

# Research on Intelligent Parking Operation and Management Planning Based on Revenue Model Function

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**Abstract:** With the development of the world, people's living standard has also improved significantly. At present, self-driving has become one of the popular ways to travel, but this improvement in living standard has also brought some problems such as "difficult parking" and "indiscriminate parking" to the society. In order to solve the problem, our country has launched the decision to develop smart parking. In the case of Shenyang, starting from 2018, due to the substantial growth of civilian car ownership in Shenyang, in order to alleviate the problems of "difficult parking" and "indiscriminate parking", the relevant areas in Shenyang began to develop smart parking. The current smart parking service mainly adopts two billing methods: mobile video collection vehicle billing and manual billing, and this paper analyzes the route planning and possible benefits of the smart parking service by establishing an appropriate mathematical model to obtain the final optimized design scheme.

**Keywords:** Smart parking; Mobile video capture vehicle billing; Manual billing; Python

## 1. Introduction

Under reasonable and necessary assumptions, considering only one parking space, a revenue model function is built to calculate the possible billing gains and losses that may result from mobile video capture vehicle billing. The solution is to build a mathematical function model and run it using python code to derive the relevant data[1].

We address certain areas of Shenyang, ranging from Shenyang Station-Taiyuan Street area (west to Shengli Street, east to Nanjing Street, north to North 5th Road (including the south side of North 5th Road), and south to South 8th Road). Based on considering the characteristics of the area, we eventually only need to analyze the specific time required for a scan car to go around and the number of scan cars for the two requested quantities, and establish a mathematical model to plan the mobile video capture vehicle's route[2].

Still still consider The region uses a two-dimensional scatter distribution diagram to establish a mathematical model to rationalize the toll collection method under different circumstances, and to re-plan the route of the mobile video capture vehicle in the section where manual toll collection has been determined[3]. On the basis of reasonable assumptions and consideration of necessary labor and volume maintenance fees and other costs (the service life of the vehicle is calculated by 10 years), an optimized comprehensive billing scheme is designed.

The continuous improvement of people's living standard and the quality of life have been changed dramatically, our travel mode has also changed dramatically, and we can clearly feel the pressure of resources as well as travel pressure[4]. Let's take an area in Shenyang as an example for analysis: with the continuous improvement of the living standard of Shenyang residents, the civilian car ownership in Shenyang reached 2.635 million by the end of 2020, among which, 2.334 million private cars were owned, and the per capita car ownership ranked the tenth in China. The growth of car ownership has brought great convenience to the transportation of citizens, but at the same time, it has also brought considerable pressure to road traffic and parking.

Since 2018, Shenyang City has started to develop smart parking in order to alleviate the problems of "difficult parking" and "indiscriminate parking". The "smart parking" uses Internet technology to realize the functions of finding parking spaces, booking parking spaces, route navigation, shared parking, automatic timing, and sensorless parking. At present, smart parking mainly uses the inventory of existing resources to provide parking services, parking billing methods are mainly mobile video collection car billing and manual billing two. For different road sections, we set different billing services, design the parking scheme as reasonably as possible, adopt the optimized billing

method, and improve the effectiveness and reliability of the smart parking management service is what we need to consider[5-7].

## 2. Model building and solving

### 2.1 Revenue function model

#### 2.1.1 Model Building

First of all, we make reasonable assumptions about the question: assume that the scanning interval of the scanning car is 30min, and since the question has divided the areas and car models we are about to process and analyze, we set the class I, class II and class III areas as  $A_1$ ,  $A_2$  and  $A_3$  respectively, and the small and medium-sized cars and large cars as  $x_1$  and  $x_2$ , and the number of times the scanning car scans the same car is  $n$ . We assume that the scanning We assume that the scanning car can input the number of scans  $n$  and the parking lot parking class  $A$  and the corresponding car type directly into the Python code of our calculation, we execute different conditions of the if statement according to the different input information, and finally, according to the result of the sum of the accumulation, we can calculate a quantity of car in a parking lot charges. We input the function into Matlab to plot the solution. At the same time, for new energy vehicles we handle it differently, that is, we only need to divide by 2 on the basis of the final charge result, that is, the charge result of new energy vehicles. If the owner of the parking space chooses "monthly" parking, 600 RMB/month for the first class area, 400 RMB/month for the second class area, and 180 RMB/month for the third class area, the charge is fixed[8].

