P&R Behavior Analysis and Models in Metropolis: A Case Study in Beijing, China

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Abstract

Building the P&R system is an effective method to lessen the traffic pressure in the Metropolitan center and to increase the trip efficiency.The research from the aspect of travel behavior will provide the foundation for planning and effective utilizing of the P&R system. In this paper, a parking behavior survey in Beijing is introduced. On the basis of analysizing the results of the survey, the influential factors for the P&R behavior are discussed with a binary logit model. The results show that the trip time and cost are very important influential factors for the P&R behavior. In addition, the departure place, the terminal parking place, trip purpose, occupation and income level of the travelers also have some influence on the P&R behavior.

Key words: P&R; Revealed preference survey; Stated preference survey; Logit model

1 INTRODUCTION

Along with the rapid development of city economy and the fast growth of the motor vehicles, traffic problems, such as traffic jam and parking difficulty, are serious especialy in the center district of the metropolis. Building P&R (Park and Ride) system is an efficient way to alleviate the traffic pression in the centre. P&R is a traffic service system which allows travelers who use their private car park at the P&R site and transfer to public transport in urban, congested areas. As a facility from low capacity to high capacity, eco-friendly traffic mode, it can increase the trip efficiency and are helpful to the sustainable development of the urban transportation.

At the present, Chinese P&R system is under active planning. To produce maximal economic and social benefit and to fully demonstrate the effect of P&R thus resolve the traffic jam in centre district, it is necessary, from the prospective of travel behavior, to analyze the influential factors.

This paper is a case study in Beijing. On the basis of P&R behavior survey, the influential factors for the P&R behavior is discussed with a binary logit model. The result will give references for the planning of P&R system.

2 LITERATURE REVIEW

Many specialists and scholars have researched on the P&R behavior. The paper made by Peter J Foote [1] is mainly about CTA (Chicago Transit Authority) weekday users: a choice market with rideship growth potential. In the fall of 1998, 1758 of CTA Park and Ride Users were surveyed on weekdays at 15 CTA Park and Ride lots. The results show that riders who chose Park and Ride primarily because it was the fastest way to make their trip, because of the high parking cost at the destination, or because they dislike driving.

Hongzhi Guan etc [2~4] established a SP/ED (Stated Preference/Experiment Day) combined model and made a sensitivity test by the stated preference data collected in Kofu. The conclusion indicates that the parking fee, commuter time and commuter fee are important factors in the mode choice.

Daniel Baldwin Hess [5] does research on the effect of parking fee on commuter mode choice by the travel diary data. The conclusions show that the policy variables affecting the mode choice for commuters are the parking cost and the travel time by transit, and the results suggest that raising the cost of parking at work sites and decreasing the transit travel time (by improving service and decreasing headways) will reduce the drive alone mode share. In addition, the income and the quantity of private car also affect the mode choice, but the sex's influence is small.

The paper made by Young Jong Kwon & Young [6] in Kwon maily analyzes the elements for the effective use of Park-and-Ride facilities in the Seoul metropolitan areas, Korea. About 550 of the facility users and 340 commuters were surveyed for this study to find the reasons why most park-and-ride facilities do not operate as transfer facilities. From the study results, the elements can be classified from three aspects: elements of the facility itself, linked public transportation, and other connected things. As the elements of park-and-ride facility itself, reduced parking fees for transfer passengers, reduction of walking distance, and convenience of accessibility were the important element for the effective use of the facility. As the elements of linked public transportation, travel time and cost savings, service of public transportation were the influencing elements to induce car users onto public transportation. As the other elements, parking restriction in the CBD was the most influential element to the effective use of park and ride facilities.

In China, the research on P&R is relatively rare. Han Congying & Ji Ling [7] summarized the necessity and function of building P&R facility in China. Liu Youjun & Yan Kefei [8] have carried a GIS-based study on the optimum location of urban P&R facilities. Qin Huanmei & Guan Hongzhi [9] have conducted an elementary analysis on the P&R system choice behavior survey in the metropolis. All these works are beneficial for further study in the P&R in China.

