# Game Analysis of Risks and Benefits of Shared Parking Stakeholders

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**Abstract.** Clarifying the risks and benefits of stakeholders becomes an important basis and prerequisite for promoting shared parking. Aiming at maximizing the shared benefits of different stakeholders, this paper constructs a complete information static game among stakeholders. And based on the equilibrium value of the game, a method is proposed to solve the conflicts and contradictions of different stakeholders' interest demands. The results showed that when parking demanders are willing to choose shared parking spaces, the shared platform should reduce the cost of active publicity, increase the service fee paid by suppliers and managers to the shared platform, and increase the management fee of parking managers; when the shared platform obtains more parking space resources at a low cost, the shared parking fee and service fee paid to the platform should be reduced and the parking fee income of the parking suppliers should be increased.

**Keywords:** Urban traffic, Shared parking, Complete information static game model, Residential area, Risks and benefits

## 1. INTRODUCTION

Shared parking model has become the most effective way to solve the problem of urban parking. However, the promotion of the shared parking model is not optimistic in practice. The most important reason is that the shared parking mode involves many stakeholders, who have contradictions and conflicts in taking risks and obtaining benefits. Some scholars have proposed the feasibility and implementation methods of Shared parking, mainly from the perspectives of shared intention [1] [2]and resource allocation optimization methods [3][4]. Only a few scholars analyzed the game relationship between stakeholders [5][6][7]. For example, Zhu Chengjuan [8] and others proposed a three-tier Stackelberg game model for government managers, private parking operators, and travelers to study the allocation and reservation price of parking spaces. Duan Manzhen [9] analyzed two game problems involved in shared parking in residential areas. One is the dynamic game between shared platform and drivers, the other is the crowded parking game between drivers and drivers. Peng Yong et al. [10] analyzed the reasonable profit distribution expression among the shared platform, the community property, and the berth owner. The existing research simplifies the game relationship between stakeholders. There is a lack of reference value for the benefit

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distribution of a shared parking stakeholder that can participate in shared parking. Therefore, it is difficult to balance the interests of all relevant parties, making it difficult for parking lots of different land properties to share parking spaces. Therefore, this paper will build a game relationship model between shared platform and demanders based on their benefits and risks. Then, according to the equilibrium value of the game, the method intended to solve the conflict and contradiction of the interest demands of different stakeholders is put forward. The solution process of game equilibrium value is demonstrated based on a case study in Ningbo, China, and a concrete solution is proposed according to the equilibrium value obtained.

## 2. Static games with complete information for shared platform and demanders

The implementation of shared parking mode brings both economic benefits and social benefits to the shared platform. At the same time, the platform needs to bear operational risks, such as the construction and maintenance costs of the platform and the risk of low enthusiasm for parking space shared. Parking demanders hope to improve the convenience and quality of life of parking by shared parking. But at the same time, they also face the problem of shared parking distance and parking cost. Therefore, in order to effectively solve the concerns of the shared platform and parking demanders under the shared parking mode, and realize the maximization of the interests of the two stakeholders under the shared parking mode, it is necessary to analyse the game relationship between them.