#### 2.1.2 Model solving

For different areas, different vehicles and the number of times they are scanned, we analyze the gain function separately and compile it on Matlab software to obtain the corresponding gain function relationship, which is very intuitive and clear for solving the problem. Figure 1 shows the mathematical model of the revenue function.

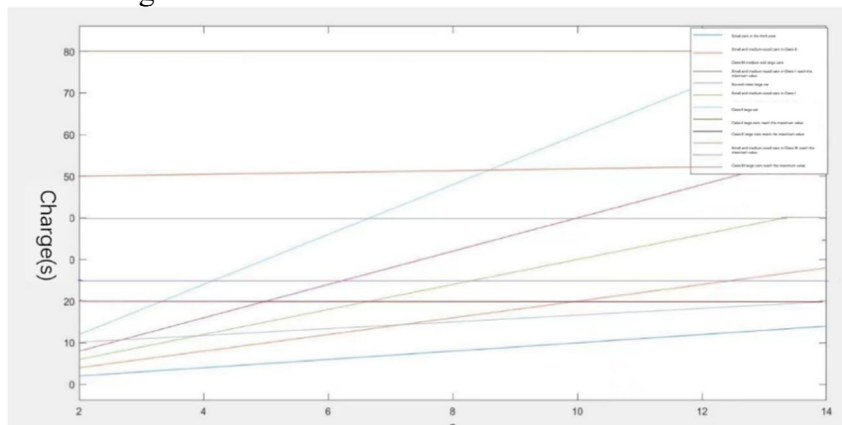


Figure 1 Mathematical model of the revenue function

### 2.2 Mathematical model for planning the route of a mobile video capture vehicle

#### 2.2.1 Model Building

Since the smart parking scheme firstly has different rates for different areas, the Shenyang Station-Taiyuan Street area (west to Shengli Street, east to Nanjing Street, north to North 5th Street (including the south side of North 5th Street) and south to South 8th Street) given in the title needs to be divided.

On the basis of getting the area map, the specific discussion of each type of area is carried out. As different areas of parking spaces, vehicle parking hours will have different characteristics, more typical are: near residential and work units, vehicles may be parked for a long time; near commercial areas, the vehicle parking hours in the middle; and near fast food restaurants and farmers markets[9], etc., may be parked for a short time. So the whole big area needs to be divided according to the

characteristics, and discuss the characteristics you meet in each area separately, and on this basis the route planning of the video collection vehicle is carried out to give the required number of vehicles.

#### 1. Planning of a class one area

The class area belongs to a class area in the peace area on-street parking, in the class area has been found on the parking space route labeling, to get the existing parking space route as Figure 2.

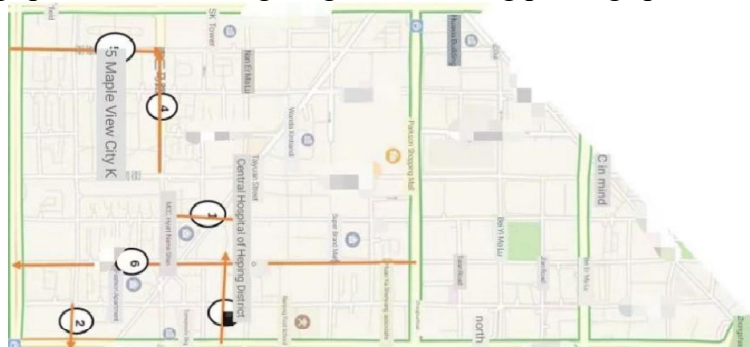


Figure 2 Class I area parking space distribution map

#### 2. Planning of Class II area

This type of area belongs to the on-street parking lot in the second class area of the peace zone, and the route of the parking space is also marked on the found second class area, and the route of the existing parking space is shown in Figure 3.