3 P&R BEHAVIOR SURVEY

At present, there is no specific P&R system in Beijing. In order to master P&R behavior, and probe into the factors influencing P&R behavior further, we carried on a survey at 11 representative parking lots in Beijing. The survey targeted at parking of home-car drivers and recorded their trip behavior data by RP (Revealed Preference) survey and choice preference data to P&R system by SP (Stated Preference) survey. RP is a survey of choice behavior that has been already realized, SP is to investigate the choice preference of the subject under the assumed conditions.

Generally speaking, the difference of utility in cost, time and so on is the primary elements that influents the trip mode choice. The transit is a mainly component of P&R system. The superiority in cost, time and so on that the transit embodied has a direct effect on the utility between P&R and car use, thus they are important elements considered by travelers who will choose P&R or not. In the design of SP survey scheme, assumed conditions are the change of trip cost and time after the P&R system as opposed to by private car by oneself. The two variables are set up 3 change levels-increase, remain and reduction, and there are 9 horizontal combinations in all like this. In order to make multifactor and multilevel efficiently and organically combined and ensure the simplicity, validity of the questionnaire, we select 5 levels combinations as the assumed conditions by Quad Orthogonal Test [10] as shown in Table 1. We inquire the P&R choice preference the persons who go out by their private car under the five assumed conditions.

In addition, the questionnaire also includes personal basic information and trip basic message including annual income, occupation, age, trip purpose, departure place etc.

In order to make the survey sample have comprehensive representativeness, we have considered the flourishing degree and the situation of land utilization in different area of Beijing while choosing the survey places. The survey places have covered the key area of Beijing as shown in Figure 1.

The survey took the method of questionnaire investigation live, namely the investigator inquire the interviewees at designated time, place and make them fill in the questionnaire.

In addition, because the composition of the respondent may be different on weekdays and weekend [11] and thus different the trip behavior and preference. The survey was conducted at 8:30~12:00 a.m on July, 8 (Thursday) and on July, 10 (Saturday) in 2004 separately.

This survey retrieved 509 effective samples in which the numbers of effective samples varies according to the items to some extant.

4 ANALYSIS ON SURVEY RESULTS

4.1 PERSONAL AND TRIP INFORMATION

In this section, the distribution of occupation, income, departure place, terminal parking place, trip purpose and paying mode are analysed.

Generally speaking, occupation and income will influence the trip choice behavior as person's economic characteristics. From Figure 2, 3, we can find out that other occupations type is distributed more even except that the proportions of civil servant and worker are smaller. Among them, the proportions of public institution persons and professional are higher on weekends than that on weekdays.

In the annual income distribution, person under 50,000 RMB/year is 75% on weekdays and 70% on weekend. Among them, the proportion of persons under 30,000 RMB/year is higher on weekend than on weekdays, yet the occasion is just the opposite for person whose income is from 31,000 to 100,000 RMB/year. In addition, for the reason that not all interviewees are willing to tell us their actual income, there probably is a little inconsistency between the survey result and the reality.

The departure place has reflected the distribution situation of trip production. Figure 4 shows that the

distribution is essentially identical on weekdays and on weekends. Most interviewees come from the new area and its proportion is higher than 60%. The proportion coming from far suburbs and other cities is only 13%.

As shown in Figure 5, there are some differences between weekdays and weekend in the distribution of terminal parking place: on weekdays 45% of the parking was within second ring while 55% outside second ring, on weekends the proportions are 51% within second ring and 49% outside second ring. This indicates that on weekends, more persons go to the center and flourishing district.

It is shown in Figure 6 that the majority of travelers are for the purpose of shopping or work/business. There are distinct differences between weekdays and weekend in the distribution. On weekdays, 48% of the travelers are for work/business, and 36% are for shopping; on weekend, 58% of the travelers are for shopping and only 18% are for work/business. The results suggest that people travel more for work/business on weekdays and more for shopping on weekend.