Game model: $G_e = \{N_e, A_e, V_e\}$

In the above equation, $N_e$ is a stakeholder, $N_e = N_i\ (i = 1,2)$, $N_1$ is a shared platform. Since all parking demanders have the same interest demands, all parking demanders are considered as a stakeholder, so $N_2$ represents parking demanders. $A_e$ is the strategy combination, $A_e = A_{ij}\ (i = 1,2; j = 1,2)$. Among them, $A_{ij}$ is the $j$ strategy made by the $i-th$ stakeholder. In this game relationship, shared platform has two strategic choices. First, when the shared platform actively publicizes shared parking, it can obtain more shared parking space resources. At this time, if the parking demander uses the shared parking space, it will make the shared platform get more benefits. Second, when the shared platform does not actively promote shared parking, the shared parking space resources will be less. This may lead to the shared platform not meeting the parking demand of parking demanders on the platform. At the same time, the benefits obtained by the shared platform will be reduced accordingly. Therefore, the strategy set of the shared platform (active publicity, inactive publicity) can be expressed as $(A_{11}, A_{12})$. Parking demanders can either put forward their parking demands to the shared platform or conduct free parking according to their own parking habits, which means parking at the ordinary parking lots. So, the strategy set of parking demanders can be expressed as (Shared parking, free parking), denoted as $(A_{21}, A_{22})$. $V_e$ is the benefit obtained by stakeholders, $V_e = V_i\ (i = 1,2)$, $V_1$ is the benefit of shared platform, and $V_2$ is the benefit of parking demanders. When the shared platform chooses to actively promote, the service fees paid by parking suppliers and parking demanders to the platform are obtained. This can bring benefits to the platform. Because of the role of shared platform, it provides an improved platform for social parking and brings social benefits. But at the same time, it costs to build a shared platform. When the shared platform is not actively publicized, the phenomenon of social parking has not been significantly improved. The shared platform can only get a few service fees paid by parking providers and parking demanders, but also bear the construction expenditure of the platform. For parking demanders, when they use shared parking spaces, they can quickly find the target parking spaces. This reduces their cruising time, but they have to pay for the platform service. When they choose to park freely, they have to bear the risk of long-term patrol and penalties for illegal parking as they failed to find available parking spaces. The specific payment function is shown in Table 1:

Table 1 Payment matrix of game relation between shared platform and parking demanders

| **Participant** | **Shared platform** | | |
|---|---|---|---|
| Parking demanders | Strategy | Actively promote | Not actively promote |
| | Shared parking | ( $B_{Pp}-E_{ss}-T_p$ , $B_{Ssp0}+B_{Snp0}-C_{xc0}-C_{es}$ ) | ( $B_{Pp}-E_{ss}-T_p$ , $B_{Ssp1}+B_{Snp1}-C_{xc1}-C_{es}$ ) |
| | Free parking | ( $-T_{p0}-C_{Ps0}$ , $-C_{xc0}-C_{es}$ ) | ( $-T_{p0}-C_{Ps0}$ , $-C_{xc1}-C_{es}$ ) |

Where: $T_{p0}$ represents the parking fee when the shared parking space is not used. $C_{ps0}$ represents the time cost of a free parking patrol. $B_{Ssp0}$ indicated that when the shared platform actively promotes, the parking provider pays the service fee to the shared platform. $B_{Snp0}$ indicated that the shared platform service fee paid by parking demanders during the active publicity. $C_{xc0}$ represents the cost of actively promoting the shared platform. $B_{Ssp1}$ indicates that the parking provider pays the service fee to the shared platform when the shared platform does not actively promote it. $B_{Snp1}$ means that when the shared platform is not actively promoted, the parking demander pays the service fee to the shared platform. $C_{xc1}$ said the cost of not actively publicizing the shared platform.

According to the above Nash equilibrium solution, it is assumed that the probability of selecting strategy $A_{21}$ for the Shared platform is $q_2(A_{21})$ and the probability of selecting strategy $A_{22}$ is $q_2(A_{22})$ . In order to obtain the optimal benefits after the shared platform chooses a random strategy $(q_2(A_{21})[A_{21}]+q_2(A_{22})[A_{22}])$ , the benefits of parking demanders using strategy $A_{11}$ and $A_{21}$ should be equal. That is to say,

$$V_1(q_2(A_{21})[A_{21}]+q_2(A_{22})[A_{22}],[A_{11}])=V_1(q_2(A_{21})[A_{21}]+q_2(A_{22})[A_{22}],[A_{12}])$$
$$q_2(A_{21})V_1([A_{21}],[A_{11}])+q_2(A_{22})V_1([A_{22}],[A_{11}])=q_2(A_{21})V_1([A_{21}],[A_{12}])+q_2(A_{22})V_1([A_{22}],[A_{12}])$$
$$q_2(A_{21})V_1([A_{21}],[A_{11}])+(1-q_2(A_{21}))V_1([A_{22}],[A_{11}])=q_2(A_{21})V_1([A_{21}],[A_{12}])+(1-q_2(A_{21}))V_2([A_{22}],[A_{12}])$$

$$q_2(A_{21})V_1([A_{21}],[A_{11}])-V_1([A_{21}],[A_{12}])=(1-q_2(A_{21}))V_1([A_{22}],[A_{12}])-V_1([A_{22}],[A_{11}])$$

$$q_2(A_{21})=\left(V_1([A_{22}],[A_{12}])-V_1([A_{22}],[A_{11}])\right)\Big/\begin{pmatrix}\left(V_1([A_{22}],[A_{11}])-V_1([A_{21}],[A_{12}])\right)\\+\left(V_1([A_{22}],[A_{12}])-V_1([A_{22}],[A_{11}])\right)\end{pmatrix}$$

