EVALUATION OF PARKING RESERVATION SYSTEM*

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1. Introduction

Illegally parked vehicles, vehicles waiting on-road for a vacant parking space and searching for an available parking space have a strong influence on the flow of traffic. To help alleviate these problems, many cities provide parking availability information. Such systems are called Parking Guidance and Information (PGI) system. However, if all the alternative routes/car parks are congested, information has little effect on drivers. In this paper, parking reservation system (PR system) is proposed. PR system ensures drivers to enter a car park without waiting if they have reserved their car park in advance.

It is apparent that the effect of PR system heavily relies on how drivers behave, and is quite meaningful to model a driver's behaviour when PR system is installed. Instead of paying the additional fee and fixing their schedule, they can reduce the uncertainty of total travel time to destination. However, when there is a mismatch between demand and supply in the use of reserved car park, PR system may not function because a total capacity of car parks excluded from PR system decrease in real by introducing PR system. Therefore, the circumstances where PR system functions efficiently should be investigated. Upon these backgrounds, this paper attempts to evaluate PR system based on behavioural analysis. The car park choice model is installed into our existing traffic simulation model and the effects of PR system are evaluated through case studies.

2. Travel behaviour under PR system[1)]

1) Questionnaire surveys

Stated preference data concerning about driver's behaviour in the presence of PR system are collected through questionnaire surveys. Authors have conducted a series of panel surveys to observe the effect of installing parking guidance and information system (PGI system), and the questions about PR system are asked in these surveys[2)]. The behavioural questions used here are asked at the fifth wave. An additional consideration is required in analysing panel data[3)]. As a limitation of spaces, the detailed modification method is not explained here. Further modification methods adopted are found in Kurauchi, et.al (2001)[1)].

Detail settings of stated preference questions are summarised in Table 1. Whether respondents use a reservation or regular car park is asked on the given conditions. Three factors, parking fee, walking time to destination and average waiting time for entering a regular car park are considered. To design questions, an experimental design technique is applied. Three levels are prepared for each factor, and consequently, nine questions are designed. A block item is applied to spread nine questions over three questionnaire sheets. Eventually, three questions are asked to each respondent.

Table 1 Values of the factors

Level	Parking fee (Yen/hour)	Walking time to a destination			Average waiting time for a regular car park
		Reserved car park	Regular car park	Difference	
1	250	3 min.	6 min.	- 3 min.	10 min.
2	300	3 min.	3 min.	0 min.	20 min.
3	350	6 min.	3min.	+ 3 min.	30 min.

2) Car Park Choice Model

Table 2 indicates the estimation results of car park choice model. The *t* test statistics of all parameters are found to be significant at 5% confidence level. Estimated parameters of parking fee and waiting time indicate that 100 yen/hour is equivalent to 9 minutes waiting time for entering a car park. From estimated parameters of walking and waiting time, the weight of walking time is 1.37 larger than that of waiting time. Another analysis conducted by the authors[4)] enhances the validity of this model because the comparative weight of these values at the past survey is similar (1.51). The estimate of the intercept of the reservation car park is compared with other individual variables. The estimated parameter is negative, and drivers tend to use regular car parks. 7.5 minutes of walking time and 10 minutes of waiting time for entering a regular car park are equivalent to the estimated intercept. This implies that if drivers have to walk 10 more minutes more, or wait for 7.5 minutes more when they use a regular car park, disutility of the reservation car parks is indifferent to the regular one.

* Keywords: Parking Demand, Parking Planning, Parking Reservation System

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Table 2 Estimation results of car park choice model

Individual variables	Parameter	*t* statistic
Intercept (Reserved Car Park)	-0.951	- 4.259
Parking Fee (Yen/Hour)	-0.010	- 6.560
Walking Time (Min.)	-0.127	- 4.941
Expected Waiting Time (Min.)	-0.093	-11.033
Number of samples	1158	
-2 ($L(0)$-$L(\theta)$)	203.106	
Adjusted Likelihood Ratio	0.125	

Table 3 Car park choice model in the simulation

Explanatory Variable	Parameter	Explanatory Variable	Parameter
Walking time (min.)	-0.553	Intercepts for reserved car parks	-1.383
Average waiting time to enter car park (min.)	-0.277	Time constraint X Reserved car park	2.828
Driving time from an origin to a car park (min.)	-0.189		
Parking fee (100yen)	-0.327	Departure shift time (min.)	-0.019

3. Case Study by the Simulation

1) Overview of the simulation

Behavioural model shown at the previous chapter are installed into our existing dynamic traffic simulation model[5]. Our simulation model is originally created in order to evaluate the effect of installing PGI system. One of the specific characteristics of our simulation is that it considers the learning behaviours of drivers. In another words, our simulation is 'double dynamic' in a sense that it simulates day-to-day dynamics as well as within-day dynamics.