According to the survey result, the difference is not distinct in the distribution of paying mode on weekdays in Figure 7. The proportion of parking fee paid by personal and organization is 48% and 52% respectively. On weekends more people pay their fares by themselves, only about 25% are paid by organization.

4.2 SURVEY RESULTS BY SP

Through SP survey, the results of choosing private car and turning to P&R system under each assumed condition are shown in Figure 8.

It shows that 59% of people will turn to P&R system under condition 1(cost and time reduced by 50% at the same time).

When only a factor changes, the proportion of turning to P&R system can still reach 39% under condition 2(cost remains, time reduced by 50%)and 35% under condition 3(cost reduced by 50% , time remains).

The proportion intending to turn to P&R system under condition 4(cost increased by 20%, time reduced by 50%) is only reduced by 9% than that under condition 2. This suggests that the little change in trip cost has no remarkable influence on transfer result.

The lowest one is under condition 5(cost reduced by 50%, time increased by 50%), and there is only 18% of persons willing to turn to P&R system.

Based on the above analysis, trip time and cost exert an obvious influence on the trip mode choice. Considering the two respects of the effect produced by P&R system and expenditure by organization, traffic effect is the best under condition 1, but it will cost organization a lot. The transfer effects is better under condition 2, 3 , 4. When the time and cost are reduced by 50% alone, the organization will pay more for time reduction than for cost ruduction. So, we recommend the condition 3 (the expenses reduce 50% alone) as the first-selection of the policy. The organization's expenditure is not very large and the effect produced is better.

5 METHODOLOGY

There are many analysis tools of the traffic choice behavior. At present, more and more people use the disaggregate models [12]. It’s representative models are logit and probit. Because the logit model has strong convincingness in the behavior analysis in theory and more accurate than probit model when the sample amount is very big and many of them distribute both sides. Furthermore, the structure of the logit model is comparatively simple, easier to be used and relatively strong in suitability, so the logit model is used in this paper.

On the basis of the econometric approach, the alternative probability model assumes that there is a response variable *y** which represents the possibility that the event happens, whose value is from negative infinite to positive infinite [13].

$$y_i^* = \beta_0 + \sum \beta_i x_i + u \qquad (1)$$

Where, β_i : coefficient,

x_i : the *i*th variable,

u : error term.

The dummy variable *y* is defined as follows:

y=1 if y^*>0 (2)

y=0 otherwise (3)

If the distribution of *u* is logistic, we get logit regression model. If the distribution of *u* is normal, we get probit model [14]. In this paper, we use the logistic distribution of *u*. *y* is defined as the available two traffic modes of private car and P&R, 0 represents choosing to drive by oneself, 1 represents choosing P&R. Thus the binary logit model can be written as formula (4),

$$\log \frac{P}{1\text{-}P} = \beta_0 + \sum \beta_i x_i \tag{4}$$

Here, *P*/(1-*P*) is ratio of the probability that an event will occur to the probability that it will not. The ratio is called the odds and thus the left-hand side of the equation is called the log-odds. In this model, the logistic coefficient can be interpreted as the change in the log odds associated with a one-unit change in the independent variable when other things are equal.

The logit model in terms of an event probability is obtatined as formula (5).

$$P(y=1) = \frac{e^{\beta_0 + \sum \beta_i x_i}}{1 + e^{\beta_0 + \sum \beta_i x_i}};\ P(y=0) = \frac{e^{-[\beta_0 + \sum \beta_i x_i]}}{1 + e^{-[\beta_0 + \sum \beta_i x_i]}} \tag{5}$$

The regression coefficient of the model can be obtained by Maximum likelihood estimation, MLE, and statistical analysis software.

6 ESTIMATE AND ANALYSIS OF P&R BEHAVIOR MODEL

6.1 ESTIMATE OF P&R BEHAVIOR MODEL

The variables need to be classified by their attribute and quantified before the estimate of the model. On basis of the data of P&R behavior survey, the categories of the influenctial factor variables are as follows:

Sex: 1 is man, 0 is woman;

Age: 1is between 40 and 60 years old, the others are 0;

Drive age : 1 is beween 2 and 4 years, the others are 0;

Payment mode of parking fee: individual is 1, organization is 0.

