

Strategies of Improving the Efficiency of Allocating Parking Slots in Shudeli Community of Nanjing City

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Abstract: Due to the continuous growth of the amount of vehicles that households possess, the scarcity of easily accessible parking slots has gradually become a universal issue, especially in old communities that are usually lack of standardized administration. Thus, how to enhance the efficiency of arranging parking slots within limited public areas has become a concerned social issue in Chinese cities nowadays. As a zealous and supportive member of Shudeli community, the author tries to find the most suitable strategies of improving the efficiency of allocating parking slots here by learning from existing advanced community planning from both foreign and domestic researchers, while applying the knowledge of Economics and Business Management to obtain a final scheme which fits the local circumstances best.

Keywords: Community re-planning, Pareto optimality, price elasticity of demand, investment return.

1. Introduction

Shudeli community, an old and typical community in Nanjing City, has outdated design of traffic roads together with poor property management. Therefore, several problems are elicited, such as no parking slots available for some new residents who move to the community later than others, which creates unfairness. However, most parking slots are idle in the morning when residents go to work; since Shudeli community locates near the downtown where lots of people drive here for work and therefore has a great demand for cheap parking slots, such spare capacity in the community indicating a misallocation of scarce resources. Through research, the author came up with three measures that managed to yield 357 new parking slots, and creatively formulated a method that could improve the utilization efficiency of parking spaces by leasing out vacant parking slots to people outside the community at daytime. The author is an economic student of the IB program, so the innovations are proposed from a rational economic well being's perspective, aiming to maximize the benefits to all stakeholders and therefore help the community to achieve the state of Pareto optimality in resource allocation; the property management company that has one vote-veto in community re-planning is a commercial organization, so its ultimate purpose is to maximize the total revenue that it could possibly gain. To determine the most suitable charges for temporary parking slots leased out, the author conducted a series of experiments to calculate the price elasticity of parking demand by setting a different charge each time and recording the corresponding occupation changes. Since the final result is inelastic, the author's hope of providing more quantity available is contradicted with the property management company's goal of increasing the per unit price. After strenuous negotiations, a compromise was made, and the charge was set at the median level of all prices tested. Finally, the author used a mathematical function to calculate the investment return period for the property management company.

2. Literature Review

Professor Sloman's illustration of Pareto optimality in his Economics inspired me to regard community planning as a part of market economy. In fact, the concept should be the ultimate goal of Shudeli community's parking arrangement. Three months ago, there was obviously much room for improvement for the three main stakeholders within the community: for the property management company, the stacking of sundries that occupied some interior roads was easy to cause a fire while other vacant areas could not bring any revenue but constantly produce additional costs of operation; for the residents in Shudeli Community, unreasonable planning of driveways greatly prolonged their commuting time, and some of them would drive to work, leaving free parking slots that could be better utilized at daytime; for people not belong to Shudeli community (mentioned as the "outsiders" in this essay), some were in need of long-term fixed parking slots because they worked near this place while some temporary irregular demand for cheaper parking areas also existed. It is clear that by then, it was possible to allocate resources better in order to benefit one stakeholder without making any other stakeholders worse off. Instead, if the community planning could be redirected, and waste could be minimized, the efficiency of allocating parking slots was to be optimal, leading the whole community's service provision into an ideal situation where every member benefits the most—Pareto optimality.

As for the theory of parking planning in urban residential areas, foreign research has been carried out relatively early, especially in some developed countries with high automobile manufacturing level, where a large number of relatively mature approaches to efficiently arranging parking slots within an enclosed district have been formed. For example, the American Society of Transportation Engineers takes the parking ratio index as the main content of the theory. However, research on community planning in China started relatively late. Until the 21st century, the surge of ownership of vehicles began to incur traffic problems in metropolis, provoking experts' attention to subsequent parking difficulties. In solving the problem of community parking, domestic scholars

Zheng Jianfei and others proposed to adjust the methods and standards of motor vehicle parking fees and establish a scientific and reasonable parking price system; Scholar Li Jianing emphasized increasing the supply of parking spaces can enhance the utilization of open areas; Scholars Duan Liren and Mao Lizeng put forward constructive thoughts on parking concepts, parking legislations, parking management and parking charges, but there is a lack of analysis regarding the interrelationship between different charges and the corresponding occupancy.

