IMPACT OF PARKING FEES ON SOCIAL BENEFITS BASED ON THE EMERGENCE OF SHARED PARKING

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Abstract
Shared parking, complementary to public parking, effectively alleviates the problem of parking difficulties in city. Shared parking spaces could reduce the difficulty of parking, which will potentially trigger the increasing of vehicles traveling, resulting in congestion, pollution and other negative externalities. In the view of environmental performance, exhaust emissions from road traffic, mainly cars, are the main reason of pollution. The rising prices of parking space, which may decrease vehicle travelling, could be an effective policy to reduce automobile travel, encourage public transport then reduce the impact of traffic on urban environment. Different from the discussion of shared parking itself, this study constructs an idealized model by discrete choice to find the relationship between the social benefits of city and public parking fees. Through the instance analysis, this paper analyzes the impact of government pricing on public parking spaces on a certain city problem including giving priority to alleviating traffic congestion, increasing fiscal revenue, reducing exhaust emissions and mitigate air pollution or the goal of comprehensive development. Increasing parking fees will result in an increase in overall income including parking fees and bus fares. And with the increasing of parking fees, more people will transfer to public transport, which will ease congestion and reduce traffic emission. To achieve the maximum social benefits, the urban public agents should develop an optimal public parking prices within a certain range.
Keywords: shared parking, public parking fees, government objectives, social benefits.

1. INTRODUCTION

Parking in city areas is always a predicament for drivers and governors in most big cities (Ye and Wang, 2017). In order to solve this problem, cities have taken variety measures such as planning the land-use rationally, controlling traffic in time-sharing, and building new parking structures (Leng, 2013; Hong, 2016). However, due to the high traffic density, continuously increasing population, the area of newly built parking structures is insufficient and alleviate the parking issues in a limited way (Li et al., 2016; Li, 2008). Taking Beijing as an example, in 2017, the shortage of parking supply was about 1.29 million parking spaces for residence and about 0.62 million parking spaces for travelers and commuters, meanwhile the utilization rate of urban parking spaces was even lower than 50% (Beijing Municipal Commission of Transport, 2017). Both the limited number of parking lots and the low utilization due to the property right problem aggravate the parking issues in cities.

In this context, the concept of "Shared Parking" was made up by the American Urban Land Institute in 1983 (Smith, 1984), in which public parking is complementary to shared private parking. Private parking owners including companies, hotels and individuals can change their parking spaces into shared ones when they do not use them (Kang, 2017). Sharing parking, same as the other forms of sharing economic, is an optimization means of resource allocation to enhance the social benefit. Differently from the public parking mode, which is organized and managed by government directly or indirectly, shared parking mode relies on relevant applications to release parking information, and make rules of the charging and bill-settlement systems by both the application platform and the owners of parking spaces, which also obey the social management framework made by government (Czerwienski, 2013).

Objectively, shared parking has both positive and negative effects. Shared parking spaces will bring convenience directly to the owners of the parking process, thus greatly reducing the parking time consuming (Shoup, 2006) and the fuel consumption of driving to find a public parking lot. The owners, including hospitals, hotels, companies and individuals who provide the private parking spaces as the shared ones, will receive the corresponding income with the phone platform operation. At the same time, because of the lower price of shared parking spaces, the drivers will save a cost of parking fees. Shared parking spaces, however, which reduce the difficulty of parking, will potentially triggering the increased number of vehicles traveling, resulting in congestion, manage problems and other negative externalities. Since exhaust emissions from road traffic, mainly cars, are the main reason for the increase of the carbon footprint (Lam et al., 2011; Ajanovic et al., 2012), the emergence of shared parking spaces facilitates vehicles traveling and parking, furtherly aggravates environmental pollution. When the original private parking spaces turn into semi-public state, security problems will come up with citizens, which leading to the increase of demand for management (Guo et al., 2019; Ji et al., 2019). Besides, the process of coordination of multi-interest will bring some social equity issues at the same time. As a result, the impact of shared parking spaces for the whole city, which affect the social benefit, is an important factor that government have to consider when studying urban objectives and developing urban traffic management policies.

Available researches associated with shared parking mainly focus on the operation mechanism (Smith, 1984; Littman, 2006; Geng and Cassandeas, 2013; Zou et al., 2015; He et al., 2016), the drivers' choice intention (Liu, 2016), the demand calculation (Shoup, 1999; Hess et al., 2006; Qian et al., 2011; Gan and Chen, 2012; Boyles et al., 2015), the effect evaluation (Chen and Xie, 2015), parking demand forecasting and shared matching algorithm optimization for mixed land (Jiang et al., 2011; Chen et al., 2012; Rowe et al., 2013; Wang et al., 2007; Shao et al., 2016), the price adjustment (Simicevic and Milosavljevic, 2014; Charman and Manville, 2014; Millard-Ball et al., 2013) and the design of the application platforms (Qin et al., 2008; Kotb et al., 2016; Liu, 2017). Among the studies on price adjustment of shared parking, He et al. (2015) used a nonlinear equation to express the equilibrium of parking; Hao et al. (2019) extended He et al.'s study by proposing a balance floating charge method for shared parking. By establishing a Hybrid Logit model, Dell et al. (2009) found that individual differences in the level of income of travelers are one of the most important factors affecting their acceptance of parking charges. Simicevic et al. (2013) established a logistic regression model based on SP survey data, and analyzed the impact of charging standards and time restrictions on travelers' parking behavior. They believed that the parking fees would affect the behavioral characteristics of trips, and that the restrictions on parking time were expected to affect choice of parking type.

Studies, however, on urban externalities and the total social benefits are insufficient, which should be taken into consideration. Besides, the rising price of parking space, together with traffic congestion fees and rising oil prices, are commonly considered as policies to reduce automobile travel (Chester et al., 2010), which will encourage public transport travel and reduce the impact of traffic on the urban environment (Sellitto, 2015). Therefore, it will be necessary to discuss the impact of rising parking costs on the proportion of bus trips, traffic exhaust emissions, and total social benefits. Considering the price of personal parking spaces should be self-adjusted to meet the demand of market, and the profit from shared parking is not directly related to the government, the price of public parking spaces can be adjusted by the city manager to maximize the social benefits.

Therefore, this study analyses the impact of residents' choices on the benefits of the city. Based on Random Utility Theory, Discrete Choice Model (DCM) and Nested Logit Model (NLM), this study constructs an idealized model by discrete choice to find the relationship between the public parking fees and the social benefits of city, which also take traffic mode, parking mode, time cost and fuel consumption into consideration. Taking the government as the research object and through the instance analysis, this paper studies the price adjustment of public parking lots under different and government goals, and give a brief vision of the parking fees to achieve the maximum social benefits.

2. THE FORMULATION

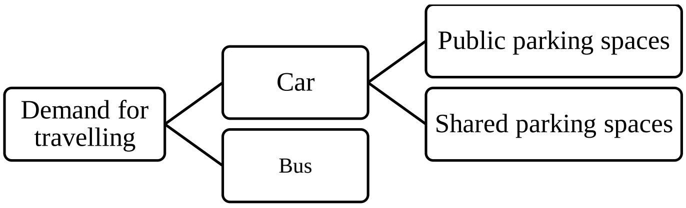
2.1. The Conditions

In this study, the model is based on an ideal environment where the following conditions are satisfied:

1. The number of travelers is fixed, and everyone has the demand for travelling.
2. Everyone has the same origin and destination (OD), and they can travel either by bus or car.
3. There is only one person in each car and every bus is expected to be full.