Departure place: old urban area, suburbs, and the outer cities are 1, the new urban area is 0;

Terminal parking place: outside Second Ring Road is 1, within Second Ring Road is 0;

Occupation and trip purpose are all 3 categories and expressed by 2 dummy variables respectively as shown in Table 2.

According to the above classification, the estimate results as shown in Table 3 can be obtained by using the statistical analysis software. The difference of each model is shown in Table 4.

In table 3, the first column is factor variables. *β* is coefficient. Sig is the significance of the Wald statistic. The smaller its value is, the importance of independent variable to dependent variable is greater. Generally, 0.05 is regarded as a division of judging whether the independent variable is significant. And OR is the odds ratio.

-2Loglikelihood is the likelihood test of the model. The less its value is, the better a predicted result of a model. Cox&Snell R Square and Nagelkerke R Square are the determinate coefficients. Their value ranges from 0 to 1. The larger their value, the higher the precision of a model is.

6.2 ANALYSIS OF THE MODEL

(1) Demography and social economic characteristic analysis

From model 1, 2, 3, we can find out that the effect of sex, age, drive age are not significant for choice results at the 0.05 significance level. The effects of occupation and income are significant at 0.01 and 0.001 significance levels respectively.

For occupation, worker is the reference category. The OR for occupation 1 is 0.504 times higher than for the worker reference category. The OR for occupation 2 is 0.749 times higher than for the worker reference category. This suggests that the workers are more likely to choose P&R system as opposed to private car than the others. The coefficient of annual income is negative. The estimated OR for income is less than 1. This proves that as income increases, people are less likely to choose P&R system as opposed to the private car.

(2) Analysis on factors related to trip and parking

Compared with model 2, the precision of model 3 have certain improvement from the determinate coefficient. Cox&Snell R Square and Nagelkerke R Square have been increased by 0.045 and 0.061 separately and 2Loglikelihood has been reduced by 140.072. Furthermore, the significant value of departure place and terminal parking place is less than 0.01 in model 3. This indicates that the effects of the two variables are significant.

For terminal parking place in model 3, the coefficient is -0.843, meaning that it has a negative effect on the probability of choosing P&R system as opposed to the private car. The estimated OR is 0.430. This suggests that the people coming from within Second Ring Road are more likely to choose P&R as opposed to the private car.

The trip purpose significantly affects the probability of choosing P&R system at the 0.001 significance level in model 1, 2, 3. The other purposes are the reference category. The estimated OR for trip purpose 1 and 2 are less than 1, meaning that people of the other purposes are more likely to choose P&R. The paying mode of parking fee has a small effect on the probability of choosing P&R system in model 1, 2, 3.

(3) Analysis on factors related to trip mode

Compared with model 1, the precision of model 3 has a certain improvement. Cox&Snell R Square is 0.076 and 0.116 respectively in model 1 and model 3. Nagelkerke R Square is 0.098 and 0.159 respectively in model 1 and model 3.

The effects of trip cost and time are significant at the 0.001 significance level in model 3. The two variables' coefficients are negative, meaning that they have negative effect on the probability of choosing P&R system as opposed to the private car.

For the above analysis, the variables of sex, age, drive age, paying mode of parking fee are not significant at the 0.05 significance level. The variables of occupation, income, departure place, terminal parking place, trip purpose have respectively important effect on the probability of choosing P&R system. The trip cost and time are the most significant variables in all the analysed variables.

7 CONCLUSIONS

The following conclusions can be drawn through the above analysis:

At the stage of Chinese economic development, income level and occupation type of the social economic factors affect people's P&R behavior to a certain extent .Persons whose income are relatively low and whose occupation is worker are more likely to turn to P&R system. The two factors are supposed to be considered in the planning of P&R system.

