

Countermeasure Analysis of Urban Basic Parking Space Shortage Based on Economic Means

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Abstract: With the rapid development trend of urbanization and motorization in China, some traffic problems such as congestion and parking space shortage come out. The motivation of the study is to seek for a possible way to deal with a special issue in China that is the parking space shortage in old residential quarters. The paper has mainly adopted theory-studying, literature review, and case study method. By dissecting the measures which are taken in Japan, it can be found that to achieve one-car-one-basic-parking-space system could be the solution. Then the paper provides countermeasure based on economic means to realize it in China; moreover, the D-S model of the old residential quarter parking is proposed to guide the reconstruction project. Furthermore, in the conclusion part, the paper proposes that changing land use pattern is the core thought of solving the city traffic problem.

Keywords: Urban Transport Problem, Basic Parking Space, Old Residential Quarter, Economic Mean

1. INTRODUCTION

With the rapid economic growth of China and the increasing of national purchasing power, the number of motor vehicles keeps ascending, and the urbanization and motorization process is at the high speed stage according to Gong (2014). But the boom of motor vehicles causes a series of traffic problems, such as traffic congestion, the shortage of parking spaces especially in the old residential area which is descanted by Xiao (2006), etc. A range of policies aiming at controlling the increasing speed of motor vehicles, like Traffic Control by Plate Number, have been implemented in Beijing, Shanghai, Guangzhou and other first-tier cities in China, yet the urban traffic situation is still grim for these policies have their own limits according to Wang *et al.* (2014). Other big cities in the world once have been faced with the same dilemma, and they adopted corresponding measures, for instance, Li (2013) introduces roundly that Japan used the “Garage Law” to deal with these problems by stipulating that one should provide the proof of owning one parking space before purchasing a car. This one-car-one-basic-parking-space system not only solved the difficulty in parking but also relieved traffic congestion in Japan. Using the experience of Japan as reference, this paper explores the practical way to achieve one-car-one-basic-parking-space system gradually in China. Through the perspective of parking management (one of the most important TDM methods), the solution to the basic parking space shortage in city residential quarters especially old ones that based on economic means is provided.

2. THE SHORTAGE OF PARKING SPACE AND CRUX ANALYSIS

Urban parking spaces are divided into basic parking spaces and social parking spaces according to ownership according to Wang (2005). Basic parking space usually refers to private parking space in the residential quarter. Car owner acquires private parking space through legal means, like purchasing. And it is used as a house for car. Parking space in a residential quarter of China usually includes private parking space and public parking space. However, the public parking space is not the basic parking space in the strict definition for it is not simple used by same person. Social parking space refers to which car owner can use temporarily through legal means, like paying parking fee. For example, the parking space in the shopping center is one kind of social parking spaces. Social parking spaces are invested by government or enterprise for different proposes. Generally, the government aims at policy regulation and the enterprise aims at making profits.

Shang (2014) assumes that a car travels 20 thousand miles per year, and the average speed is 40 kilometers per hour, then dynamic travel time is about 500 hours. Yet, static parking time is up to 8000 hours, the time is over 90% of a whole year. Further, when a car is in a state of stationary, the time it locates in basic parking space is much longer than in social parking space. Thus, basic parking spaces are essential in the city parking infrastructure, and the amount of basic parking space should be much more than social parking space. Actually, it is not the case.

2.1 The Parking Space Shortage Problem

Almost all big cities in China are facing parking space shortage now, thus the problem has drawn lots of attention. Only adequate parking spaces can ensure the parking order; the shortage inevitably leads to parking mess, which influences the efficiency and safety of urban traffic system and reduces the life quality.