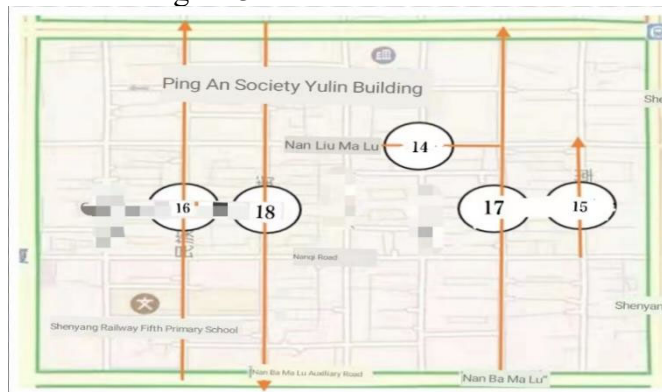


Figure 3 Class II area parking space distribution map

#### 3. Planning of Class III areas

This type of area belongs to the three types of on-street parking in the peace area, and the route of the parking space is marked on the found type of area to get the route of the existing parking space as Figure 4.



Figure 4 Three types of regional parking space distribution map

### 2.2.2 Model solving

We assume that there are parking spaces along each street and the length of the parking spaces is assumed to be 6 m. After the division, we calculated the length of each path separately and formed a closed curve (for the scanning route of the scanning vehicle) for the relevant paths. We performed

the path planning separately for the scanning vehicles in different zones. The purpose of these steps is to find the solution that minimizes the number of scanning vehicles needed and maximizes the number of scans.

Based on the total distance of the route we want to travel measured according to the figure, because the speed of the collection vehicle is certain, so we may assume that the speed of the collection vehicle is  $v$  m/s, so that the time of each section of the journey we can calculate, respectively,  $t_1, t_2, t_3, \dots$ , and then according to the type of different lots, the length of the parking time, set the relevant detection vehicle travel The interval time  $T_1, T_2, T_3$ , and then compare the detection car in the road travel time and detection interval, if  $0 < t_1 < T_1$ , send a detection car on; if  $T_1 < t_2 < 2T_1$ , then send two detection cars in the corresponding interval to share the interval, and then the corresponding analogy

The designed roadmap is shown in Figure 5-7.

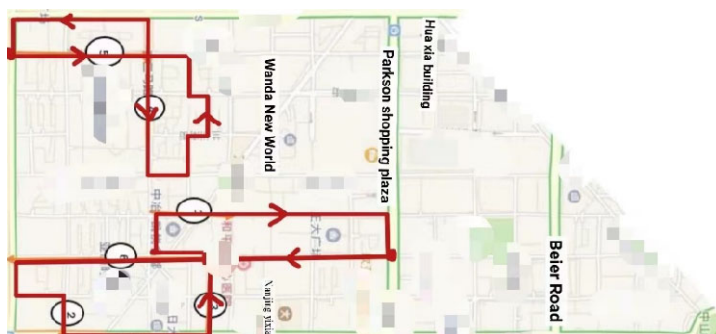


Figure 5 Class I regional mobile video truck collection route

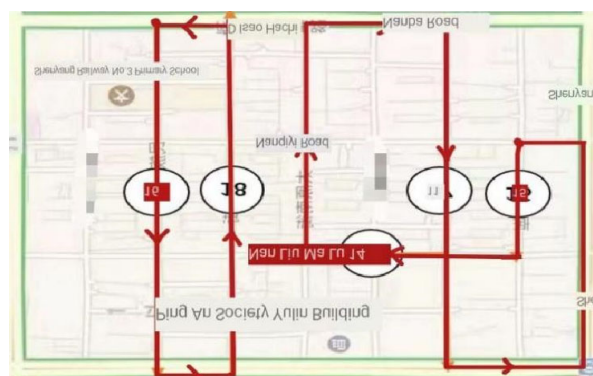


Figure 6 Class II regional mobile video truck collection route



Figure 7 Class III regional mobile video truck collection route

Ultimately, according to the design of the route, taking into account the collection vehicle travel, a class I area is recommended to require five collection vehicles, a class II area requires three collection vehicles, and a class III area requires three collection vehicles.