The persons whose terminal parking place is within Second Ring Road of the city center (commercial district) are more willing to choose P&R. It is mainly resulted from the lack of parking lots and traffic jam in the center and the relatively easy parking and free traffic outside Second Ring. Therefore, the P&R system have great

appeal to the persons whose terminal parking place is in center of Beijing.

The trip purpose have important effect on the probability of choosing P&R, and the persons of long time trip purpose are relatively likely to choose P&R. Paying mode of parking fee has a small effect on the probability of choosing P&R system. This suggests that parking fee can't play a role in influencing the trip mode choice at present and the parking fee rate needs to be improved further.

Trip time and cost are more important than other influential factors on the P&R choice. Therefore in China, to utilize P&R facilities effectively, the trip time and cost of P&R should be less than that of the private car. Some measures is recommended, such as charging a small amount of parking fee or parking free in P&R lots, raising service level of the public transport, etc.

This paper has established binary logit model about influential factors. The research can also give references for the analysis on the other influent factor (parking fee, walking time, etc) and the establishing of Multinomial Logit model.

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APPENDIX A

LIST OF TABLES

Table 1 The full SP design

Condition	Cost	time
1	-50%	-50%
2	0	-50%
3	-50%	0
4	+20%	-50%
5	-50%	+50%

The variables of cost and time are those of Park and Ride relative to the individual's current trip.

Table 2 The classification of occupation and trip purpose

Variable		Classification	Dummy variable		
Occupation	1	Senior executive	1	0	0
	2	Civil servant, technician, public institution and other	0	1	0
	3	Worker	0	0	0
Trip purpose	1	Drink/dining	1	0	0
	2	Shopping, recreation, work/business	0	1	0
	3	Other	0	0	0

Table 3 Estimation result of P&R behavior model

	Model 1			Model 2			Model 3		
	β	Sig.	OR	*β*	Sig.	OR	*β*	Sig.	OR
Demographic and social economic characteristics									
Sex	0.112	0.385	1.119	0.030	0.812	1.031	0.103	0.437	1.109
Age	0.144	0.188	1.155	0.139	0.202	1.149	0.164	0.143	1.178
Drive age	0.066	0.578	1.068	0.154	0.189	1.166	0.038	0.756	1.038
Occupation=3 (worker)		0.005**			0.001**			0.007**	
Occupation=1	-0.685	0.005**	0.504	-0.580	0.016*	0.560	-0.637	0.011*	0.529
Occupation=2	-0.289	0.170	0.749	-0.086	0.680	0.918	-0.229	0.292	0.796
Annual income	-0.169	0.000***	0.845	-0.191	0.000***	0.826	-0.192	0.000***	0.825
Variables related to trip and parking									
Departure place	0.343	0.001**	1.409				0.313	0.003**	1.367
terminal parking place	-0.774	0.000***	0.461				-0.843	0.000***	0.430
Trip purpose =3 (other)		0.000***			0.000***			0.000***	
Trip purpose=1	-0.946	0.051	0.388	-1.002	0.038*	0.367	-0.916	0.063	0.400
Trip purpose=2	-0.592	0.000***	0.553	-0.507	0.000***	0.602	-0.589	0.000***	0.555
Payment mode	0.083	0.425	1.087	0.122	0.235	1.130	0.130	0.226	1.139
Variable related to trip mode									
Trip time				-1.178	0.000***	0.308	-1.277	0.000***	0.279
Trip cost				-0.070	0.000***	0.933	-0.077	0.000***	0.926
Constant	1.348	0.000***	3.848	-0.283	0.296	0.754	0.914	0.004**	2.494
-2Loglikelihood			2493.286			2537.489			2397.417
Cox&SnellRSquare			0.076			0.071			0.116
NagelkerkeRSquare			0.0104			0.098			0.159

Note：*denotes α=0.05；** denotes α=0.01；*** denotes α=0.001.

If the logistic coefficient is positive, the odds ratio is greater than 1 and if the coeffient is negative,the odds ratio is smaller than 1:an odds ratio greater than one indicates an increased probability of choosing P&R and odds ratio smaller than one indicates an decreased probability of choosing P&R.

