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Optimization of Parking Spaces

Zihui He, Yuanhao Ma and Yuliang Liu

School of Water Conservancy And Environment,China Three Gorges University, YiChang 443000, China

ABSTRACT. *Aiming at the optimal planning problem of parking lots with limited space, this paper, from the perspective of the existing economic and social background, establishes the optimization model of parking space arrangement, nonlinear integer programming model and module aggregation model to optimize the design of parking space arrangement.*

KEYWORDS: *optimization of parking space arrangement, nonlinear integer programming, module aggregation, arrangement and combination*

1. Introduction

With more and more family cars entering ordinary households, the contradiction between supply and demand of parking spaces has attracted more and more attention. How to plan the limited parking space reasonably, so that more vehicles can be parked, and it is easy for vehicles to enter and leave the parking lot, has become an urgent problem to be solved. Under this economic and social background, this paper probes into the problem of parking space planning.

The main goal of this paper is to construct the optimization system according to the plane schematic diagram of the parking lot. The overall research method is to establish the optimization model of the parking space arrangement mode by optimizing the parking space arrangement and parking angle in the parking lot, so as to realize the parking lot. Optimal design of parking space.

2. Analyse

Now take the family car as an example, suppose that the turning radius of the family car is 5.5 meters, the length is 5.5 meters and the width is 2.5 meters when parked vertically (including the parking space marking line).This paper will design a parking lot with a length of 79 meters and a width of 26.5 meters under the condition that the entrance and exit direction of vehicles is east-west. In this paper, an optimization model of parking space arrangement mode is established to

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maximize the number of parking Spaces, and the design scheme and plane diagram of the parking lot are presented.

2.1 Symbol description

Table 1 Symbol description

m: Number of parking spaces	n: Number of single row parking spaces
θ: Stop belt length	N: Angle between the long side of the parking space and the passage
k: Number of lanes	d: Lane width
p: Parking belt width	q: Total width of horizontal parking area
S: Total width of longitudinal parking area	L: Residual space area
L: Back-to-back parking belt width	

2.2 Analysis of General parameters and data processing

In order to conveniently represent the arrangement of parking spaces, we use to θ represent the angle between the long side of the parking space and the through lane.

Single emission optimization diagram:

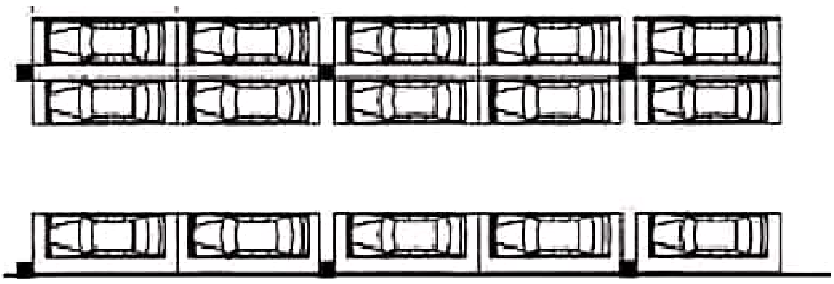

Figure. 1 Parallel discharge

It should be noted that each vehicle enters the parking space by parallel parking, which is a common situation in real life of roadside parking space, which is rarely seen in the general parking lot.