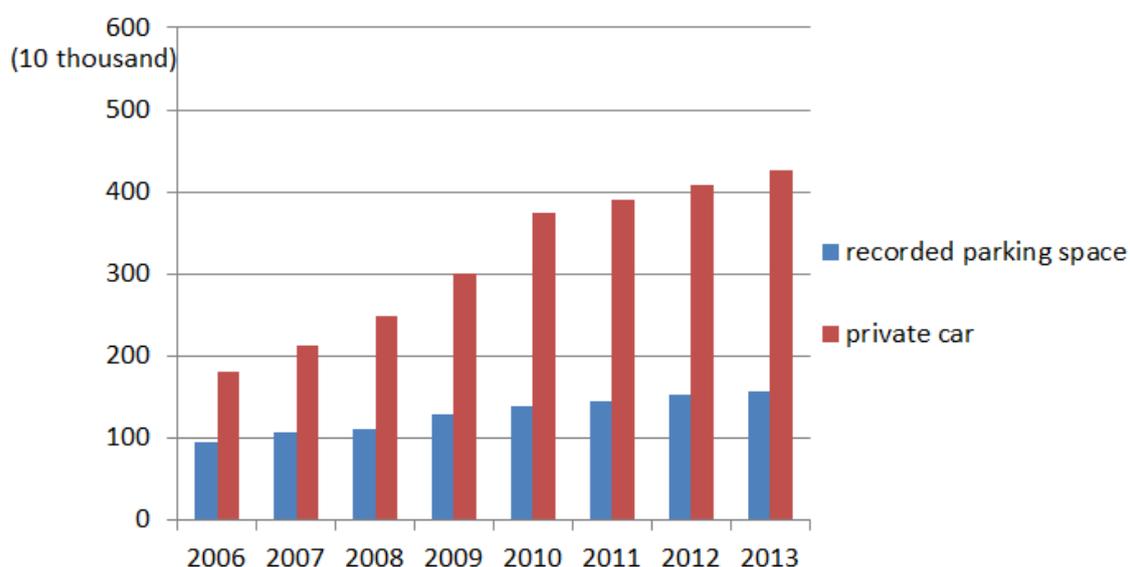


Figure 1. Supply and demand of Parking space in Beijing

Taking supply and demand of parking space in Beijing as an example, the data is released by Beijing Transportation Research Center, one of the most authoritative official research institutes. It can be seen from Figure 1 that the insufficiency of parking spaces is bigger and bigger. By the end of 2013, the amount of motor vehicles has reached 5,371 thousand, among them there are 4,075 thousand private cars. While according to the parking

space record information released by Beijing Transportation Committee official site in April, 2014, there are 1,570 thousand parking spaces totally, among them there are 921 thousand residential quarter parking spaces which can be regarded as basic parking spaces in general. Relatively, Guan *et al.* (2002) summarized that the international standard of city parking spaces matching ratio is 1:1.2, which means every car needs one basic parking space and every five cars share one social parking space. Only when parking infrastructure reaches this level, the urban traffic operation can be in good condition. Thus, it can be seen from the data that both the number of basic parking space and social parking space cannot come to the international standard. Obviously, the shortage of basic parking space is more serious than social parking spaces, about 3/4 of totality.

The data in Table 1 is the statistical result of car parking place at night in Beijing coming from Beijing Transportation Research Center (2014). Type 2, the Area except private parking space in residential quarter includes the public parking space and blind area in residential quarter. In addition, behavior of parking in blind area results from inadequate basic parking spaces and no definite ban of parking in that place which used to be living space. It is a kind of behavior which gets out of the line. Type 3, the Other means place outside residential quarter, like social parking space along roadside. It can be seen from the Table 1 that scale of cars that parked in the private parking space at night is decreasing year by year, while scale of cars that parked in the type 2 at night is increasing fast. Therefore, to solve the shortage of basic parking spaces is the priority among priorities and brooks no delay.

Table 1. Car parking statistics at night in Beijing classified by parking place

| Type of parking place at night | 2010(%) | 2011(%) | 2012(%) | 2013(%) |
|--|---------|---------|---------|---------|
| 1.Private parking space | 56.6 | 45.7 | 41 | 38.7 |
| 2.Area except private parking space in residential quarter | 23.4 | 31.2 | 39.1 | 44.2 |
| 3.Other | 20 | 23.1 | 19.9 | 17.1 |

2.2 The Analysis of Contributory Factors for the Issue

Most of cities around the world have once faced the same problem. The reason of the problem is that the city planners made an error prediction at the beginning of city motorization process. The prediction of variation tendency of vehicle ownership does not match the actual situation. Initial consideration of the variation tendency at urban parking planning stage is linear increasing with time, but the actual variation tendency is S-shaped curve, as shown in Figure 2. It can be found in the mid-term there has been an explosive growth stage, and the shortage begins to emerge. Thus, parking planning and construction based on the error prediction results in lack of parking spaces inevitably.