4. Every car has the parking demand, and they can park either in public parking spaces or shared parking spaces.

5. The bus only runs on the bus transit lanes.



The conditions can be expressed as:

$$Q = Q_{bus} + Q_{car} \quad (1)$$

$$Q_{car} = Q_{car\_pub} + Q_{car\_sha} \quad (2)$$

where Q is the total number of travelers which is given and fixed. Q_{bus}, Q_{car} are respectively the total number of travelers who travel by bus or by car. Q_{car_pub}, Q_{car_sha} are respectively the total number of travelers who travel by car then park in public parking spaces or in shared parking spaces.

2.2. The total social benefits based on the government objectives

Based on the Random Utility Theory, this model evaluates the impact of shared parking spaces on government objectives with the factors as follow: the public parking fees and bus fares income IN, the total emissions E, the amount of parking management fees MF, the time and fuel consumption due to congestion ΔCO, the time and fuel consumption generated during parking ΔPC, and the savings in land cost ΔLC, indicating the shared parking spaces effectively reducing the amount of urban land occupied by new parking lots. Therefore, the total social benefits based on the government objectives can be calculated as:

$$SoB = IN + E + MF + \Delta CO + \Delta PC + \Delta LC \quad (3)$$

where these factors can be explained as follow.

Factor 1: IN is the public parking fees income and the bus fares income, expressed as:

$$IN = p_{pub} \cdot Q_{car\_pub} + P_{fare|bus} \cdot Q_{bus} \quad (4)$$

where p_{pub} is the unit price of public parking space, $P_{fare|bus}$ is bus fare.

Factor 2: E is the total emissions of cars and buses, expressed as:

$$E = E_{bus} + E_{car\_pub} + E_{car\_sha} \qquad (5)$$

where E_{bus} is the exhaust emissions by buses; E_{car_pub}, E_{car_sha} are respectively the emissions of cars which use public parking spaces or shared parking spaces, quantified and expressed as:

$$E_{bus} = -e_{bus} \cdot t_{in\_veh|bus} \cdot {Q_{bus}}/{C} \qquad (6)$$

$$E_{car\_i} = -e_{car} \cdot (t_{in\_veh|car} + t_{p|car\_i}) \cdot Q_{car\_i} \quad (i = \text{“}pub\text{” or “}sha\text{”}) \qquad (7)$$

where e_{bus} is the exhaust emissions of per bus in one minute, and the emissions of each car in one minute can be expressed as e_{car}; $t_{in\_veh|bus}$ and $t_{in\_veh|car}$ are respectively the in-vehicle time by bus or by car; $t_{p|car\_i}$ is the parking time of the car which use the public parking spaces or the shared parking spaces. As we assumed before, every bus is expected to be full to meet the maximum capacity C, so the Formula (6) can express the total number of buses.

Factor 3: MF is the amount of parking management fees, including both the public ones MF_{pub} and the shared ones MF_{sha}, expressed as:

$$MF = MF_{pub} + MF_{sha} \qquad (8)$$

$$MF_i = -p_{m|i} \cdot Q_{car\_i} \quad (i = \text{“}pub\text{” or “}sha\text{”}) \qquad (9)$$

where $p_{m|pub}$ and $p_{m|sha}$ are respectively the unit price of management for public parking spaces, and shared parking spaces.

Factor 4: ΔCO is the time and fuel consumption due to congestion, quantified and expressed as:

$$\Delta CO = \Delta CO_{time|bus} + \Delta CO_{time|car} + \Delta CO_{fuel|bus} + \Delta CO_{fuel|car} \qquad (10)$$

$$\Delta CO_{time|k} = -(t_{in\_veh|k} - t^0_{in\_veh|k}) \cdot VOT \cdot Q_k \quad (k = \text{“}bus\text{” or “}car\text{”}) \qquad (11)$$

$$\Delta CO_{fuel|bus} = -f_{bus} \cdot (t_{in\_veh|bus} - t^0_{in\_veh|bus}) \cdot {Q_{bus}}/{C} \qquad (12)$$

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

$$\Delta CO_{fuel|car} = -f_{car} \cdot (t_{in\_veh|car} - t^0_{in\_veh|car}) \cdot Q_{car} \quad (13)$$

where $t^0_{in\_veh|bus}$ and $t^0_{in\_veh|car}$ are respectively the in-vehicle time for buses and cars with no congestion; VOT is the value of time, in which we assume that travelers who travel by bus or by car both have the same value of time, even though the social status and wages can affect the choice of transportation according to the according to sociological research; f_{bus} and f_{car} are respectively the fuel consumption per minute of each bus and each car.

Factor 5: ΔPC is the time and fuel consumption generated during the process of parking considering both the travelers and the vehicles, expressed as:

$$\Delta PC = \Delta PC_{time} + \Delta PC_{fuel} \quad (14)$$

where ΔPC_{time}, focusing on the travelers, is the total cost of time during parking including the time of walking from the parking spaces to the destination and the time of cruising for parking (Shoup, 2006); ΔPC_{fuel}, is the fuel consumption during cruising for parking. ΔPC_{time} and ΔPC_{fuel} can be quantified and expressed as:

$$\Delta PC_{time} = -VOT \cdot \sum((t_{p|car\_i} + t_{walk|car\_i}) \cdot Q_{car\_i}) \ (i = \text{"pub" or "sha"}) \quad (15)$$

$$\Delta PC_{fuel} = -f_{car} \cdot \sum(t_{p|car\_i} \cdot Q_{car\_i}) \ (i = \text{"pub" or "sha"}) \quad (16)$$

where $t_{walk|car\_pub}$ means the time walking from the parking space to the destination.

Factor 6: ΔLC is the savings in land cost because of the shared parking spaces which effectively reduce the amount of urban land occupied by new parking lots, expressed as:

$$\Delta LC = p_{land} \times S \times Q_{car\_sha} \quad (17)$$

Where p_{land} is the price of per square meter of land in the city; S is the area each parking space occupies, we assume that public parking space built by enterprises or government and shared parking space provided by hospitals, hotels and individuals, are in the same size.

2.3. The travelers' choice

As what we assumed before, the travelers can be divided into two types: travel by bus or by car, among which can be further divided into people who use public parking spaces or shared parking spaces.

$Q_k = Q \times Pr_k$ (k = "*bus*" or "*car*" or "*pub*" or "*sha*") (18)

where Pr_{car} and Pr_{bus} are the proportion of different vehicles, Pr_{car_sha} and Pr_{car_pub} are the proportion of different parking spaces.