## 2.3 Mathematical modeling using two-dimensional scatter plots in the region

### 2.3.1 Model Building

We collect the relevant data about how much the number of traffic flow of parking spaces in three types of districts in Shenyang on the network, and by analyzing the data, we can design the relevant two-dimensional scatter plot through Matlab. Through the analysis of the two-dimensional scatter plot, we can know that the number of point traffic flow is positively related to the number of collected cars[10]. The scatter plot of the relationship between the change of traffic flow and the number of scanned cars is shown in Figure 8.

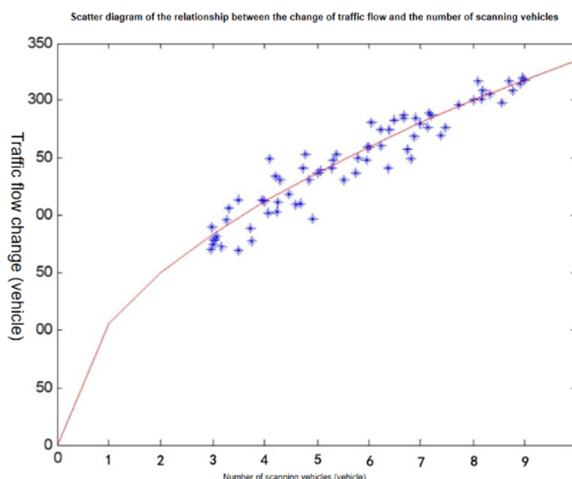


Figure 8 Scatter plot of traffic flow variation versus the number of scanned vehicles

Let's assume that

Let us assume that the value of the change in the number of parkings at nine time points on a given day in a Class III area is set to the matrix A.

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \quad (1)$$

Assuming that we have enough acquisition vehicles to scan, we set the 9 times interval matrix T of these working scanning vehicles.

$$T = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix} \quad (2)$$

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} * \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix} = C \quad (3)$$

where C matrix is the change in the number of vehicles during this day.

If  $C < 0$ , then we need to add more collection vehicles in that time period, if  $C > 0$ , we don't need to increase the number of collection vehicles.

### 2.3.2 Model solving

On the basis of the known actual distance of the road section concerned, we looked up the information and concluded that it takes about 2-3 min for a normal person to walk 200 m. Therefore, for the actual length of the road section  $< 600$  m, manual billing is used. The road sections marked as 1, 2, 3, 14, 15, 76, 79 use manual billing. The rest are billed using the video mobile car, so the route of the mobile video collection vehicle planned in question two should also be changed, and the re-planned route is shown in the following figure.

The red line segment in Figure 9-11 represents the video capture vehicle billing method, and the blue line segment represents the manual billing method.