It is Professor Gregory Pierce's evaluations on the SFpark program, a proved successful innovation that determines the optimal pricing for parking in San Francisco, specifically enlightened me to apply the knowledge of the price elasticity of demand to set the right parking price for the stakeholder "outsiders", which would obtain the largest total revenue from parking charges that could be considered as an extra source of income for the community. Trying to imitate the experiment method of the SFpark program but in shorter time intervals, I planned to conduct a series of trials to examine the responsiveness for parking slots of "outsiders" during daytime and acquire the accurate per hour charge of parking for them.

3. Methodology

3.1. Data Collection

This essay mainly collects data through a survey and an experiment.

3.1.1. Survey Method

By designing a list of detailed questions, the author aims to document the general utilization of parking areas within the community before and after the re-planning of parking slots. The objects of the investigation are the residents living in Shudeli community, and I entrust the task of carrying out the survey to property managers of the community. The survey is actually executed in three ways: online questionnaire distribution, face-to-face investigations, and telephone return visits. According to the executors, 99% of residents have participated in the survey through one of the ways.

3.1.2. Experimental Method

In order to precisely analyze the price elasticity of demand, the author heavily relies on the support of the community to my re-planning scheme to conduct a series of trails in nine months. Starting at an initial price of ¥4/h, the author increases the price by ¥0.5 every week until it reaches ¥8/h and then record the number of parking lots rented each trial. In this experiment, the property managers of the community are still the main executors. Automatic surveillance equipment, one of whose functions is license plate identification, and the routine registration at three guard booths here are used to document the exact number of cars that occupy parking slots in Shudeli community in the morning and the corresponding time that each car stays. To further guarantee the preciseness of the statistics, a particular property manager is asked to select a random sample of one day's parking data from every two weeks' data collection, and then check its accuracy using the playback of the monitors at several gates.

3.2. Data Processing

When constructing graphs and using quantitative methods for data processing, this essay pays attention to minimize the impact of possible errors, ensuring reliability and validity of

the experiment results.

3.2.1. Before Data Processing

The main focus of this article is the establishment of a general function that estimates the overall income that the community could gain after the redirection of the parking areas.

3.2.2. During Data Processing

After receiving the complete data collection from the executors, extreme outliers are discarded, and a best-fit line of the demand is constructed based on the original scatterplot. To minimize possible errors by ensuring an obtaining of the same elasticity between two price points whether there is a price increase or decrease, the midpoint method is used to calculate the approximate price elasticity of demand for parking slots that would be provided for "outsiders" based on the best-fit line. The equations used are illustrated as following:

$$\begin{aligned} \text{Price Elasticity of Demand} &= \frac{\text{percent change in quantity}}{\text{percent change in price}} \\ \text{Percent change in quantity} &= \frac{Q2 - Q1}{(Q2 + Q1) \div 2} \times 100 \\ \text{Percent change in price} &= \frac{P2 - P1}{(P2 + P1) \div 2} \times 100 \end{aligned}$$

After calculation, if the absolute value of PED is greater than 1, then the "outsiders" are relatively sensitive to any increase in the parking charge, so decreasing per hour parking charge seems the best way to maximize the total revenue that could be earned; in comparison, if the absolute value of PED is less than 1, then the "outsiders" are relatively insensitive to any increase in the parking charge, so increasing per hour parking charge seems the best way to maximize the total revenue. There's the possibility that the absolute value of PED equals 1, representing a unit elastic situation which is very rare in real life.

3.2.3. After Data Processing

The optimal parking charge for "outsiders" who want to park their cars within Shudeli community can be derived from the PED. In theory, the efficiency of allocating parking slots can be greatly improved towards the Pareto Optimality. In reality, some evaluations will be made concerning some inaccuracy during data collecting and processing stages.

4. Basic Information

Shudeli community is located in Qinhuai District, Nanjing City, with an area of about 0.1 km², adjacent to Qinhuai River in the East, Santiao Lane in the west, Fucheng Lane in the south, and Zhongshan Road in the north. There are 88 residential buildings, 2800 households, and 10020 permanent residents owing a total of 935 private cars in the community. Since it is close to the city center, 93 shops also locates near it.

This area is dense with narrow internal roads, and there are many shops on both sides of the roads. Regions other than residential buildings mainly include traffic lanes, green landscapes, a small number of parking spaces, garbage stations, some infrastructure and public facilities, accounting for about 40.2% of the total area.

The east of the community is close to the Qinhuai River, with a total of 16 entrances. Vehicles enter the community from 5 main entrances, while the rest 11 entrances are entrances for pedestrian. The main carriageway is four roads

in the north-south direction. Other internal lanes are narrow and difficult for vehicles to pass, often causing traffic jams.

