. It is a typical large-scale shopping mall and is equipped with the largest and most complete parking lot in the Harbin commercial district. The parking lot has 90-110 parking spaces as a partition, which can be divided into areas B, C, D, and E as a whole. There are more than 400 parking spaces and a total of 2 entrances and exits, respectively connecting Hengshan Road and Ganshui Road. Since the parking lot was put into use in 2007, due to the long service life of the parking lot and the difference between the parking requirements during planning and design at that time and the current parking requirements, the current parking lot traffic organization is chaotic, which will cause traffic congestion and parking resources in the parking lot. Use imbalance, mixed traffic and other issues. Combined with on-site investigation, the traffic organization problems of underground parking lots are mainly reflected in the following three aspects.
2.1. Serious congestion at entrances and exits
The entrance and exit control of the parking lot is also a very important part of the traffic organization of the parking lot. The control of the entrance and exit of the parking lot is as important as the signal lights on the road. Restricted by physical conditions such as the space layout of the parking lot, the sharing capacity of the entrance and exit is not matched with the parking area, and the vehicle will be delayed when entering the underground parking lot, causing itinerary delays. The increasing number of entrances and queues for service parking will affect road traffic has caused traffic congestion and indirectly has a great impact on the surrounding traffic, reducing the speed of operation and affecting the capacity of the surrounding roads.

![Figure 1. Entrance and exit of parking lot](image1.jpg)

2.2. Backward parking guidance system
Some facilities inside the parking lot are seriously aging, the guidance of the traffic organization lacks continuity and systematization, the signs and markings are blurred, the passages do not have clear signs and direction signs, causing vehicles to move in disorder, which will cause certain because of the congestion, and because there are not enough obvious guidance signs, the driver cannot quickly find the location of his vehicle after arriving at the underground parking lot from the mall, which will inevitably cause the driver to find it difficult. There are only two-way toll gates at the entrances and exits, but there is no electronic display to remind the driver of the remaining parking spaces in the parking lot.

![Figure 2. Interior map of the parking lot](image2.jpg)

2.3. Disorganized external traffic organization
Due to the lack of parking spaces, the phenomenon of random parking of vehicles is serious, resulting in static traffic affecting normal dynamic traffic. The random parking of vehicles occupying lanes has caused disturbance to the normal order of the city. Since the problem of vehicle parking has not been solved for a long time, not only the main and secondary roads, but all available urban spaces have become parking lots. The random parking of a large number of vehicles has caused serious safety hazards.
Figure 3. Exterior of the parking lot

3. PARKING SURVEY AND STATISTICAL ANALYSIS
The survey conducted on-site surveys from April 10, 2018 to April 16, 2018, to investigate the situation of the Xiangfang Wanda underground parking lot. The survey was conducted by issuing questionnaires and continuous observation statistics at observation points. The survey questionnaire is mainly based on the RP parking intention survey, which can obtain actual reflections of daily parking behaviors, and has strong persuasiveness. The content of the questionnaire mainly includes two parts of personal attributes and parking behavior characteristic information survey, and a total of 640 valid samples have been obtained. Observation point survey is a survey of the number of parking in the parking lot and the traffic volume of the road connecting the parking lot.

3.1. Analysis of the personal attributes of the parking person
According to the survey results, the proportion of women who parked is higher than that of men, accounting for 54% of the total. This may be related to women’s preference for shopping; in terms of age structure, parkers are mainly distributed in the 25-45 age range, accounting for 87%, while the 18-25-year-old group only accounts for 13%; from the occupational attributes of the surveyed, it can be seen that the proportion of students is at least 7%, while the proportions of other occupations are relatively close; the other 16% are parking The proportion of parking users whose monthly income is below 3000 yuan, the monthly income between 3000-5000 yuan and 5000-7000 yuan is similar, the average proportion is 34.5%, and 16% have monthly income higher than 7000 yuan.

| TABLE I. Questionnaire items | Options       | Sample size/person | Proportion of each option/% |
|-----------------------------|---------------|--------------------|-----------------------------|
| gender                      | male          | 294                | 46%                         |
|                             | Female        | 346                | 54%                         |
| age                         | 18-25         | 83                 | 13%                         |
|                             | 25-35         | 166                | 26%                         |
|                             | 35-45         | 256                | 40%                         |
|                             | ≥45           | 134                | 21%                         |
| Personal attributes         | Mall staff    | 179                | 28%                         |
| Occupation                  | Corporate staff| 154               | 24%                         |
|                             | student       | 45                 | 7%                          |
|                             | Freelancers   | 147                | 23%                         |
|                             | other         | 115                | 18%                         |
| monthly income              | ≤3000         | 96                 | 15%                         |
|                             | 3000-5000     | 230                | 36%                         |
|                             | 5000-7000     | 211                | 33%                         |
|                             | ≥7000         | 102                | 16%                         |
3.2. Analysis of parking behavior characteristics

The parking feature is an index to evaluate the operation status of the parking lot, which can reflect the internal operation law of the parking lot. There are many indicators that can evaluate parking characteristics. In this paper, the four indicators of parking type, parking frequency, parking time, and parking duration are used as the evaluation indicators of parking characteristics.

a) The type of parked vehicles refers to the different types of vehicles in the parking lot. According to statistics, there are three types of parked vehicles, 84% of which are cars, passenger cars account for 12%, and the number of ordinary trucks parked is only 4% of the total.