Beside the insufficient construction, excessive parking demand is also one significant factor. For basic parking space shortage, exorbitant development intensity of residential quarter is the major contributing factor. Limited region in residential quarter cannot hold all private cars belonging to the massive household. For social parking space, urban land use patterns affect shortage problem. If the city spatial pattern is a single-center model, some may-existed defects of it will emerge with the perspective of parking. As central region will attract a lot of traffic, once its development intensity is too high, the high degree of vehicles' concentration will make this land resource limited area even crowded. This leads to social parking space shortage in the case of single-center city.

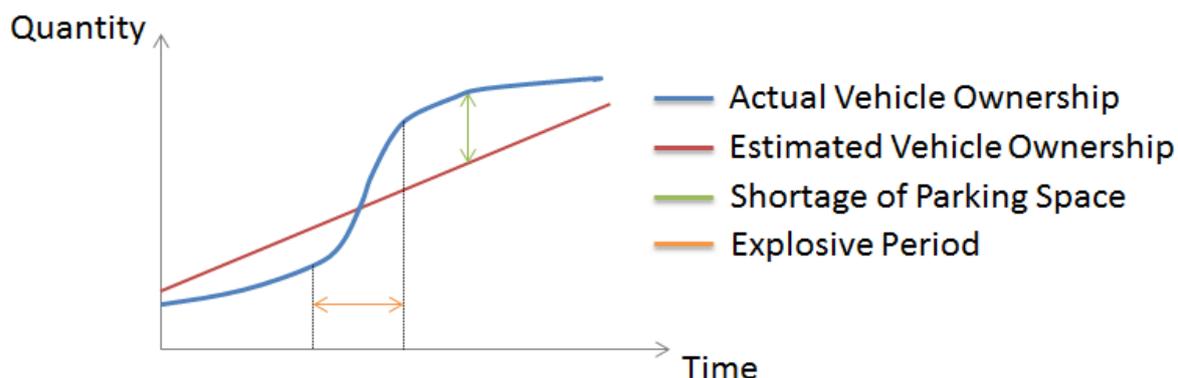


Figure 2. Vehicle Ownership Variation Curve

With the development of city, when insufficient parking space crisis arises, due to limited land resources and urban land use patterns have been relatively fixed, the construction costs of parking lot goes up greatly, so it is difficult to meet the demands just by building new parking lots in a short time. The government has to introduce various policies such as the vehicle-purchasing limitations to control the number of cars, and prevent the deterioration of the parking problems. But in Beijing, the capital city of China, this is not enough, further efforts are still needed, especially for the old residential quarters.

3. THE FUNCTION OF ONE-CAR-ONE-BASIC-PARKING-SPACE SYSTEM

To solve the parking problem, different cities in many countries adopt different measures, including economic measures, administrative measures, etc. And the effect of different policy implementation is also different.

3.1 Garage Law in Japan

As early as 1962, using the parking management as a penetration point, Japan implemented "Garage Law". It stipulates that one must have got one parking space before buying a car, which means only after providing the certificate of owning a parking space and police affirm it by fieldwork, the car can be registered and license plate can be issued. This law practice was first applied in big cities, and gradually spread across the country in 10 years, eventually one-car-one-basic-parking-space system formed. "Garage Law" stipulates that the parking space can be a home garage, or an open space, also can be a fixed space near the residential quarter (within 500 meters from the residential quarter at first, now within 2 kilometers), but the certificate must be issued by the parking lot operator.

Although the initial target of "Garage Law" is to solve the traffic congestion, it is also effective on solving parking problem. To cooperate with "Garage Law" and ensure that cars can find fixed parking spaces at the place of departure, government put forward specific requirements for parking construction of residential quarter. In the early 1990s, for commercial house, the number of parking space in residential quarter was required to be 100% of households, and for rental house, it was 70%. In addition to "Garage Law" (enacted in 1962), there are "Parking Lot Law" (enacted in 1957), "Road Traffic Act" (enacted in 1960), "Urban Planning Law", "Tokyo Metropolitan Parking Regulations" and the like. These laws mainly cover the entire contents of the parking lot construction and parking management.