After continuous observation, I find the vehicles parking in this area can be sorted into 3 categories: (1) internal parking

by residents who live in Shudeli community, (2) regular external parking by people who work in two nearby public institutions and the surrounding shops (3) irregular external parking.



Figure 1. Basic information about Shudeli Community

5. Problem

Lack of spaces elicit unfairness among residents living in Shudeli community, as some of them own individual parking slots while others who enter the community later no longer have parking slots available. Moreover, many residents leave free parking slots in the community during daytime while lots of “outsiders” are in urgent need of cheap parking spaces (the parking charges in city center are usually very high), so it’s a misallocation of resources without intervening to make a change.

6. Solution

357 parking spaces can be increased through the following

three measures:

(1) The property company should implement complete identification system for the vehicles parked in the area, and then assign certain workers to check whether each vehicle owner is also the house owner living in the community. Then, by cleaning up zombie vehicles and external vehicles, 34 new parking slots can be created.

(2) Re-plan the traffic routes in the area, transform all traffic lanes into one-way roads, and close 7 unnecessary, narrow entrances among the original 17 entrances. After such reconstruction, 175 parking spaces can be yielded. As shown below, the left part represents Shudeli community before the remediation, while the right part represents Shudeli community after remediation.



Figure 2. Traffic roads in Shudeli community before and after remediation

(3) Distribute different parking slots to different cars based on their sizes. Cars are divided into two groups: group A cars are 3.85-4.35m long and group B cars are 4.55-4.9m long. Accordingly, parking slots will be reconstructed in two lengths—4.5m and 5m, and the two types of parking slots will be built based on the ratio of two types of cars. Therefore, the limited spaces can be better utilized, and 148 new parking slots can be created.

7. Analysis

According to the investigation results, 535 owners of the 700 parking slots are people who drive to work. Their parking spaces are therefore generally vacant from approximately 8:30 a.m. to 5:30 p.m. on weekdays, so they can be leased out to “outsiders” during the time. Since there are about 200 officers working in nearby institutions who have stable

demand for parking during this period, a total of 232 real-name parking permits can be issued to them with a fixed fee for each. The remaining 253 vacant parking slots are opened to the public as temporary parking spaces during the same period. Furthermore, because there are many old people living in the community, 50 gratuitous parking slots are reserved for the family members of the elderly who drive here to visit them sometimes.

7.1. Cash Inflow

After the community rearrangement is executed, the number of parking slots is increased from 343 to 700. The parking charge for residents living in Shudeli community is ¥150/month, and the parking fee charged for each parking permit is ¥300/month. Suppose that among the remaining parking slots, about 150 ones can be leased out for an average

of 5 hours every day for all 22 workdays in one month at the price of ¥5/h (the reason for the assumption of price will be explained later). Other components of cash inflow mainly include property management fees and advertising revenues.

input. Fixed input includes the construction of basic infrastructure and equipment such as more guard booths and more monitors. Variable input includes labor costs and other management costs.

7.2. Cash Outflow

The cash outflow is divided into fixed input and variable

Table 1. Estimation of monthly cash inflow after parking re-planning

Subjects	Quantity	Unit price	Total cash inflow
Parking charges for residents	700 units	150 yuan	105000 yuan
Regular fees of parking permits	232 units	300 yuan	69600 yuan
Charges for temporary parking slots	150 units	550 yuan	82500 yuan
Property management fees of residential buildings	196000 m ²	0.5 yuan/m ²	98000 yuan
Property management fees of other buildings	5000 m ²	1 yuan/m ²	5700 yuan
Advertising revenues	5 billboards	4000yuan/billboard	20000 yuan
Total cash inflow: 0.3808 million yuan			

Table 2. Estimation of monthly cash outflow after parking re-planning

Categories	Subjects	Quantity	Unit price	Total cash outflow
Fixed Input	Guard booths	5 units	20000 yuan	100000 yuan
	The control center	1 unit	300000 yuan	300000 yuan
	Electronic gates	11 units	18500 yuan	203500 yuan
	Monitors	120 units	3000 yuan	360000 yuan
	Smart trash cans	15 units	3000 yuan	45000 yuan
	Small playgrounds	2 units	50000 yuan	100000 yuan
	Removing unauthorized building works, improving virescence, and etc.	/	/	1000000 yuan
	Other fees (including maintenance)	/	/	903000 yuan
Total cash outflow of fixed input: 3.0115 million yuan				
Variable input	Labor costs	/	/	201500 yuan
	Other management costs	/	/	49500 yuan
Total cash outflow of variable input: 0.251 million yuan				

The general function that models the monthly cash inflow can be constructed as: $z=298300+110xy$, where z represents the total revenue earned by the community every month, x represents the per hour charge for temporary parking slots, and y represents the actual number of parking slots that are leased out every day. For the estimated situation above, x is considered to be 5 while y is the corresponding constant number 150.