Step 1*. Choose the vehicle: bus or car?*

Based on the Discrete Choice Model (DCM), the proportion of different vehicles Pr_{car} and Pr_{bus} can be expressed as:

$$Pr_{bus} = \frac{e^{\beta U_{bus}}}{e^{\beta U_{bus}} + e^{\beta U_{car}}} \quad (19)$$

$$Pr_{car} = 1 - Pr_{bus} \quad (20)$$

where β acts as a scale parameter, characterizes the preferences of the traveler. U_{bus}, U_{car} are respectively the utility of travelling by bus or by car for each person. Taking the deterministic part including $t_{walk|bus}$ as the time of walking to the bus station, $t_{wait|bus}$ as the time of waiting for bus and $t_{in\_veh|bus}$ as the in-vehicle time by bus into account, while considering the random part such as comfort or travelers' mood have been influenced by the preceding factors rather than double-counting, the utility of travelling by bus can be expressed as:

$$U_{bus} = -(t_{walk|bus} + t_{wait|bus} + t_{in\_veh|bus}) \times VOT - P_{fare|bus} \quad (21)$$

where $P_{fare|bus}$ is the cost of each bus ride.

Based on the Nested Logit Model (NLM), the utility of travelling by car can be calculated as:

$$U_{car} = \frac{1}{\beta} \ln \sum e^{\beta U_{car\_i}} \quad (i = \text{"pub" or "sha"}) \quad (22)$$

$$U_{car\_i} = -(t_{p|car\_i} + t_{walk|car\_i} + t_{in\_veh|car}) \times VOT - P_{fare|car\_i} - P_{fuel|car\_i}$$

(i = "*pub*" or "*sha*") (23)

where U_{car_i} (i = "*pub*" or "*sha*") are procedure values, $P_{fare|car\_i}$ is the parking fees, $P_{fuel|car\_i}$ is the cost of fuel consumption during the whole travelling process.

Step 2. *Choose the parking space: public or shared?*

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

People who use cars have two choices of parking: use public parking spaces or shared parking spaces. The proportion of different parking spaces, Pr_{car_pub} and Pr_{car_pri}, can be expressed as:

$$Pr_{car\_i} = \frac{\exp(\beta \times U'_{car\_i})}{exp(\beta \times U'_{car\_i}) + exp(\beta \times U'_{car\_i})} \times Pr_{car} \ (i = \text{“}pub\text{” or “}sha\text{”}) \qquad (24)$$

$$Pr_{car\_pub} = Pr_{car} - Pr_{car\_pri} \qquad (25)$$

where U'_{car_i} is the utility of using public or shared parking spaces without considering the time in vehicle, expressed as:

$$U'_{car\_i} = -(t_{p|car\_i} + t_{walk|car\_i}) \cdot VOT - P'_{fuel|car\_i} - P_{fare|car\_i}$$

(i = “*pub*” or “*sha*”) (26)

$P_{fuel|car\_i}$ is the cost of fuel consumption for using public or shared parking spaces in the whole travelling process, while $P'_{fuel|car\_i}$ is the fuel consumption without considering the time in vehicle, expressed as:

$$P_{fuel|car\_i} = f_{car} \cdot (t_{p|car\_i} + t_{in\_veh|i}) \ (i = \text{“}pub\text{” or “}sha\text{”}) \qquad (27)$$

$$P'_{fuel|car\_i} = f_{car} \cdot t_{p|car\_i} \ (i = \text{“}pub\text{” or “}sha\text{”}) \quad (28)$$

Considering the congestion effect, the in-vehicle time is impacted by number of cars and buses on the road, expressed as:

$$t_{in\_veh|k} = t^0_{in\_veh|k} \cdot \left(1 + \alpha_1 \cdot \left(\frac{Q}{capacity}\right)^{\alpha_2}\right) \ (k = \text{“}bus\text{” or “}car\text{”}) \qquad (29)$$

where α_1 and α_2 are coefficients, $capacity$ is the capacity of roads.

3. INSTANCE ANALYSIS

3.1. Basic Parameters

Based on the investigation of Nanjing[1] and other large cities in China, the simulated city M City is selected as an instance analysis. M City take the RMB as the monetary unit. Assuming that

[1] The basic statistics of Nanjing are investigated from the Statistics Yearbook of Nanjing 2016, 2017, 2018 made by Nanjing Municipal Bureau, http://221.226.86.104/file/index.htm.

1. The average land price in M is 9147 RMB/m^2 (the average land price in Nanjing in 2017 is 9147RMB/m^2), then we get the parameter p_{land}=0.13RMB/hour (the average lifetime of parking space in Nanjing is 8 years).
2. The value of time is VOT=0.196RMB/min (the average annual salary of non-private employees in urban areas in 2017 in Nanjing is 101503RMB/year).
3. The fuel consumption per minute of each car is f_{car}=0.26RMB/min (the average speed of cars on the road in Nanjing is 28.58km/h, the petrol price in June, 2018 in Nanjing is 7.28RMB/L, and the average fuel consumption is 0.075L/km). The fuel consumption per minute of each bus is f_{bus}=0.5RMB/min (the average speed of bus on the road in Nanjing is 14km/h, the average fuel consumption is 0.3L/km)
4. The management fee of public parking spaces is $p_{m|pub}$ =0.2RMB/(min·lot), and the management fee of shared parking spaces is $p_{m|sha}$=0.5RMB/(min·lot).
5. The area of each parking space is S=15m^2, the average capacity of each bus is C=60
6. The distance between the origin(O) and the destination(D) is 13km (the commuting distance in Nanjing in 2018 is 13km), the total number of travelers is Q=10000, the road traffic capacity is $capacity$=4000, the traffic capacity for bus transit lanes is $capacity'$=150
7. The emissions of each bus in one minute is e_{bus}=0.12RMB/min, and the emission of each car in one minute is e_{car}=0.05RMB/min.

We assume the buses run on the bus lanes. In this context, only two possibilities of the transportation.

Possibility 1: By car

The average in-vehicle speed of car is 50km/h, then the in-vehicle time spend on a car is $t^0_{in-veh|car}$ =13min as the situation of no-congestion, and the in-vehicle time considering congestion can be calculated by formula (31). Then the drivers have two choice on parking. The first one is to park in the shared parking spaces. In this scenario, parking fee per hour is $P_{fare|\text{car\_sha}}$=8RMB/h. The time of the act of parking itself is $t_{p|car-sha}$=2min. If the distance between the shared parking spaces to the destination is 100 meters, the walking speed is 100m/min, then the time of waking will be $t_{walk|car-sha}$ =1min. The second choice is the public parking spaces. Parking fee per hour is the variable in this study.

The time of the act of parking itself is $t_{p|car-pub}$=4min. If the distance between the public parking spaces to the destination is 200 meters, then the time of waking will be $t_{walk|car-pub}$=2min.

Possibility 2: By bus

We assume the distance between the origin(O) and the bus station A is 500 meters as long as the distance between the destination(D) and the bus station B. The average in-vehicle speed of bus is 40km/h, then the in-vehicle time spend on a bus is $t^{0}_{in-veh|car}$=18min as the situation of no-congestion, and the in-vehicle time considering congestion can be calculated by formula (31). The bus fare is 2 RMB, the average time of waiting for bus is $t_{wait|bus}$=8 minutes. If the walking speed is 100m/min, then the time of walking to/from the bus station is $t_{walk|bus}$=10min.