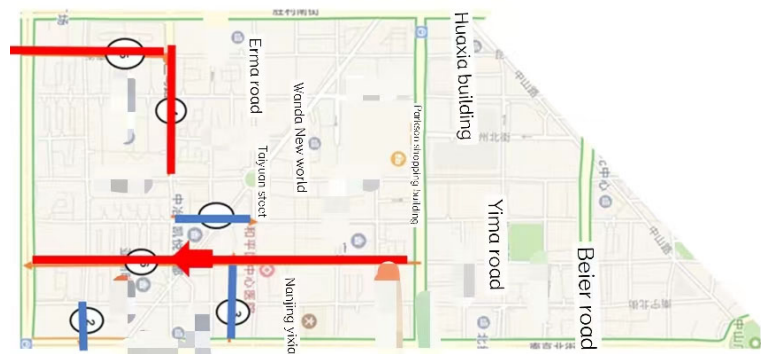


Figure 9 Roadmap for the redesign of a class I area

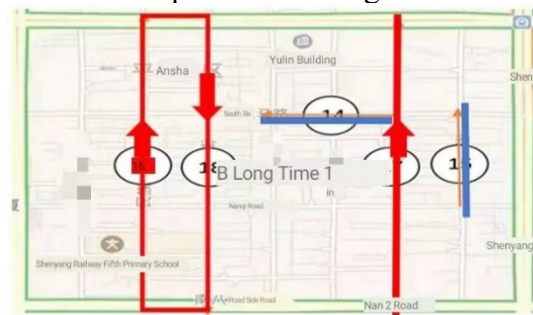


Figure 10 Roadmap for the redesign of a class II area

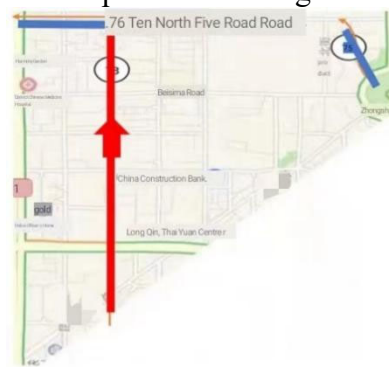


Figure 11 Roadmap for the redesign of a class III area

Consideration of cost.

Labor costs: mainly including the salaries and welfare costs of the acquisition personnel, the purchase and depreciation costs of the electronic equipment required by the acquisition personnel, and the office space for the acquisition personnel, etc.

Vehicle costs: fixed loss of fuel, maintenance costs, and depreciation costs of mobile video acquisition vehicles, wages and welfare costs of personnel driving acquisition vehicles, etc.

## 4. Conclusion

The current smart parking service mainly adopts two billing methods, mobile video capture vehicle billing and manual billing. In this paper, the route planning and possible gains of the smart parking service are analyzed by establishing an appropriate mathematical model, and the final optimized design scheme is obtained. First, for a parking space, the possible gains as well as losses from its detection are analyzed. Firstly, the gains are analyzed. Since the actual problem is divided into different time periods, different types of areas, and different car models, we use flowcharts for logical analysis, and then use python to code the different cases to calculate the possible gains, and also discuss the losses arising from the uncertainty of the detection time in the process. Secondly, the actual road length is mapped according to the characteristics of typical areas, and the number of parking spaces and the moving speed of mobile video acquisition vehicles are assumed, whereby the acquisition time and interval time of the acquisition vehicles are obtained, and then a reasonable

number of vehicles and acquisition routes are determined. Finally, re-planning of certain road sections, using manual billing method on the road sections with short distances and few parking spaces, and using mobile video collection vehicles on the road sections with long distances and denser parking spaces, and then re-routing the three areas and considering certain costs, designing a comprehensive billing scheme and giving the related gains and losses.

## References

- [1] Yan Huijia, Research and design of laser distance measurement based smart parking management system, Laser Journal [J], Vol. 8, No. 40, 2019
- [2] Lijun Tang, Modeling research of intelligent parking system, School of Mathematics and Computer Science, Ningxia University
- [3] Ma Snap Yun, Research on the interaction design of smart parking system in the context of smart city, Hebei University of Technology
- [4] Bai Qizheng, Mathematical Modeling Case Study [M], Ocean Press, 2000
- [5] Daoyuan Zhu, Selected Cases in Mathematical Modeling [M], Science Publishing House, 2003
- [6] Cai Lockzhang, Mathematical Modeling: Principles and Methods [M], Ocean Press, 2000
- [7] Li Junyu. City-level smart parking platform based on big data [J]. Internet of things, 2020, 10(1):83-87
- [8] Fu Hui. Smart city construction starts from smart parking [J]. Strait Science and Industry, 2014, (7):86-90
- [9] He Yang. A preliminary investigation of intelligent parking management application [J]. Reform and Innovation, 2021, 35(1)
- [10] Liu Na. Urban intelligent parking[J]. Urban governance and planning 2018, (12)