Table 4 Details of the models' differences

Model	Description
1	Don't consider the variable of trip cost and time
2	Don't consider the departure place and terminal parking place
3	Using the original survey dates

APPENDIX B

LIST OF FIGURES

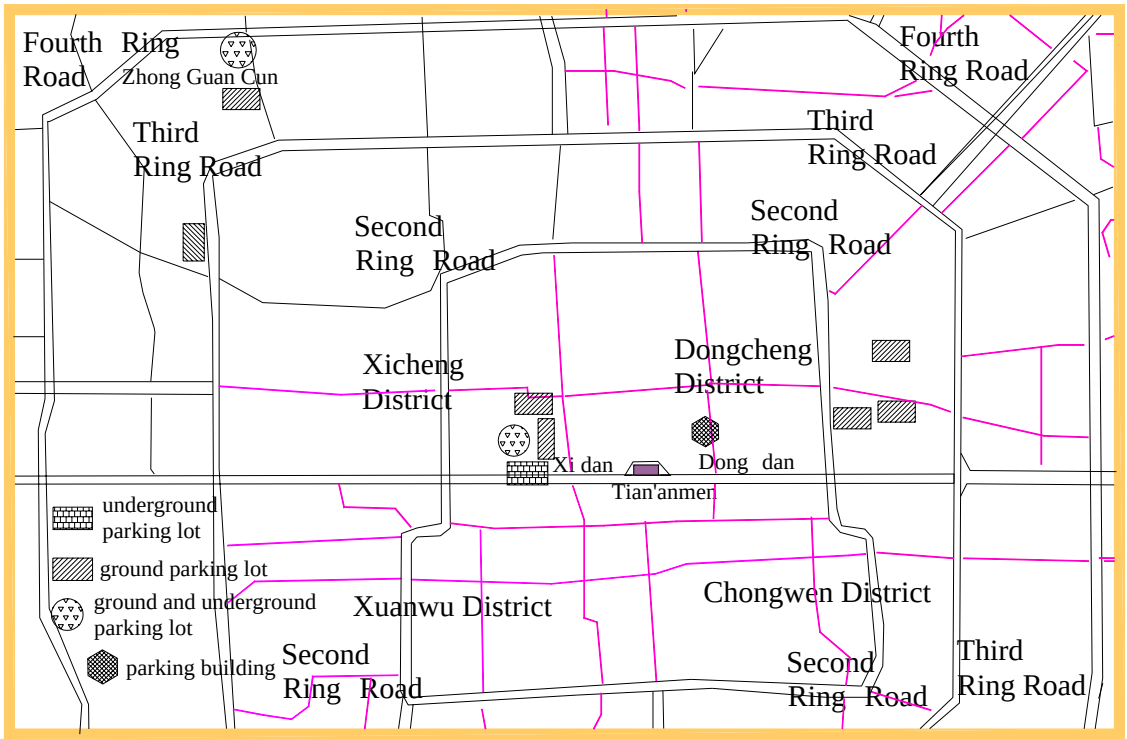

Fig.1 The survey area