Compared with European and American countries, the laws and regulations carried out in Japan are more comprehensive and meticulous. The government had seized the opportunity, for the introduction time was at the beginning of the rapid growth of cars, this helps lay the foundation for standardized parking management in future vehicle ownership rapid growth period.

Decades after the enforcement, the effect is significant: traffic congestion eases. What is more, by 1998, according to the actual data of Japan's Statistics Bureau (1998), the parking spaces of commercial housing residential quarter had reached 80% of the households, and rental housing residential quarter had reached 60% of the households, the basic parking spaces shortage problem is relieved.

3.2 Parking Status in China

In contrast, due to the surge of motor vehicles in big cities like Beijing, basic parking spaces shortage problem has been exposed before car-purchasing limitation policy is carried out. The lack of basic parking spaces causes the difficulty of parking in residential quarters; cars have to invade living space. This not only lowers the residents' life quality, but also increases safety risks; rub phenomenon emerges in an endless stream in the residential quarters. Lack of parking spaces in residential quarters forces the surrounding roads to serve as parking resources at night. This method of improving the utilization of space resources has its advantages; however, because of different resident trip characteristics, it usually results in road resources forcibly occupied in the daytime, and causes serious inconvenience. And there are still some other problems.

3.3 The Function of One-Car-One-Basic-Parking-Space System

Through the comparison of parking situation of Japan and China, it can be summed up that one-car-one-basic-parking-space system mainly has 3 following functions.

1) It can solve the parking problem in the residential quarters directly, reduce the living space occupied phenomenon, and is in favor of the residents' safety.

2) It can manage parking demand and influence the number and space distribution of cars progressively by limited basic parking spaces, thereby affect people's travel destination, and alleviate the insufficient social parking spaces problem effectively.

3) It can relieve congestion through regulating the relationship between supply and demand; improve overall operating efficiency of urban transport system on a macro scale.

4. COUNTERMEASURE PROPOSAL OF THE URBAN BASIC PARKING SPACE SHORTAGE

The government can implement policies based on economic, legal and administrative means to solve the parking spaces shortage problem, but no matter what means are adopted, Li (2013) have suggested that Chinese special land system of ownership and management methods should be considered abortively.

4.1 Countermeasures Analysis

For the lack of social parking spaces, the problem can be addressed by increasing the supply directly and it is relatively easy to be achieved. Social parking spaces mostly occupy the land in urban public area, thus government-led and enterprise-participated mode can be used in the

construction project according to Wei *et al.* (2013).

For the basic parking spaces shortage problem, it depends on the situation. For new residential quarter, one-car-one-basic-parking-space system can be achieved from two aspects. On the one hand, the developer should fully predict the future parking demands at the construction planning stage, and then provide appropriate basic parking spaces according to a reasonable ratio. On the other hand, the operators of residential quarter (mainly refers to property management company) should control the future number of cars by setting several regulations such as charge system to orient the resident behaviors.

However, for the old residential quarter, the problem has been quite chronic, because it is more complicated and knotty. There are some difficult points to be solved before bringing out the countermeasure.

As mentioned before, one-car-one-basic-parking-space system could be one solution to the problem. But if China government draws from the experience of Japan and implements the "Garage Law" immediately, it would be also unable to solve the insufficient basic parking space problem. As the parking space management system in old residential quarter is not perfect, adopting the parking space certificate system easily brings the problem that several cars may share one space, and the number of motor vehicles may further rise which goes against with the car-purchasing limitation policy and makes the urban traffic situation worse. Moreover, the motorization stage of Beijing today is not the same with Japan in 1962; taking strong legal measures immediately to achieve one-car-one-basic-parking-space system will only cause public discontent and stimulates social conflicts. The countermeasure should be a long-term process.

The most important thing is how to meet the parking demand. In other words, new parking lots are needed. It is hard to build new parking lots in the old residential quarter because of the limited space. And to build new parking lots nearby, cost will be a consideration, so lack of financing source will be another obstacle.

4.2 Parking Fee and Parking Tax

The characteristics of economic means are strategic, macroscopic, guidance and indirect. Economic means include pricing, taxation, credit interest rates, exchange rates and other economic levers, in general, they do not effect on the economic body directly but impact the production and operation of market players through benefit induction. The result of economic means will manifest only after some time. Legal means are mandatory and binding of economic bodies universally, its regulation of the economy has relative stability and clear stipulation. To solve this problem, economic means and legal means could be adopted simultaneously. The parking reconstruction process in old residential quarter is proposed in Figure 3.