In addition, the scale parameter is β=0.2 in the formula (21), (24), (26) based on the Discrete Choice Model, the coefficients in the formula (31) is α_1=0.5 and α_2=4 as the empirical value.

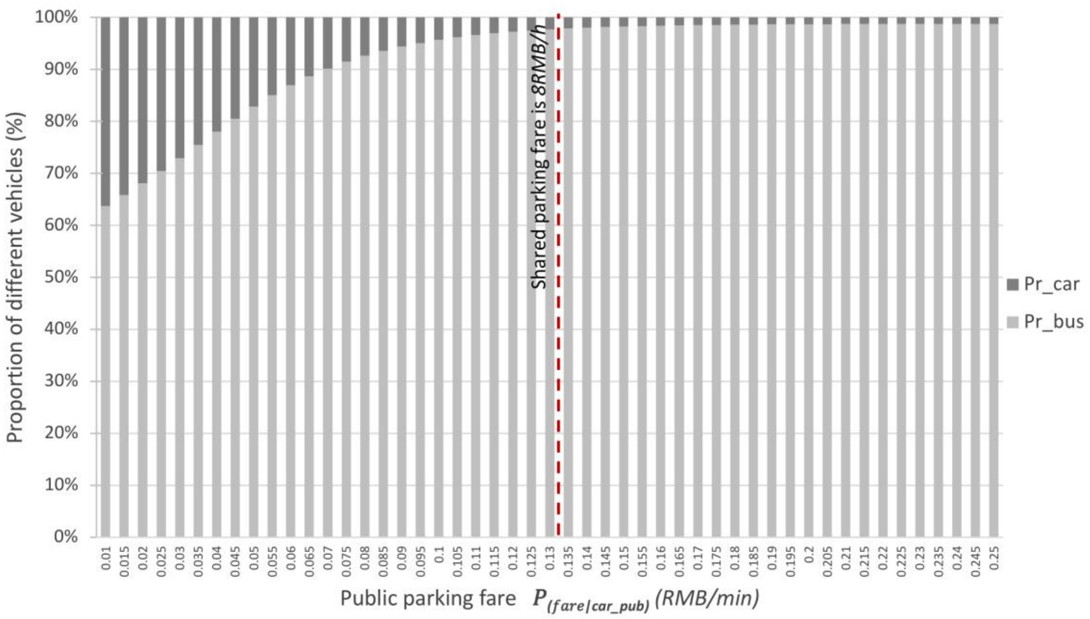


FIGURE 1 - PROPORTION OF BUSES AND CARS

3.2. Results and Analysis

The price of public parking lots significantly affects the choice of travel options and the choice of parking options. As shown in Figure 1, with the price of shared parking spaces unchanged, as the price of public parking spaces rises, people's bias toward bus increase significantly. However, even if the price of public parking spaces continues to rise, a small number of groups still choose to drive, whose value of time (VOT) can be higher than the social average because of their high salary and social status. Furthermore, according to the principle of complementary goods, the increase of public parking fees results in the increase of the number of shared parking spaces, as shown in Figure 2, which is similar to the logistic growth curve.

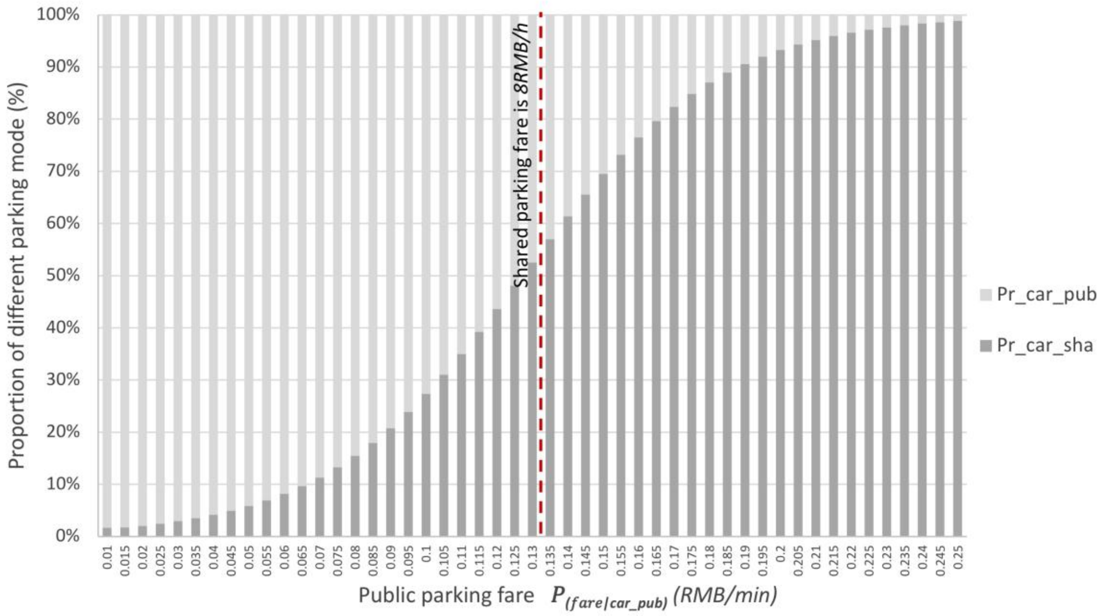


FIGURE 2 - PROPORTION OF PUBLIC PARKING AND SHARED PARKING

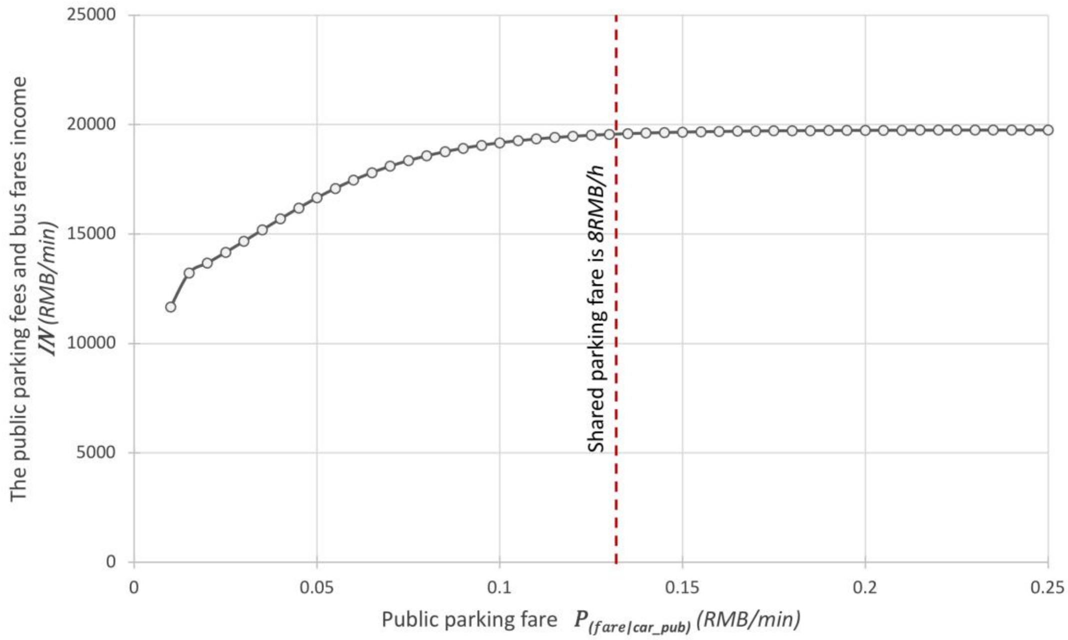


FIGURE 3 - PUBLIC PARKING FEES AND BUS FARES INCOME AT DIFFERENT PUBLIC PARKING FEES

People's preference for travel mode and parking mode further lead to variation in the factors in Formula (3). With the iterative calculation method, the trend of the public parking fees and bus fares income, the total emissions, the amount of parking management fees, the time and fuel consumption due to congestion, the time and fuel consumption generated during parking, and the savings in land cost are shown in Figure 3 to Figure 8.