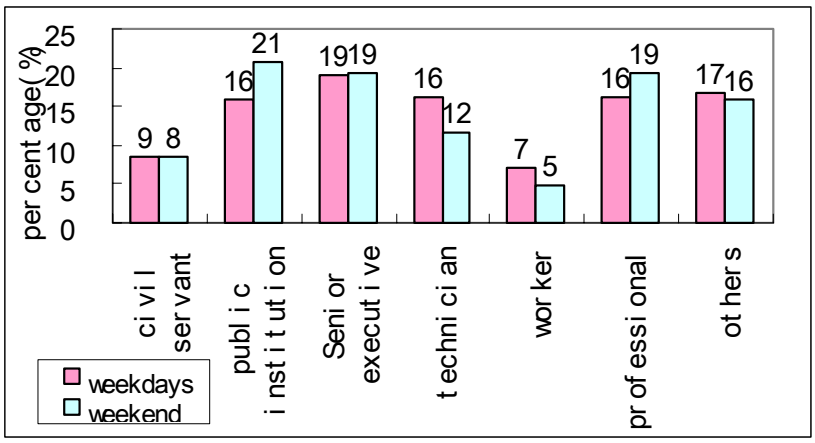

Fig.2 The distribution of occupation

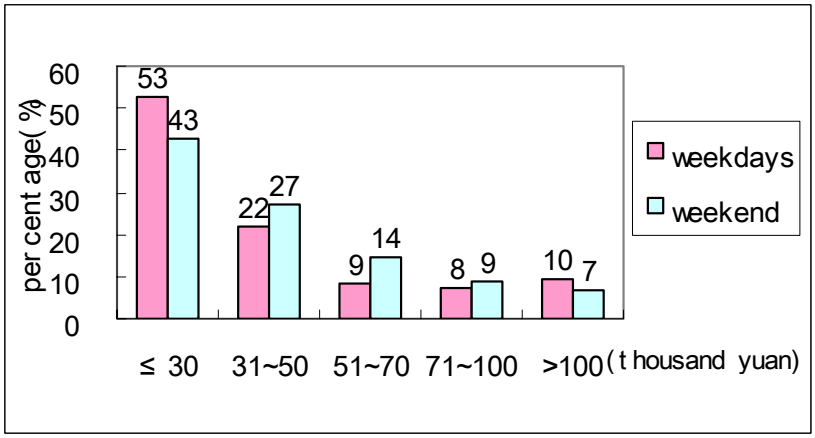

Fig.3 The distribution of annual income

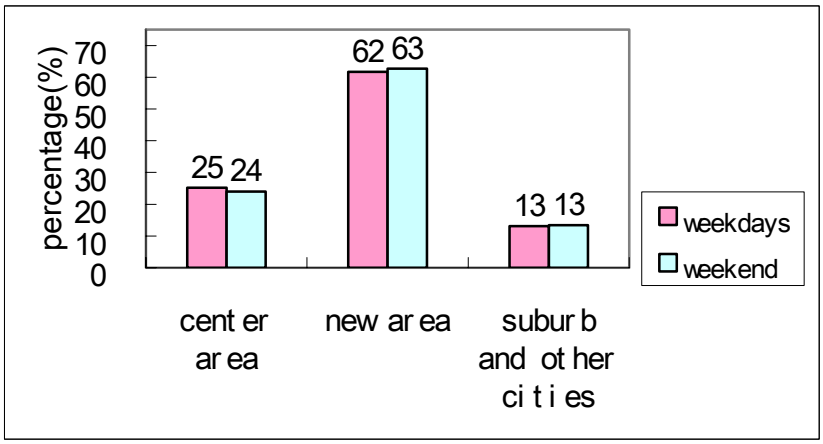

Fig.4 The distribution of departure place

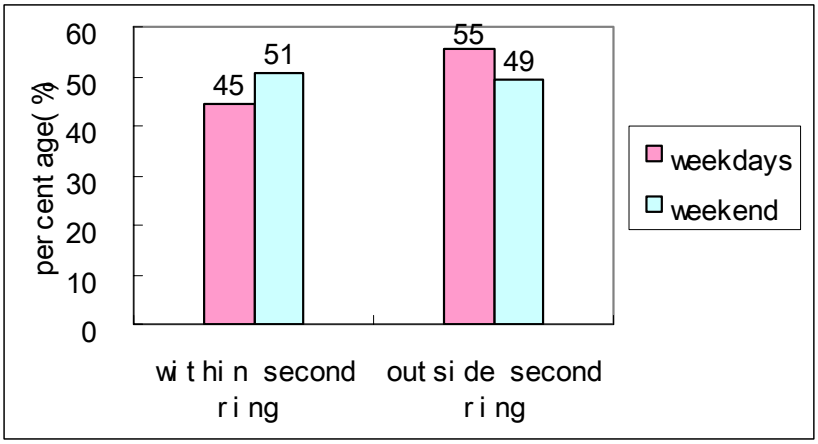