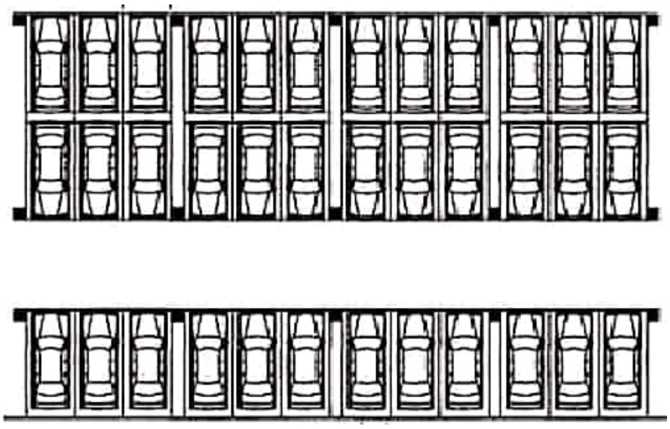

Figure. 2 Vertical emissions

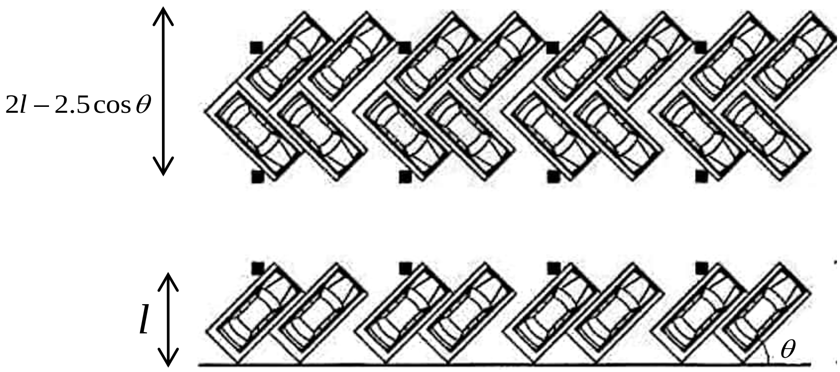

Figure. 3 Oblique emissions

It is to be noted that the width of the parking belt occupied by the single row of crossbars is l, but when the two rows of diagonal parking belts are together, that is, the back-back parking belts, their widths overlap, at which time the total width L = 2 l-2.5 cos θ,rather than 2 l.

Based on the actual situation of the car entering the parking space (shown in figure 4), the relationship between the width of the through lane d and θ can be calculated:

$$d = 5.5 - 3\cos\theta$$

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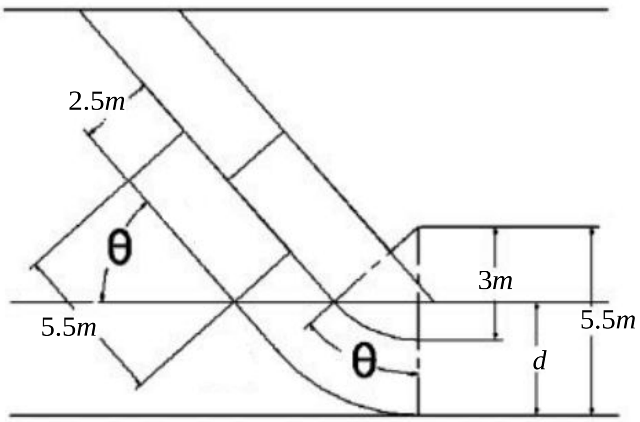

Figure. 4 Driveway trajectory of a car turning into a parking space

2.3 Model building

According to the design method of parking belt, we have carried on the following classification discussion:

(1) All parking belts are horizontal:

We regard the two parking belts with a through lane as a parking area, and fill the rectangular parking lot from north to south until the remaining space can no longer be put into the parking area. We can conclude that there are k_1 parking areas in the complete parking area.Then the remaining space is calculated:

$$k_1 = [\frac{26.5}{2l_1 + d_1}]$$

$$S_1 = (26.5 - k_1 d_1 - m_1 l_1) \times 79$$

Plug in the passageway and parking belt in the remaining space, end the process when no passway or parking belt can be placed, and calculate the number of parking spaces.

According to the above ideas, we establish the optimization model of parking space arrangement, and list the following objective functions and nonlinear constraints:

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$$Max\ \mathrm{m}_1 n_1$$

$$s.t.\begin{cases} N_1 = \dfrac{2.5(n_1 - 1)}{\sin\theta} + 5.5\cos\theta + 2.5\sin\theta \le 79 \\ k_1 d_1 + m_1 l_1 - (L_1 - l_1)m_1 / 2 \le 26.5 \\ d_1 \ge 2.5 \\ d_1 \ge 5.5 - 3\cos\theta \\ l_1 = 5.5\sin\theta + 2.5\cos\theta \\ \mathrm{L}_1 = 5.5\sin\theta + 8\cos\theta \end{cases}$$

(2) All parking belts are longitudinal:

Since the parking lot entrance and exit are located in the east and west direction, if the parking belt is all longitudinal, there is at least one through lane running through the east and west direction.

$$k_2 = [\frac{79}{2l_2 + d_2}]$$

$$S_2 = (79 - k_2 d_2 - m_2 l_2) \times 21$$

The other steps are the same as class (1), and so on, we get the following objective function:

$$Max\ \mathrm{m}_2 n_2$$

$$s.t.\begin{cases} N_2 = \dfrac{2.5(n_2 - 1)}{\sin\theta'} + 5.5\cos\theta' + 2.5\sin\theta' \le 21 \\ k_2 d_2 + m_2 l_2 - (L_2 - l_2)m_2 / 2 \le 79 \\ d_2 \ge 2.5 \\ d_2 \ge 5.5 - 3\cos\theta' \\ l_2 = 5.5\sin\theta' + 2.5\cos\theta' \\ \mathrm{L}_2 = 5.5\sin\theta' + 8\cos\theta' \end{cases}$$