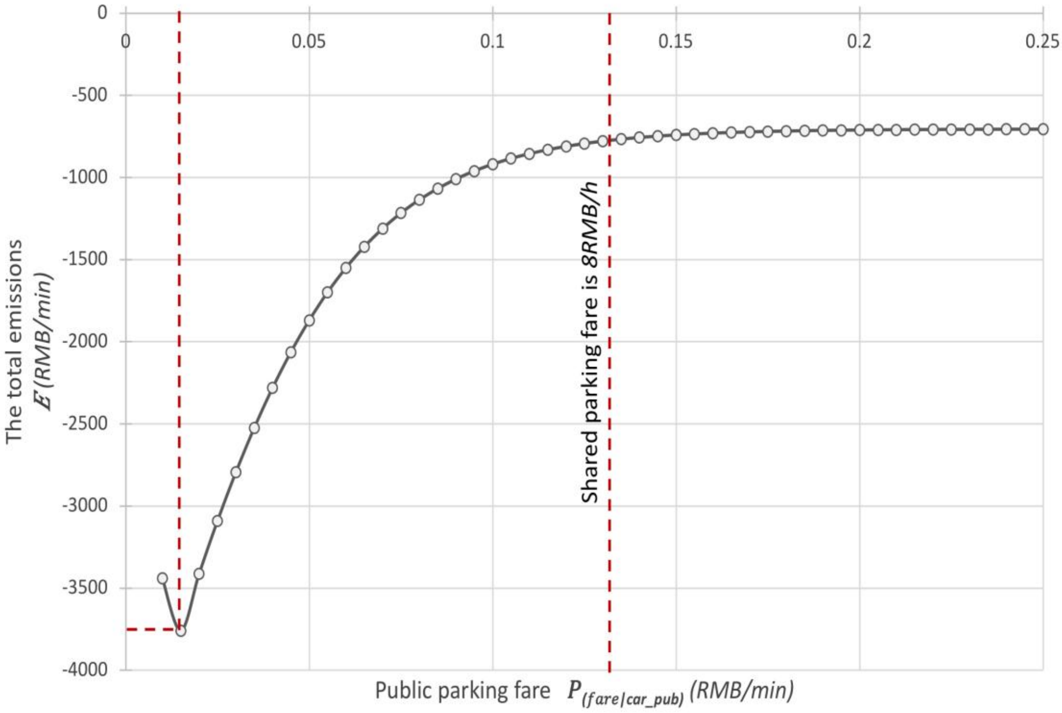


FIGURE 4 - TOTAL EMISSIONS AT DIFFERENT PUBLIC PARKING FEES

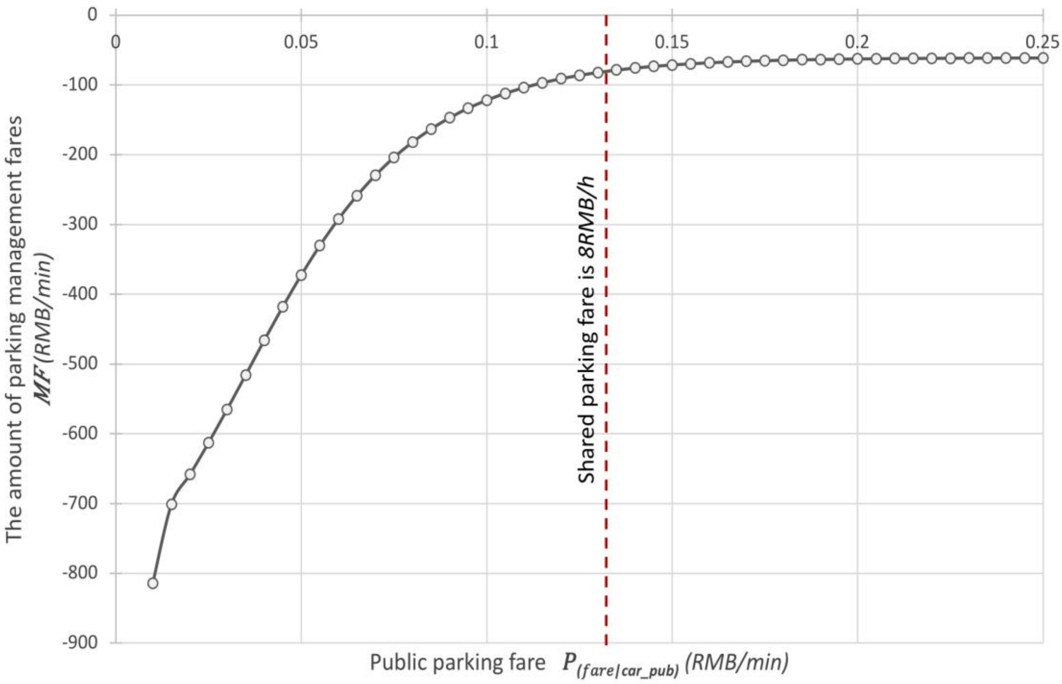


FIGURE 5 - PARKING MANAGEMENT FEES INCOME AT DIFFERENT PUBLIC PARKING FEES

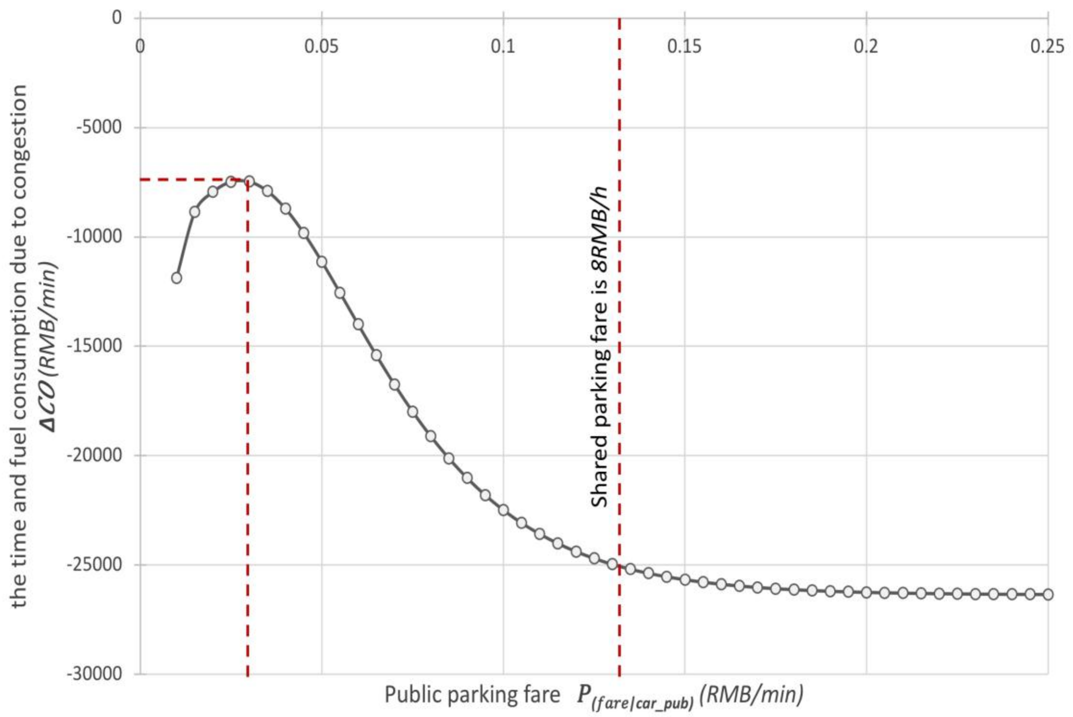


FIGURE 6 - TIME AND FUEL CONSUMPTION DUE TO CONGESTION AT DIFFERENT PUBLIC PARKING FEES

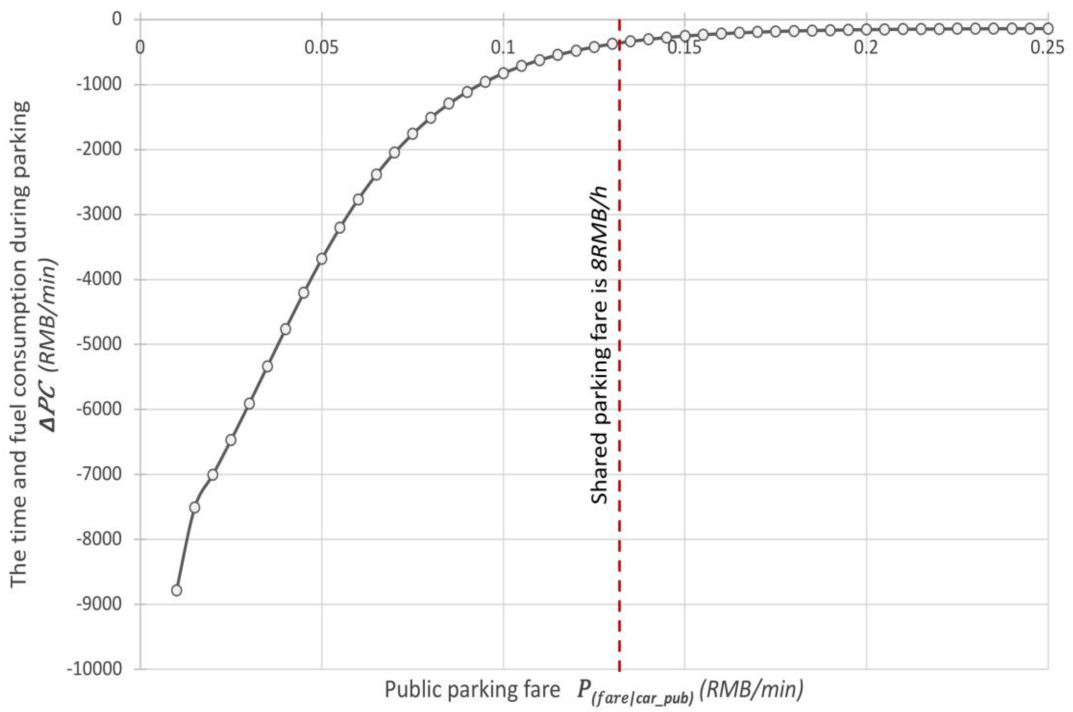


FIGURE 7 - TIME AND FUEL CONSUMPTION DURING PARKING AT DIFFERENT PUBLIC PARKING FEES