Let

$Q_{A2}=\left(V_1([A_{22}],[A_{12}])-V_1([A_{22}],[A_{11}])\right)/\left(\left(V_1([A_{21}],[A_{11}])-V_1([A_{21}],[A_{12}])\right)+\left(V_2([A_{22}],[A_{12}])-V_1([A_{22}],[A_{11}])\right)\right)$

So,

$q_2(A_{21})=Q_{A2}$, $q_2(A_{22})=1-Q_{A2}$.

Therefore, the mixed strategy of shared platform is $s_2=Q_{A2}[A_{21}]+(1-Q_{A2})[A_{22}]$.

In the same way, it is assumed that the probability of parking demanders choosing strategy $A_{11}$ is $q_1(A_{11})$, and the probability of choosing strategy $A_{12}$ is $q_1(A_{12})$. To get the best benefit after parking demanders choose on-board strategy $q_1(A_{11})[A_{11}]+q_1(A_{12})[A_{12}]$, the benefits of shared platform using strategies $A_{21}$ and $A_{22}$ should be equal, namely:

$$V_2(q_1(A_{11})[A_{11}]+q_1(A_{12})[A_{12}],[A_{21}])=V_2(q_1(A_{11})[A_{11}]+q_1(A_{12})[A_{12}],[A_{22}])$$

$$q_1(A_{11})=\left(V_2([A_{12}],[A_{22}])-V_2([A_{12}],[A_{21}])\right)\Big/\begin{pmatrix}\left(V_2([A_{11}],[A_{21}])-V_2([A_{11}],[A_{22}])\right)\\+\left(V_2([A_{12}],[A_{22}])-V_2([A_{12}],[A_{21}])\right)\end{pmatrix}$$

Let

$Q_{A1}=\left(V_2([A_{12}],[A_{22}])-V_2([A_{12}],[A_{21}])\right)/\left(\left(V_2([A_{11}],[A_{21}])-V_2([A_{11}],[A_{22}])\right)+\left(V_2([A_{12}],[A_{22}])-V_2([A_{12}],[A_{21}])\right)\right)$

So,

$q_1(A_{11})=Q_{A1}$, $q_1(A_{12})=1-Q_{A1}$.

Therefore, the mixed strategy of parking demanders is as follows:

$$s_1=Q_{A1}[A_{11}]+(1-Q_{A1})[A_{12}]$$

Thus, the only Nash equilibrium between Shared platforms and parking demanders is $S_A^*=\left(Q_{A1}[A_{11}]+(1-Q_{A1})[A_{12}],Q_{A2}[A_{21}]+(1-Q_{A2})[A_{22}]\right)$.

## 3. Case Study

### 3.1 Data Collection

This paper conducted a field survey of more than 40 residential areas in the core areas of Haishu District, Yinzhou District, Jiangbei District and Beilun District in Ningbo, China. A series of data was obtained, such as the number of parking spaces in the residential area, acceptable shared parking fees, shared time, number of managers, managers' salaries, berth turnover rate, and acceptable losses from various safety risk accidents. The specific calculation parameter values are shown in Table 2:

Table 2 Parameter list

| Parameter name | Parameter symbol | Ranges |
|---|---|---|
| Parking fee | $P$ | 4-8yuan/h |
| Parking time per stop | $T_{Ji}$ | 0.5-8 h |
| Purchase cost of parking equipment | $C_{JBS}$ | 135000yuan-183000yuan |
| Number of parking spaces for shared parking | $n_{Js}$ | 100-250 |
| Berth turnover rate | $O_{Ja}$ | 2-3.5 |
| Probability of traffic accidents | $P_{Jtr}$ | 0.02% -0.12% |
| Average loss value per traffic accident | $\overline{B_{Jcr}}$ | 4500-6000yuan |
| Probability of privacy and security information leakage | $P_{Jpi}$ | 0.009% -0.055% |
| Average loss caused by the occurrence of privacy security breaches | $\overline{C_{JPj}}$ | 5500-10000yuan |
| Probability of conflicts between foreign vehicles and opponents | $P_{Jcr}$ | 0.007% -0.029% |
| Average loss caused by one conflict | $\overline{C_{JCf}}$ | 6000-11000yuan |
| Time consumed for parking without using shared parking spaces | $C_{Cb}$ | 0.02-0.3 h |
| The time consumed for each patrol parking when using the shared parking space | $C_{Ca}$ | 0.01-0.2 h |
| The area of shared parking spaces in the area | $A_{Csh}$ | 1375$m^2$-3437.5$m^2$ |
| Average area value | $V_{CA}$ | 3444.12yuan/㎡ |
| Social benefits brought by employment opportunities | $B_{Caw}$ | 1500-3500yuan |
| The amount of fine for one violation | $P_{Cwt}$ | 150yuan |
| Probability of Violation | $P_{wz}$ | 0.2%-5% |
| Time average value | $W$ | 85.184yuan/h |
| Social discount rate | $i$ | 8% |

### 3.2 Solution to equilibrium value of game between shared platform and parking demanders

According to the matrix payment function in Table 1, the benefit value of the game relationship between the shared platform and the parking demander is calculated, as shown in Table 3.

Table 3 Benefit value of game relationship payment function between shared platform and parking demanders

| **Participant** | **Shared platform** | | |
|---|---|---|---|
| Parking demanders | Strategy | Actively promote | Not actively promote |
| | Shared parking | (-14.2333, -0.6838) | (-12.5933, 1.1323) |
| | Free parking | (-12.5933, -11.8277) | (-14.2333, -7.1638) |

After normalizing the revenue values under different strategy choices, the following table can be obtained. And then, the strategy selection probability and Nash equilibrium solution of shared platform and parking demander are solved. The results are shown in Table 4.

Table 4 The benefit value of the normalized payment function

| **Participant** | **Shared platform** | | |
|---|---|---|---|
| Parking demanders | Strategy | Actively promote | Not actively promote |
| | Shared parking | (0, 0.97) | (0.1, 1) |
| | Free parking | (0.1, 0.16) | (0, 0.46) |

$$Q_{A1} = |0.46 - 0.1| / (|0.97 - 1| + |0.46 - 0.16|) = 0.91$$

$$1 - Q_{A1} = 1 - 0.91 = 0.09$$

$$Q_{A2} = |0 - 0.01| / (|0 - 0.01| + |0 - 0.01|) = 0.5$$

And so, $1 - Q_{A1} = 0.5$

From the calculation results above, it can be seen that the only Nash equilibrium between parking demanders and the shared platform is $S_A^* = (0.91[A_{11}] + 0.01[A_{12}], 0.5[A_{21}] + 0.5[A_{22}])$.

As to get the maximum benefit in the game relationship, the probability of parking demanders choosing the strategy of shared $A_{11}$ is 0.91, the probability of choosing the strategy of free parking $A_{12}$ is 0.01, and the probability of actively promoting $A_{21}$ and not actively promoting $A_{22}$ in the strategy of shared platform are both 0.5. Shared parking is not the only best choice for parking demands, and active publicity is not the best choice for shared platforms, either. Therefore, the acceptance of the shared parking model by parking demanders should be strengthened to make sure the shared parking model can be better promoted. And the utilization rate of shared parking spaces by parking demanders should be increased. To enable the shared platform to obtain abundant parking resources with the lowest publicity costs. We can make the parking demanders choose the strategy $A_{11}$ with the probability $Q_{A1} = 1$, and the shared platform to choose the strategy $A_{22}$ with the probability $1 - Q_{A2} = 1$, that is, $Q_{A2} = 0$.