First, the government should promulgate old residential quarter parking lot reconstruction requirements. In China, urban land belongs to the country, and the government can exercise land use rights. Before the construction, the developer has gained land use rights of residential quarter from the government, and after residents live in, the property management company takes charge of the daily operation including the residential quarter parking management. Thus policies introduced by the government should act on the residential quarter's property management company directly, and then the effectiveness will be remarkable. The requirements need to include the calls upon strict parking space regulation. As the surplus cars (which do not have a private parking space) have taken the public parking space and blind area as their basic parking space, there should be new regulation for current situation. In consideration of the disability of providing new parking space immediately, the

The charged parking fees should be divided into two parts with a certain proportion. One part, together with collected parking tax, is used in the setup of old residential quarter parking reconstruction funds which is used for building new parking lot. The other part should be used for operation of the parking fee system, equipment maintenance and updating, residents' welfare, etc.

The whole period of reconstruction is a long process; it cannot be attained in a short time. The economic mean's effect is hysteretic. That is the reason why the regulation does not decrease the parking area directly at the beginning of charging. Instead the new public parking space is set up and charged. It includes the original public parking space and blind area, maybe even bigger area. When the reconstruction fund reaches a certain amount of money, the property management company should start to construct new parking lot. Due to the available space is limited, Zhou (2009) indicated the parking tower is one choice, or it can be constructed in vacant land near the residential quarter. When new parking lot is built, the parking demands in old residential quarters will transfer to there for seek less parking cost. And new public parking space in old residential quarters can be reduced and turn into living space gradually for there are less remained cars (preserve a few of them at last as real public parking space).

Only when using both economic means and legal means, it is possible to balance the number of motor vehicles and basic parking spaces dynamically. The effect of such economic means is obvious. By using the high parking fees to influence parking demand, the surplus cars will leave the old residential quarter to search for basic parking spaces that car owners can afford. It gives consideration to fairness. Moreover, this economic method will solve the lack of financing source in increasing parking space supply, and the setting up of a special fund will make whole procedure transparent and then corruption will not occur.

From the perspective of long-term benefits, the advantage of the economic means is more remarkable. The ultimate goal of this method is to influence the car use region and to control the number of cars. It is entirely possible that if one cannot find a basic parking space, he will give up using car due to the high parking cost, or he will move to some place where he can get one. When the basic parking spaces and the number of vehicles reach equilibrium in general, the region of motor vehicles distribution and travel destination will be relatively reasonable. Then cities that adopting car-purchasing limitations policy can gradually relax restrictions, and promulgate the "Garage Law" which could alleviate and resolve the prominent social contradictions because of car-purchasing limitations. In the future, with perfect record information parking spaces and rational parking space market system including renting and auction, one-car-one-basic-parking-space system will be built finally, and the parking resources will be allocated rationally and urban automobile society will step in benign development condition ultimately.

5. D-S MODEL OF OLD RESIDENTIAL QUARTER PARKING RECONSTRUCTION

To guild the reconstruction, a D-S model has to be set up. The model should figure out the car leaving (transferring) process and then the best construction scheme of new parking lot can be got from it.

5.1 Demand function and Supply function

The core of D-S model is the demand and supply function. The demand function is used to describe decrease of parking demand which equals with the number of cars that leaving old parking place due to the high parking fee.

According to recent study of Zou *et al.* (2015), the demand function is decided by lots of factor, like parking fee, time, surrounding parking condition and some other factors. Here \dot{N} is used to denote the leaving number in unit time.

$$\dot{N} = f_1(x_1, y_1, \dots, y_n, t) \tag{1}$$

where

- x_1 : Parking fee
- y : Other factors
- t : Time
- f_1 : Leaving speed

Thus, the number of removed car (2) can be got by integral (1).

$$\Delta N = \int_0^t f_1(x_1, y_1, \dots, y_n, t) dt \tag{2}$$

In general, the higher the parking fee is, the fewer cars will remain. And as Figure 4 shows, transfer speed is positive correlation with parking fee which means the higher the parking fee is, the faster the transfer speed is.