However, in reality, situations vary a lot. Depending on the responsiveness of “outsiders” to the changes in charges of temporary parking slots, whether most of them would accept the charge directly determines the actual occupation rate of the vacant parking slots and therefore the extra revenue that Shudeli community may obtain. Therefore, 9 trials were

conducted to test the price elasticity of parking slot demand. Since previous investigation shows that the per hour charge in other parking areas near the city center is ¥9/h for light-duty vehicles and ¥11/h for medium-duty vehicles while most of the cars parking in Shudeli community are light-duty vehicles, so the upper limit of the parking charge is set as ¥8/h, a bit cheaper than the current market price. Since there is an underground station 1 km away from the city center and the average fees of medium-distance journeys taking the underground is ¥4 in Nanjing, so the lower limit of the parking charge is set as ¥4/h. The data collected is displayed in the following table.

Table 3. Raw data of 9 trials

Per hour charge for temporary parking slots (yuan)	Average daily quantity of parking slots leased out	Total revenue (yuan)
4	168	372200
4.5	158	376500
5	150	380800
5.5	143	384800
6	136	388100
6.5	132	392700
7	126	395300
7.5	124	400600
8	122	405700

Based on the data, a scatterplot is created to show the relationship between per hour parking charge and the average

daily quantity of parking slots leased out, and a best-fit line of demand is also drawn.

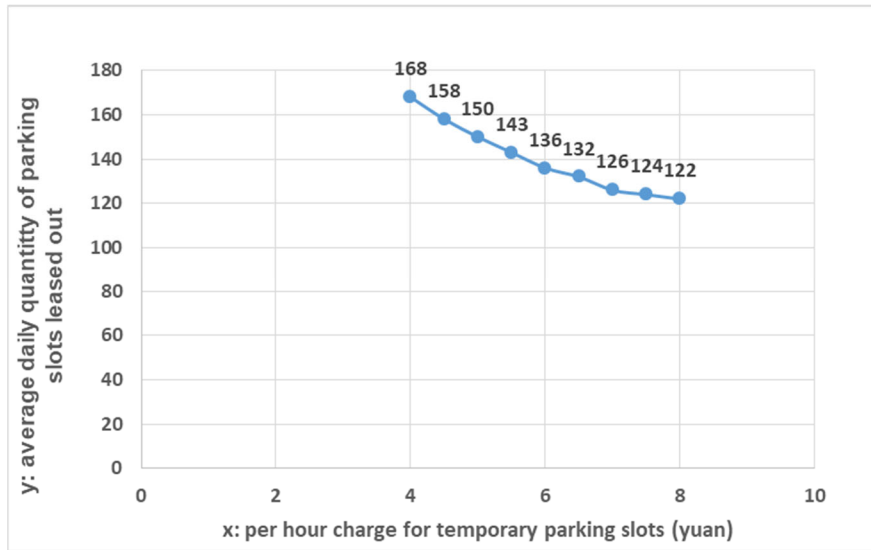


Figure 3. PED of free parking slots in Shudeli community

By using the midpoint formula, the overall PED was calculated to be approximately -0.951, which proves a relatively inelastic relationship between the per hour parking charge and the average daily quantity of parking slots leased out. Since the demand is inelastic, increasing the per hour charge as much as possible is the best way to maximize the total revenue, which also fits the trend represented in Table 3: as shown in Table 3, the maximum total revenue 405700 yuan takes place at the charge of ¥8/h, while the minimum total revenue 372200 yuan takes place at the charge of ¥4/h, producing a total difference of 33440 yuan between the two.

Thus, to maximize the total revenue by renting temporary parking slots and therefore the cash inflow gained by the community, the per hour parking charge should be set as ¥8/h for the “outsiders” who want to park their cars in cheaper parking spaces.

However, in this case, Pareto optimality cannot be achieved. This is because there are still many resources left unused if the per hour parking charge is set too high, and the demand of “outsiders” is still greatly unsatisfied. In the hope of both improving the utilization efficiency of parking slots and increasing the possible revenue earned by renting them, the author and the property management company negotiated three times and eventually decided to set the charge at a median level: ¥5/h. That’s why x is considered to be 5 for the specific situation displayed in Table 1.