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

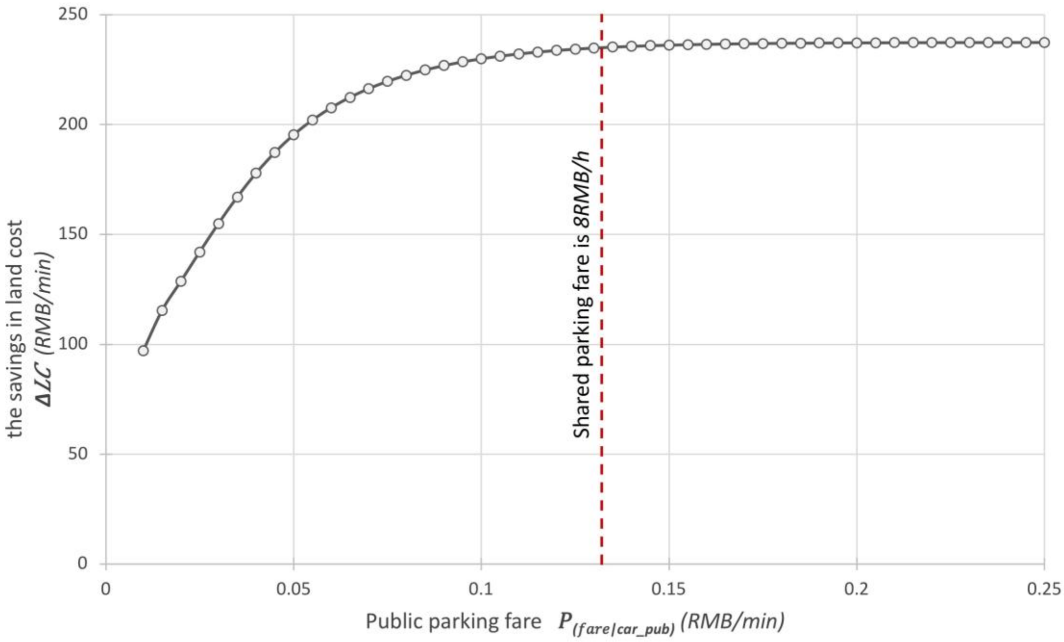


FIGURE 8 - SAVINGS IN LAND COST AT DIFFERENT PUBLIC PARKING FEES

Shared parking spaces are provided by enterprises, hospitals and individuals, which is under less control of government compared to the public parking spaces. In the view of different sub-goals of government, we can analyze the impact of government pricing on public parking spaces on a certain city problem as follows.