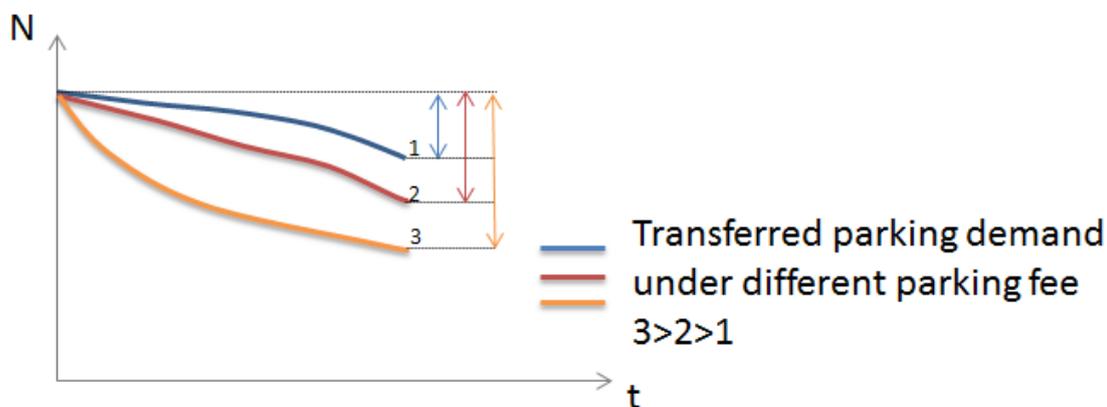


Figure 4. Parking demands variation diagram

The Supply function is used to describe the parking space that provided by building new parking lot. Through analyzing the influence factors of building new parking lot, the Supply function (3) can be got.

$$S = f_2(x_2, z_1, \dots, z_n, t) \tag{3}$$

where

- x_2 : Investment
- z : Other factors
- t : Time
- f_2 : New-built parking spaces quantity

As equation (3) shows, investment is one main factor influencing construction. Other factors like construction cost, time, etc. The S function can be a piecewise one if the parking spaces are built in batches; it depends on the construction scheme and use plan.

5.2 Case Study

A real case will be studied as an example of the D-S model. Olin Spring Residential Quarter locates on the north of Beijing Olympic Forestry Park, shown in Figure 5. And it is completed in 2004. There are about 500 household while the underground parking spaces (private parking spaces) are a little above 500 in the residential quarter. The parking infrastructures could totally meet the demand in early years. However, with the explosion of cars in residential quarter, parking spaces are not enough. Parking mess and security problem follow and solution is badly needed.



Figure 5. Olin Spring Residential Quarter

The current parking infrastructure is shown in Figure 6. Due to the shortage, the car owners begin to occupy the public parking space over a long period of time and use them like private parking space; furthermore, the cars invade the blind area which is used to be living space. To change the current situation, countermeasure mentioned can be used and parking fee will be charged in new public parking space as Figure 7 shows.

There is no other available parking lot nearby the residential quarter, so the cars owners only have 2 choices after the new public parking space is charged parking fee. One is that they remain in charging area and suffer the high fee till the new parking lot is built to provide parking spaces; the second one is that cars move to other place or the owners give up using them.



Figure 6. Present Parking Situation



Figure 7. Charging area

In our case, the model is simplified. Without the consideration of the second circumstance, it is assumed that all surplus cars transfer to new parking lot in the end. There is vacant land on the east of residential quarter which can be used to build new parking lot. When the number of new-built parking spaces equals with car transferred from residential quarter, balance is reached. And the ultimate goal is to transfer all surplus cars and reconstruct the residential parking infrastructure; the charging area will reduce and transfer to public parking space in the end. The ultimate plan is shown in Figure 8 (3 new-built parking lot is just an example, actual number is uncertain).



Figure 8. Final Reconstruction Plan

Equation (4) is the basic form of D-S model in this case; it means that the balance is reached at the time T (when the reconstruction project is finished).

$$m = \Delta N = S \tag{4}$$

where

m : The surplus cars in residential quarter

Then, D-S model can be applied in guiding the actual reconstruction. After the basic information of the residential quarter got, the factors y and z in the model can be obtained. Then, an equation (5) is introduced to connect the capital in these two functions.

$$x_2 = \alpha \int_0^t x_1 \cdot (N - \Delta N) dt + x_3 \tag{5}$$

where

x_1 : Parking fee

x_2 : Residential quarter parking reconstruction fund

x_3 : Car parking tax

α : Proportion

If the project period T is fixed, the price of charging x_1 can be obtained by solving simultaneous equations; vice versa, the project period can be estimated under a certain parking fee. Also, the requirement of project can be met by adjusting the two variables simultaneously. In addition, x_1 should be within a certain range for at least it has to support the reconstruction project to go on, but cannot be higher than national legal regulations.