Fig.5 The distribution of terminal parking lots

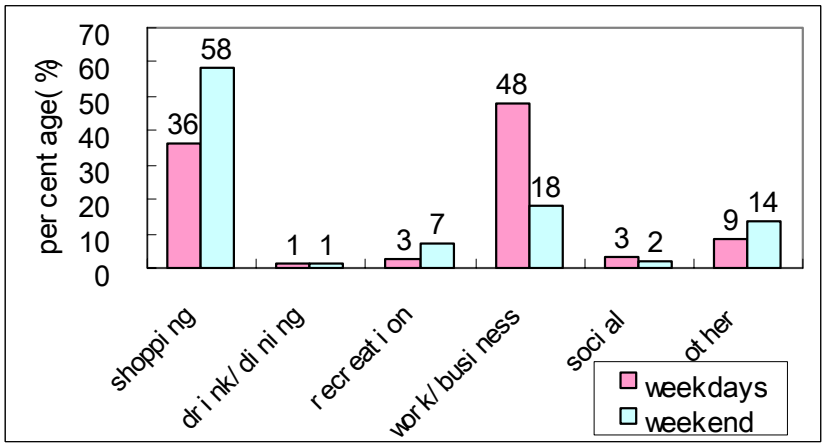

Fig.6 The distribution of trip purpose

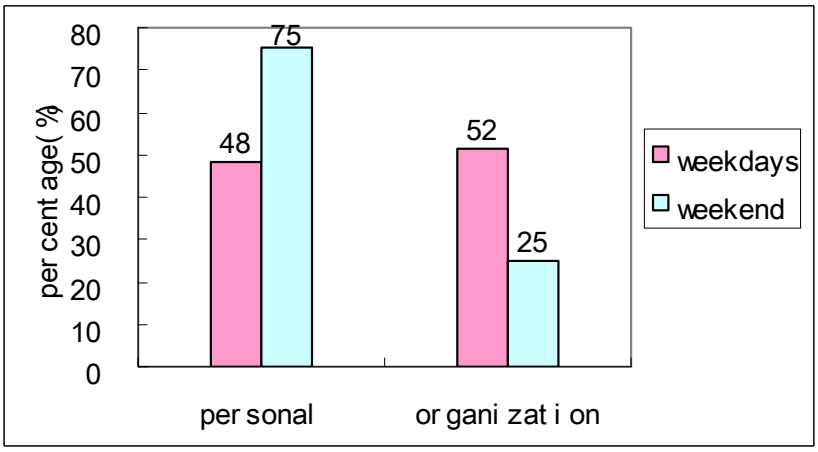

Fig.7 The distribution of paying mode

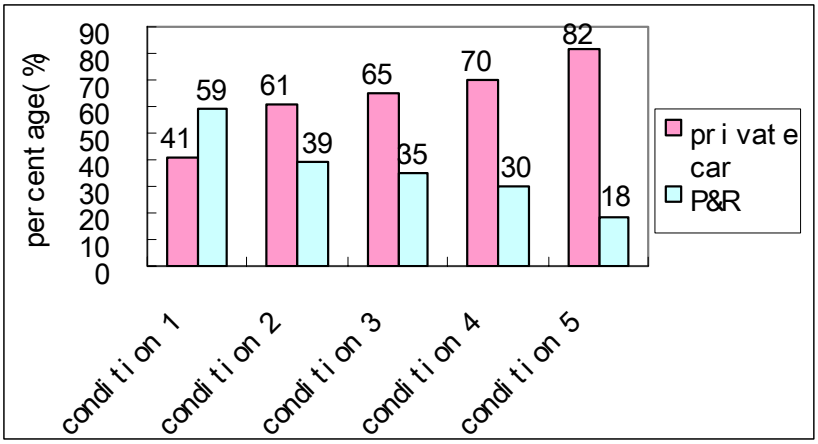

Fig.8 Choice results of the trip modes under supposed conditions