Let $V_2([A_{11}],[A_{21}]) - V_2([A_{11}],[A_{22}]) = 0$. We can substitute it into the payment function to get $-0.6838 - 1.1323 = -1.8161$ (ten thousand yuan). When parking demanders are willing to choose shared parking spaces, the shared platform should try to reduce the cost of positive publicity to 18161 yuan / month. On the premise of meeting the interests of the suppliers, part of the expenses of the parking lot suppliers are handed over to the shared platform. Or the service fees paid to the shared platform by suppliers and managers are appropriately increased, and the additional revenue of the shared platform is increased by 18,161 yuan / month. If the extra income still cannot reach the equilibrium value, it is necessary to apply for the financial support from the government to meet the shared interest demands of the shared platform.

$V_1([A_{22}],[A_{12}]) - V_1([A_{22}],[A_{11}]) = 0$, replace the payment function to $14.2333 - (-122.5933) = -1.64$ (ten thousand yuan). It means that when the shared platform obtains more parking space resources at a lower cost, it should try to reduce shared parking fees and service fees to 16,400 yuan/month. At this time, if the parking lot supplier cannot satisfy its own shared interests because of the low parking revenue, the cost saved by the shared platform can be shared with the parking supplier, in other words, the reduced revenue of the shared platform due to the lower service fees of the parking demanders will be compensated by the cost savings. If the equilibrium value is still not reached, the government needs to invest corresponding funds to meet the needs of parking service providers and platforms.

## 4. Conclusions

Based on game theory, this paper constructed the game model between parking demander and shared platform. Then the solution method of game equilibrium value between different stakeholders was deduced to better understand the compensation made by the cost saved by the shared platform and make the implication in term of government support. Taking the residential area in downtown Ningbo as an example, the equilibrium solution of the game relationship between parking demanders and shared platforms was analysed. The results show that when parking demanders are willing to choose shared parking spaces, the shared platform should reduce the cost of active publicity as much as possible, or appropriately increase the service fee paid by suppliers and managers to the shared platform to 18,161 yuan per month. When the shared platform obtains more parking space resources at a lower cost, the shared parking fee for parking demanders and the service fee paid to the platform should be reduced to 16,400 yuan per month.

## References


[1] XIE Jin, YE Xiao-fei, LU Li-li et al. Risk and benefit analysis of shared parking in residential areas based on structural equation model[J]. Technology and management, 2019,5(21):1-7.

[2] Jin Xie, Xiaofei Ye et al . Impact of Risk and Benefit on the Suppliers'and Managers'Intention of Shared Parking in Residential Areas. Sustainability 2020, 12, 268.

[3] Yanfeng Geng, Christos G. Cassandras. New "Smart Parking" System Based on Resource Allocation and Reservations. transaction on intelligent transportation systems, 2013,14(3):1129-1139.

[4] Ni, L.L. Evaluating Shared Parking for New Developments. Public Work. 1984, 115, 2.

[5] CHEN Jun, XIE Kai. Dynamic allocation model and effect evaluation of parking berth sharing in central city[J]. China highway journal, 2015,28(11):104-111.

[6] DUAN Man-zhen, YANG Zhao-sheng, MI Xue-yu, et al. Bilevel programming induction model based on Shared parking in residential area [J]. Journal of Southwest Jiaotong University, 2016,51(5):1250-1257.

[7] YAO En-jian, ZHANG Zheng-chao, ZHANG Jia-lin, et al. Model and algorithm for optimal allocation of Shared berth resources in residential area [J]. Transportation systems engineering and information, 2017,17(2):160-168.

[8] Hamid, A. Applying Shared-Parking turn-time(SPATT)model and geographic information system in the supply and demand analisis of parking space. Malays. J. Real Estate 2006, 1, 57–76.

[9] ZHU Cheng-juan, JIA Bin, HAN Ling-hui. Parking space allocation and pricing based on Stackelberg game[J]. Transportation systems engineering and information, 2015,15(3):19-24.

[10] PENG Yong et al. Research on sharing revenue distribution of parking space -- based on incomplete information bargaining game model[J]. Price theory and practice, 2018,2:67-70.