![Figure 4. Types of parked vehicles](image)

b) The frequency of parking times refers to the parking frequency of vehicles in the parking lot. According to statistics, it can be concluded that the parking frequency has the highest proportion of once a week and once a day, respectively, 35% and 31%, which may be related to people's daily shopping habits and the travel habits of employees in the mall. The 18% parking frequency is two to three times a week, and the parking frequency is only 16% once a month. This shows that the parking frequency is still high among the parkers.

![Figure 5. Parking frequency chart](image)

c) The parking time refers to the time when the vehicle starts to park in the parking lot. According to the results of the questionnaire feedback, 7 am to 10 am and 16:00 to 19:00 are the highest proportion of parkers, and the sum of the two can be accounted for. The overall proportion is 55%, which may be related to the commuting period. The parking time is close to the ratio of 13:00-16:00 and 19:00-22:00, with an average of 15%. The lowest number of people who choose to park from 10 am to 13 am is only 6%.

![Figure 6. Distribution of parking time](image)
d) The parking time refers to the time the vehicle is parked in the parking lot. According to the results of the questionnaire feedback, 80% of the parking time exceeds 30 minutes, and 29% of the parking time data is between 30 minutes and 1 hour. 25% of the parking time data is between 1 hour and 2 hours, and the proportion of more than 2 hours is 26%.

![Figure 7. Parking time distribution](image_url)

### 3.3. Analysis of observation points

Through the survey of observation points, the cumulative number of vehicles arriving at the parking lot, the arrival of traffic at the entrance and exit of the parking lot, and the traffic volume of the road connecting the parking lot can be obtained. The number of vehicles in the parking lot is recorded in units of 15 minutes. Through continuous observation, the relationship between the number of vehicles in the parking lot over time is shown in Figure 4. It can be seen from the figure that the cumulative number of parking at 7 o'clock in the parking lot is the largest, and the number of parking at 7 to 9 o'clock shows a downward trend. There will be a local peak in the parking volume between 9 o'clock and 12 o'clock, and the number of parking from 12 o'clock to 20 o'clock is slow increase, and reach the peak of the number of parking in a day at 20 o'clock, and the number of parking between 20 o'clock and 2 o'clock decreased significantly.

![Figure 8. The cumulative parking volume of the parking lot](image_url)

The traffic statistics at the entrance and exit of the parking lot are taken to observe the number of vehicles arriving and departing at 15-min intervals. The results are shown in the following table:

At present, there are 2 entrances and exits of the parking lot, which are on Ganshui Road and Hengshan Road. The traffic flow statistics of its connecting roads are now carried out. The specific statistics are as follows:

| Table II. Connecting road information |
|--------------------------------------|
| **Road name** | **Connecting road grade** | **Number of lanes** | **Traffic** | **Lane width** |
|------------|---------------------------|---------------------|------------|---------------|
| Ganshui Lu Road | Secondary road | 4 | 655 | 3.5 |
| Hengshan Road | Secondary road | 6 | 935 | 3.5 |
4. Optimization of Traffic Organization Design

4.1. Entrance and exit queuing model calculation
When the vehicle arrives at the parking lot, if there are no vehicles in line, you can directly enter the parking lot to park, otherwise you need to queue for service. Therefore, the entrance and exit of the parking lot can be regarded as a system queuing model. Assuming that when vehicles arrive at the parking lot, they obey a Poisson distribution with a parameter $\lambda$, the parking queuing rule is a single-service waiting system, and the time to enter the parking lot is approximately satisfied with a negative exponential distribution with a parameter $\mu$.

Therefore, according to the queuing theory, it is available when the system is in equilibrium.

$$\lambda P_0 = \mu \cdot P_1, \quad (1)$$

$$\lambda (P_n - 1) + \mu (n + 1) (P_n + 1) = (\lambda + n \mu) P_n, \quad n \leq s, (2)$$

$$\lambda (P_n - 1) + \mu s (P_n + 1) = (\lambda + um) P_n, \quad n > s. \quad (3)$$

Note that:

$P_n$ is the probability that there are $n$ vehicles parked, and $s$ represents the number of available parking spaces. When the number of vehicles is greater than the number of available parking spaces, queues are required.

Correspondingly, relevant system indicators can be obtained, as follows:

Parking lot berth utilization rate:

$$\rho_1 = \frac{\lambda}{\mu}. \quad (4)$$

Average queue length $L_q$:

$$L_q = \frac{\lambda}{\mu - \lambda}. \quad (5)$$

Average queue time $T_q$:

$$T_q = \frac{L_q}{\lambda}. \quad (6)$$

According to the survey and observation, the average arrival rate of vehicles is 20 vehicles/h, and the passing time of each vehicle is 2 minutes. The average queuing length $L_q$ is calculated to be 2 vehicles, and the average queuing time $T_q$ is 6 minutes.