Objective 1: Give priority to alleviating traffic congestion

Theoretically, the fewer vehicles driving on the road, the better the smoothness of the road. One of the ways to control the vehicle is to increase the price of the parking space. However, as the daily travel of residents is just needed, the reduction of cars will inevitably increase the demand for buses. Assumed that the bus only runs on the bus transit lane, when the number of buses is much larger than the road capacity, the same congestion will occur, and the travel cost of the original residents on the private car is transferred to the bus. Therefore, as shown in Figure 6, the time and fuel consumption due to congestion decreased at the beginning, but as the public parking price continuing increasing, the negative effects caused by congestion turn to increase.

Objective 2: Increase fiscal revenue

In terms of urban public transportation and parking, government revenue can be increased by increasing bus fare revenue, public parking fees income, and reducing parking lot management fees. When the government intends to increase the price of public parking fees, the public parking lot management fees will drop, as shown in Figure 5. Separately, the increase of demand for buses result in the increase in bus fare revenues, and the revenue from public parking fees continue to rise. The public parking revenues, however, increase firstly and declined sharply due to the decrease of the number of parking lots and the increase in the unit price of parking which can be shown in Figure 9.

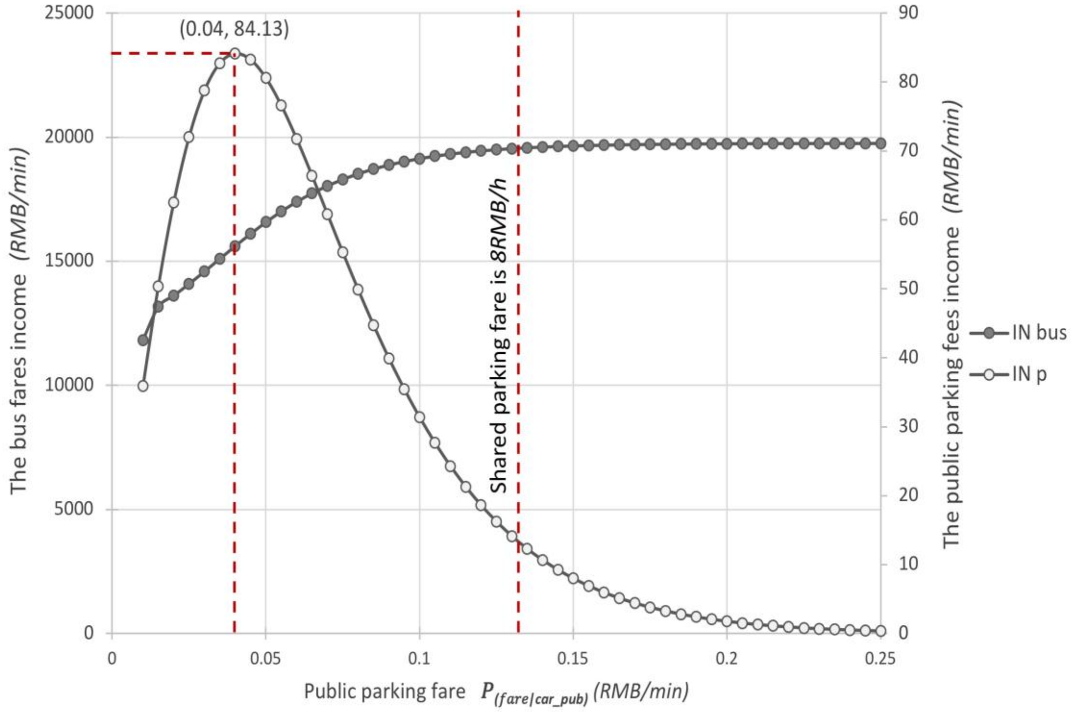


FIGURE 9 - COMPARISON OF PUBLIC PARKING FEES INCOME AND BUS FARES INCOME

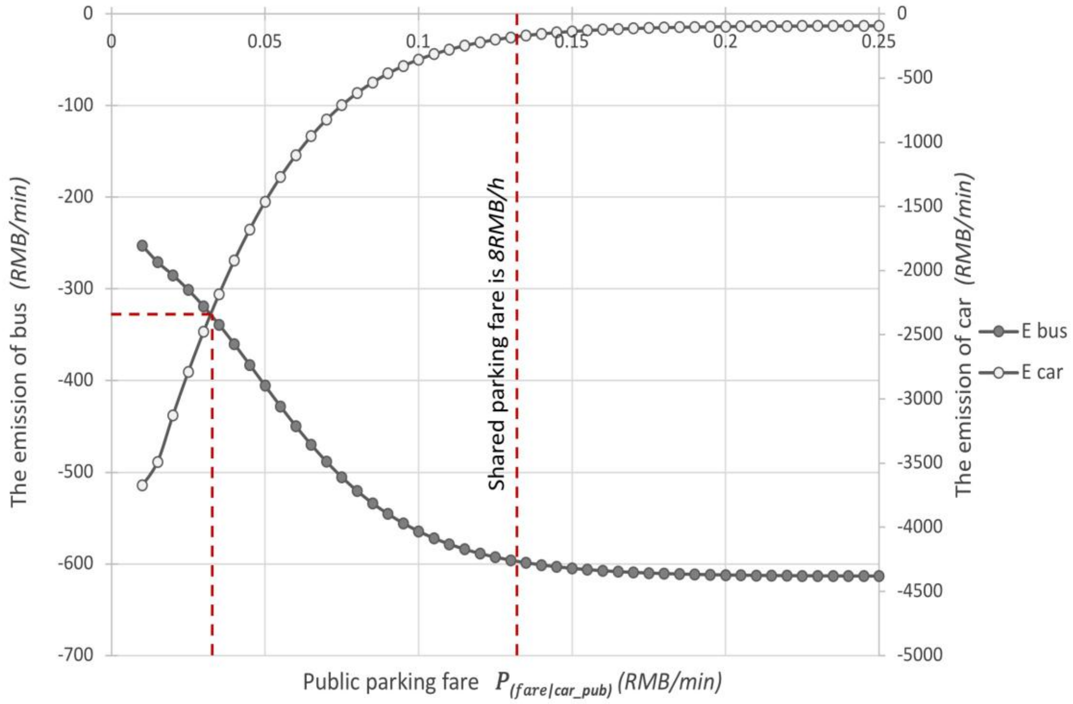


FIGURE 10 - COMPARISON OF EMISSION OF BUSES AND EMISSION OF CARS

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

Objective 3: Reduce exhaust emissions and mitigate air pollution

With the increasing awareness of environmental protection, the government has begun to advocate energy conservation and emission reduction, in which reducing vehicle exhaust emissions is an effective way. Assumed that both cars and buses use gasoline as fuel, emissions from cars and buses are directly related to the number of vehicles. With the increase of parking fees, the emissions from cars transfer to the buses as it shown in Figure 10. In reality, the rapid increase of new energy vehicles and buses has effectively reduced pollutant emissions.

Objective 4: Comprehensive development

Although the government has many sub-goals, in fact, the government's goals are often comprehensive. Aiming to solve a certain problem, we must also consider the impact on other issues when making reasonable measures. Therefore, according to the Formula 3, the factors above are superimposed, and it is concluded that as the price of public parking spaces rises, the urban total social benefits show a trend of increasing firstly and then decreasing. Shown in Figure 11, in M City, the government will get a maximum objective profit when the public parking fee is 0.045RMB/min (2.7RMB/h).