Finally, to calculate the investment return period, Table 1 and Table 2 are used. The estimated monthly total cash inflow is 0.3808 million yuan, while the estimated monthly total cash outflow of variable input is 0.251 million yuan, so there’s an overall cash inflow of 0.1298 million yuan every month, which generates an overall cash inflow of 1.5576 million yuan every year. Based on the data, we can make the conclusion that the period of investment return is 1.93 years, which means that this re-planning is going to make profits for the community after about 23 months and 5 days.

8. Evaluation

To simplify the procedures while doing the experiment for determining the optimal charge, some estimations are boldly made, which may incur inaccuracy towards the final result.

8.1. Estimation of the Daily Quantity of Parking Slots Leased Out

Since each of the author’s trial persist for one entire week, the daily quantity of parking slots leased to the “outsiders” can only be derived from calculating the mean quantity of parking slots leased out during the seven days. The equation used here is

$$\text{average daily quantity of parking slots leased} = \frac{Q_1+Q_2+Q_3+Q_4+Q_5+Q_6+Q_7}{7}$$

8.2. Estimation of the Occupation Time of Each Temporary Parking Slot

When counting the time that each car stay in a temporary parking slot, it’s impossible to build a general function regarding the cash inflow if each individual time period is taken into consideration. Therefore, the author calculated the mean occupation time of each vacant parking slot, which is 5 hours per day, to be used as a component of the function. The occupation data is collected only from 8:30 a.m. to 5:30 p.m. when most residents leave for work, and this is another general prediction that has subtle variations every day.

8.3. Overgeneralization when Calculating PED

In fact, the price elasticity of parking demand varies with different time periods even during one day. It seems that “outsiders” are less responsive to changes in charges in the morning because those who are in need of temporary parking slots during this time period usually go to the city center for working purposes. Therefore, many of them can apply for reimbursement later, so different parking charges have little significance to their decisions. In comparison, “outsiders” tend to be more sensitive to changes in charges in the

afternoon because such groups of people usually go to the city center for relaxation purposes and they themselves should undertake the parking fees. However, the author didn't differentiate between different time periods within a day in my experiment; instead, the smallest unit of time when calculating the quantity of parking slots leased out is one day.

8.4. Limited amount of Samples and Limited Testing Time

The author selected the range of charges to test based on the factor that influences the price elasticity of demand of a certain object, which is the availability of close substitutes to that specific object. In this experiment, the two substitutes of parking slots in Shudeli community are other parking areas nearby and another form of travelling—travelling by the underground. However, to further improve the completeness and accuracy of the result, the destined range can be bigger, and more subtle price changes should be made each time (for example, rather than increase ¥0.5 each time, one can increase ¥0.1 each time). Furthermore, the enduring period of each of my trial is relatively short, which means that many may even not have time to notice the price change before the next trail already starts. Instead, longer testing intervals should be chosen.

9. Conclusion

By establishing identification system for vehicles, re-planning traffic routes, and distributing different sized cars to different parking slots, more parking slots can be created, generating more resources available for allocating. Meanwhile, by leasing out vacant parking slots during daytime to “outsiders”, the overall efficiency of utilizing scarce spaces in Shudeli community can be enhanced.

There's still some room for improvement in the future:

9.1. Technical Assistance

The property management company can construct an online tool, such as a Wechat mini program, to report the in time occupation of parking slots. Therefore, users can easily find how many parking slots are still available whenever they

want, and check during what time the most amount of parking slots is free for leasing. Such technical assistance is able to present information more directly and clearly, hence matching different sides' demand, generating more revenue.

9.2. Benefiting the Residents Within the Community

Due to the execution of the community re-planning, two stakeholders are obviously benefited: the property management companies and the “outsiders”. However, there's not yet apparent gains for the third stakeholder—the residents. In fact, as long as the property management company starts to make profits, it can give compensations to the residents who lease out their parking slots to “outsiders” at daytime by abating part of the regular parking charges for them. One thing to emphasize is that every piece of compensation for a parking slot owner can be no more than ¥150/month for the purpose of avoiding adverse selection, since otherwise the resident may lease out his or her parking slot regardless of whether he or she is also in need of the parking slot.

Overall, if eventually all three stakeholders are better off, Shudeli community's situation will move one step closer to the ideal situation of Pareto Optimality.

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