4.2. Optimization of external traffic organization
The Xiangfang Wanda parking lot is located at the intersection of Civil Aviation Road and Hengshan Road and Ganshui Road. The traffic volume is relatively large, especially in the morning and evening peak hours. There will be conflicts between the traffic flow on the road and the vehicles entering and exiting the parking lot. The entrances and exits of the parking lot lack no-stop signs and markings, and the yellow lines in the no-parking areas are not clear. These have caused vehicles to park at will and traffic jams. Therefore, no parking signs and markings should be added to the entrances and exits. In this way, the interference to the entry and exit of vehicles is avoided, which can alleviate the impact of road traffic flow due to the entry and exit of vehicles, avoid mutual interference between exit vehicles and entrance vehicles, and improve the efficiency of parking lots.

4.3. Optimization of internal traffic organization
The flow of people and vehicles in the parking lot is mixed, and the parking lot has a direct impact on the surrounding traffic environment. Therefore, the traffic order of the parking lot must be carefully designed and organized to ensure safety and minimize the impact on the surrounding traffic environment. Because the Wanda parking lot has two entrances and exits, the traffic flow lines can be used flexibly. For these problems of parking facilities, it is necessary to solve the problems through the internal traffic flow lines that can circulate through and reduce the number of vehicles entering and leaving the parking spaces.

Specifically, it is recommended to strictly implement pedestrian and vehicle isolation inside the parking lot to ensure smooth traffic flow; the entrance and exit of the parking lot should be connected.
to the pedestrian passage to minimize the walking distance; continuous and systematic parking guidance signs should be set up to facilitate finding parking spaces.

5. EVALUATION BASED ON FUZZY COMPREHENSIVE MODEL

5.1. Construction of evaluation indicators
Fuzzy comprehensive evaluation is based on fuzzy mathematics evaluation method, with clear results and hierarchical characteristics. In order to better evaluate the traffic organization of the parking lot, from a scientific, objective and comprehensive perspective, two factors, including the conditions of the road connecting the parking lot and the interior of the parking lot, are selected for evaluation. The influencing factors are shown in Table III.

| Evaluation index          | nature   |
|---------------------------|----------|
| Congestion level of the connecting section B₁ | Quantitative |
| Average vehicle delay B₂   | Quantitative |
| Machine non-isolation degree B₃ | Quantitative |
| Average queue length B₄    | Quantitative |
| Vehicle waiting time B₅    | Quantitative |
| Conflict points B₆         | Quantitative |

5.2. Model optimization evaluation
Based on the qualitative and quantitative factors involved in the evaluation of the parking lot, based on the statistical survey data, an evaluation model of the parking lot traffic organization plan is established.

(1) Determine the influencing factors. According to the fuzzy evaluation method, the influencing factors of the construction of the parking lot transportation organization plan are constructed. This article has 6 evaluation indicators and their corresponding values to describe.

(2) Normalized processing evaluation index. Since the meaning of each index in the evaluation plan is different, in order to facilitate the evaluation, its value needs to be normalized. The processing results are shown in Table IV.

| index | B₁ | B₂ | B₃ | B₄ | B₅ | B₆ |
|-------|----|----|----|----|----|----|
| Normalized result | 0.74 | 0.68 | 0.35 | 0.56 | 0.84 | 0.32 |

(3) Calculate the weight value of each evaluation index, construct the composite element of the evaluation index weight, and calculate the weight value of each index as shown in Table V.

| index | ω₁ | ω₂ | ω₃ | ω₄ | ω₅ | ω₆ |
|-------|----|----|----|----|----|----|
| Weights | 0.19 | 0.17 | 0.24 | 0.16 | 0.11 | 0.14 |

(4) Determine the evaluation value of the traffic organization plan

The comprehensive evaluation result is

\[ U = \begin{bmatrix} B_1 & B_2 & B_3 & B_4 & B_5 & B_6 \end{bmatrix} \begin{bmatrix} \omega_1 & 0.19 & 0.17 & 0.24 & 0.16 & 0.11 & 0.14 \end{bmatrix} \]

The available comprehensive plan value is 2.68.
6. CONCLUSION
Optimizing the parking lot traffic organization is a way to improve the use of parking lots. This article proposes parking lot traffic organization optimization measures and simulation evaluation methods based on the current status of parking at home and abroad, taking Xiangfang Wanda underground parking lot as the research object. Firstly, it summarizes and analyzes the current problems of the parking lot, and obtains parking characteristics and surrounding traffic characteristics information through on-site field investigation, and provides effective data for traffic organization optimization. This paper proposes improvement measures from three aspects of parking lot entrance and exit, internal traffic organization, and external traffic organization. Finally, the fuzzy evaluation model is combined to make effective evaluation. The results show that the parking lot has achieved better results after the optimization of traffic organization.

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