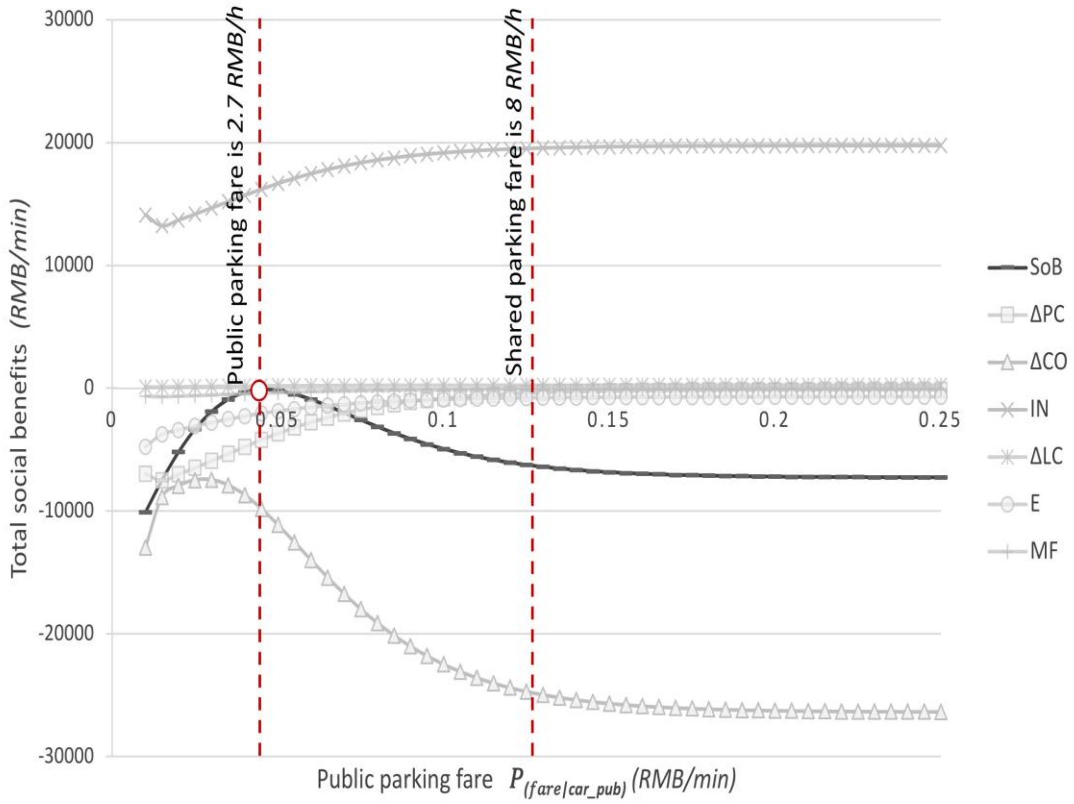


FIGURE 11 - CHANGE OF THE TOTAL SOCIAL BENEFITS AND OTHER FACTORS AT DIFFERENT PUBLIC PARKING FEES

4. CONCLUSIONS

The shared parking mode effectively alleviates the city problem of parking difficulties. Different from the discussion of shared parking itself, this study analyzes the impact of residents' choices on various urban benefits from the perspective of urban residents' travel choices and parking options.

In this study, based on the public parking fees as an independent variable, the model of the choice of residents' travel mode and the choice of parking mode are constructed. Furthermore, this study builds a model to explore the impact of public parking fees on urban efficiency, including the time cost of vehicle congestion, environmental pollution caused by emissions during driving and parking, parking costs, management costs, etc. At the same time, these factors are often reflections of the government objectives in a certain period of time. In the meanwhile, the supply of shared parking spaces, which affected by the public parking spaces in this study, can affect the total social benefits in different scenarios.

Conclusion 1: When the city aims to solve the traffic congestion problem firstly, increasing the price of the parking spaces (this study focuses on public parking spaces), together with traffic congestion fees and rising oil prices, can be an effective solution for urban public agents to convey people from individual to public transport. Then the traffic flow could decrease significantly. Besides, as experiences in most cities, appropriately reducing the supply of parking spaces will also lead people to choose public transportation, thus easing traffic congestion.

Conclusion 2: When the objective is to obtain more fiscal revenue, increasing the parking price will lead to changes in the number of parking and the number of passengers on the bus. With the increase of public parking fares, the bus fare income increases with a decreasing growth rate, while the public parking income increase firstly and declined sharply. In general, it will result in an increase in overall income. But when the parking cost is much higher than normal, most people will switch to public transportation, and the total income approaches a certain amount.

Conclusion 3: When reducing emissions become the main objective, the reduction of cars by increasing parking fees will also result in the exhaust emissions transfer from cars to buses. With the increase of parking fees, the emissions from cars decrease with a decreasing decline rate. With the demand of bus increase, the emissions of buses will gradually increase, theoretically as it shown in the model of this research. It cannot be ignored that if the number of buses does not increase due to people's preferences for buses, the emissions of buses would increase slower than in the model. But in both cases, total exhaust emissions, including buses and cars, will decrease. And with the rapidly increasing number of buses and cars using low-carbon energy, the pollutant emissions have reduced effectively.

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

Theoretical and Empirical Researches in Urban Management
Volume 15 Issue 1 / February 2020

In reality, the more common situation is that the government will formulate comprehensive development goals. Considering the above various factors, the overall benefits of the government will fluctuate with the increase of public parking prices with an optimal solution within a certain range.

5. ONGOING STUDY

The ideal model of this research still has many shortcomings. Firstly, this study assumes that the choice of long distance travelling only between cars and buses, but in many big cities, the operation of subway takes a considerable part of the passengers, and some people drive to the P+R (Parking and Ride) parking lot and change to the bus. Secondly, the model in this study assumes that the bus only runs on the bus lanes. But in many cities without bus lanes, buses and cars run on the same lanes, and they can both result in congestion. Moreover, because of the slowly speed of buses, and buses would stop frequently on the road, the congestion caused by buses in the cities without bus lanes cannot be ignored. Thirdly, the applications (APPs) now make the shared parking price more favorable, and the fees are regulated with the traffic flow which is not fixed as described in this model.

Therefore, the ongoing research will make breakthroughs in the following aspects:

1. In the view of urban planning, the study will further consider the location relationship between shared parking spaces, public parking spaces, the origins (O) and destinations (D), and explain how they can affect the social benefits with comprehensive consideration of living density and land use properties.
2. A model considering subway need to be established in the study of big cities. In this circumstance, the type of travelling will be divided into by car, by bus and by subway. And the distance of the trip needs to be considered, since the prices of subway increase rapidly as travel distance increase, together with the increasing time on transfer between metro lines, which may convey some people from subway to cars. As a result, the price of public parking lot and the distance of trip are both independent variables in the model.
3. Since the shared parking price can be regulated with the traffic flow, both the price of sharing parking and public parking should be considered in the model. It will be meaningful to explore the impact of relationship of shared parking price and public parking price on the total social benefits.

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