(3) The parking belt is mixed horizontally and longitudinally:

In practice, if the horizontal and longitudinal mixed type is adopted, the position distribution of the transverse parking belt and the longitudinal parking belt will not be clearly divided. In order to facilitate understanding and calculation, we divide the rectangular parking lot into two, put all the horizontal parking belts on one side and all the longitudinal parking belts on the other side, so that the horizontal and longitudinal parking areas can be formed, and the number of parking spaces will not be changed.

The total width of the horizontal and longitudinal parking areas is p,q , the other steps are the same as (1), (2), and so on, we get the following objective functions:

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$$Max\ m_1^{'}n_1^{'}+m_2^{'}n_2^{'}$$

$$s.t.\begin{cases} p+q\le 21 \\ \dfrac{2.5(n_1^{'}-1)}{\sin\theta_1}+5.5\cos\theta_1+2.5\sin\theta_1\le 79 \\ k_1^{'}d_1^{'}+m_1^{'}l_1^{'}-(L_1^{'}-l_1^{'})m_1^{'}/2\le p(k_1^{'}=2m^{'}\ or\ k_1^{'}=2m^{'}+1) \\ \dfrac{2.5(n_2^{'}-1)}{\sin\theta_2}+5.5\cos\theta_2+2.5\sin\theta_2\le q \\ k_2^{'}d_2^{'}+m_2^{'}l_2^{'}-(L_2^{'}-l_2^{'})m_2^{'}/2\le 79(k_2^{'}=2m^{'}\ or\ k_2^{'}=2m^{'}+1) \\ d_1^{'}\ge 5.5-3\cos\theta_1\quad d_2^{'}\ge 5.5-3\cos\theta_2 \end{cases}$$

3. Results and discussion

3.1 Parking space design scheme

Table 2 Model results

Arrangement mode	θ (°)		Row number		Number of single row parking spaces		Number of parking spaces
	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	
Horizontal arrangement	51.02	48.96	3	1	19	20	77
Longitudinal type	45.78	33.58	3	1	15	16	61
Transverse and longitudinal hybrid	row	col	row	col	row	col	61
	53.07	47.67	3	7	18	1	

By comparing the table information, we can make sure that the horizontal row type and the angle and row number are consistent with the table is better than the longitudinal and horizontal and longitudinal hybrid type. At this time, the parking lot can have the largest number of parking spaces, which is 77.

Cause analysis: because the direction of entrance and exit of the rectangular parking lot has been stipulated, and the direction of entrance and exit is consistent with the direction of horizontal row, in order to go from west to east, it is necessary to open up another through lane from east to west, which means that the area left to the construction parking belt is further reduced, which is particularly disadvantageous to the purpose of increasing the number of parking spaces.

To sum up, the best design scheme in this paper is to adopt horizontal parking belt, in which there are 3 rows 51.02°and 1 row 48.96°oblique parking space.

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3.2 Plane diagram of parking lot

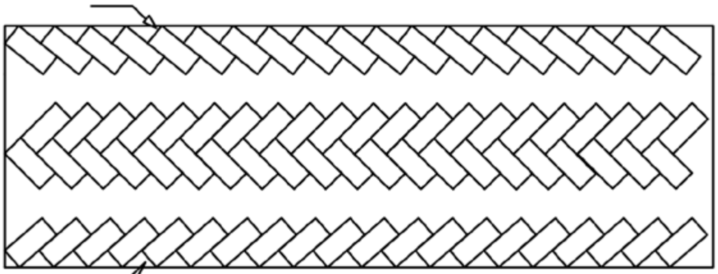

Figure. 5 Plane diagram of parking lot

4. Conclusion

Taking rectangular parking lot as an example, this paper provides a basic idea for optimal design of parking Spaces, which can inspire similar situations, but this situation is ideal. In real life, most parking lots are irregular in shape, which requires more consideration. The method mentioned in this paper can be applied to other similar problems such as warehouse cargo placement planning and store distribution, etc. If the two-dimensional plane model is converted into a three-dimensional model, it can also be applied to three-dimensional packing problems such as port terminal design.

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