The S function equals with new built parking spaces, and it is usually a piecewise function. The parking lot can be built and come into service all at one time or in batches, and numbers can be adjusted for each time. Also, interval between two segments is variable. Further, the construction scheme can be optimized by solving the nonlinear programming (6).

$$\min W = \int_0^T (S - D) dt \tag{6}$$

s.t.

Conditions due to different projects.

As Figure 9 shows, equation (6) means the scheme should pursuit for reducing the vacant parking space as much as possible, thus it will be less economic waste. However, the parking space is provided by building new parking lot, it has to subject to some conditions. For example, the number of segment cannot be too many. For each segment represents a new parking lot is built and basic parking space is increased. More segments in the construction means the added fixed cost of building new a new parking lot is higher. When it is over the profit made by increasing construction segment, the scheme is not economical any more.

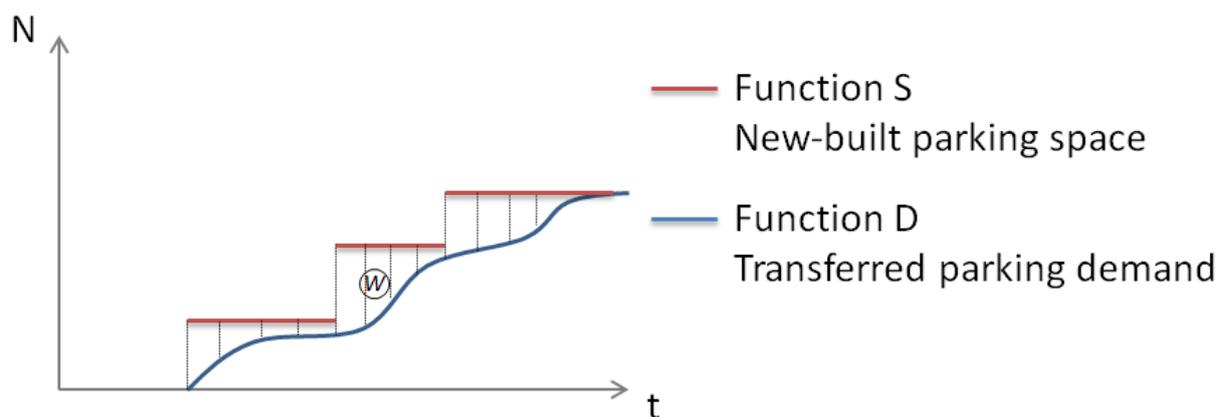


Figure 9. Reconstruction Scheme

6. SUMMARY and CONCLUSION

This paper discusses the parking spaces shortage problem in big cities and the causes of its formation. By the comparison of parking situation in Japan and China, the effect of one-car-one-basic-parking-space system for urban transportation especially parking field was analyzed. Then the paper analyses current situation: the land resource is limited, land use pattern and development intensity are fixed basically, proposes that under such conditions the government can use economic means as core methods, legal means as auxiliary to solve basic parking spaces shortage and achieve one-car-one-basic-parking-space system gradually. Finally, old residential quarter parking reconstruction flow chart and D-S model of the old residential quarter parking reconstruction are given.

In further specialized studies on old residential quarter parking reconstruction, the demand function (1) can be given out with mathematical tools including the regression and other methods; parameter can be calibrated based on the actual data. It is not a simple economic model and it relates to the consumer psychology closely. Further study on the demand function is badly needed.

In fact, vehicle ownership, trip generation rate and other factors affect the demands for parking together, so the need of basic parking spaces is closely related to land development intensity; furthermore, the cost of parking is actually land use consumption. Thus, only recognizing no matter what economic means are adopted to manage parking demand, the ultimate goal is to guide or change the land use patterns, and transportation policy of which the core ideology is based on it can solve the urban traffic problem fundamentally.

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