Discussions in the previous chapter only handle the car park choice behaviours. In reality, drivers have wide range of choice options As we address PR system as a scheme to disperse the demand temporally as well as spatially, a departure choice behaviour should be considered. In this study, we adopted a joint choice model with car park and departure time. Without PR system, by repeating a use of car parks, drivers accumulate their knowledge of travel time from their origin to each car park together with expected waiting time to enter them. By considering the negative utilities of driving time from an origin to a car park, departure time is determined together with car park. With PR system, an additional consideration is required. Our previous analysis encourages that these trips with time constraint encourages to the use of reserved car parks[1]. Therefore, we assume that a certain amount of drivers have to reach at their destination at a specific time. On the other hand, they can not shift their time of activity because they have a time constraint. If a driver does not have a time constraint, the utility of the reserved car parks is reduced according to this shift time, and they will choose any of regular/reserved car parks. We do not have enough data to analyse the value of parameters for shifting a departure time. However, the value of them should be relatively low because a driver can spend this time by doing other behaviours at their origin. Expediently in this study, the parameter for this shifting time is set to be one tenth of driving time from their origin to a car park. A car park choice model used in our simulation is shown as Table 3. Additionally, there is no evidence that all drivers will consider about using reserved car parks. We set it as a parameter called *ratio of drivers accessing to PR system*. The effect of this parameter is analysed in our case studies.

2) Case Studies

Case studies are conducted on the network shown in Figure 1. Simulation settings are summarised as Table 4. Two case studies are analysed here. One is to evaluate the impact of the locations of reserved car parks onto the effect of the system, and the other is to evaluate the ratio of the people accessing to the PR system. The settings of scenarios are summarised as Table 5. Note that in this simulation, we do not consider on-road parking behaviours. Therefore, drivers have to choose any one of five car parks.

a) <u>User benefit</u>

To evaluate the effect of PR system when the locations of reserved car parks are different, 4 scenarios are carried out. The traffic demand level of 3,000 means that all car parks are fully occupied in peak hours. Figure 2 illustrates the average travel time of car park users. In this simulation, drivers will be in a queue if any spaces in queuing area are available, and they do not leave the queue for any reasons. Ratio of drivers accessing to PR system is set to be 50%. From the result of A(0.5) in Figure 2, total average of travel time to their destinations increased comparing with a basal case N. Setting car park A as reserved is not suitable. Car park A is rather less popular because it is located further from the centre of the demand. This implies that if we set a less popular car park as reserved, then the demands concentrate to other more popular car parks. From the comparison of the results of cases B and BCD, setting three popular car parks as reserved is preferable when a ratio of people accessing to PR system is 0.5. Also the travel time when a driver use reserved car parks is rather stable regardless to the cases.

The ratio of drivers accessing to the system is an important factor that influences on the effect of PR system. Figure 3(a) and (b) illustrates the relationship between ratio of accessing people and the total travel time to their destinations. Note that zero of this ratio means none of drivers refer to PR system

although some car parks are set to be reserved. From both figures (a) and (b), total travel time increases if we set many car parks as reserved although the ratio of people referring to the system is small. Especially when we set three car parks as reserved, the travel time increase than the basal case even one forth of the drivers consider using reserved car parks.

The important finding here is that, unlike information provision schemes, the effect of PR system increase as the ratio of users increase. It is generally said that if many people refer to information, the effect of information may decrease, or the traffic condition may get worse. In installing PR system, this may not happen. Moreover, it is interesting to say that the travel time of regular car park users also decrease enormously when we have larger amount of people accessing to PR system.

b) Social effects

So far we look at user side effects. From here, PR system is evaluated from the view point of public. Figure 4 shows the total occupied spaces and waiting queues of car parks. The usage of car parks in case B(0.5) is almost the same as case N while total travel time of drivers decreased a lot. Also, when we look at the result of case BCD(1.0), the total length of waiting queues decreased to 10 vehicles. This contributes to the safety and efficiency of the road network. To evaluate the effect of PR system onto the flow of the traffic, daily link traffic volumes are calculated. Links are categorised into three zones as is shown in Figure 1. Figure 5 shows the calculation results. Link traffic volumes in zone 1 and 2 reduced by installing PR system. One major reason is that users of reserved car parks are guaranteed to use a car park and do not have to wander in the city to look for available car parks. The other reason is that, especially in case BCD(1.0), all car parks in zone 1 are reserved, and drivers knows that they can not use them without reservation. Therefore, the number of vehicles flowing into the downtown area decreased. From these findings, we can say that when we set all car parks in a downtown area as reserved, we can control the volume of the traffic spatially by installing PR system.

4. Summary

In this study, Parking Reservation system (PRs) is proposed to disperse parking demands temporally. We conducted the questionnaire survey to collect driver behaviours, and drivers parking choice behaviours under PR system are studied. The estimated car park choice model is installed into our existing traffic simulation model to evaluate the effect of PR system. Through some case studies, PR system is evaluated from both

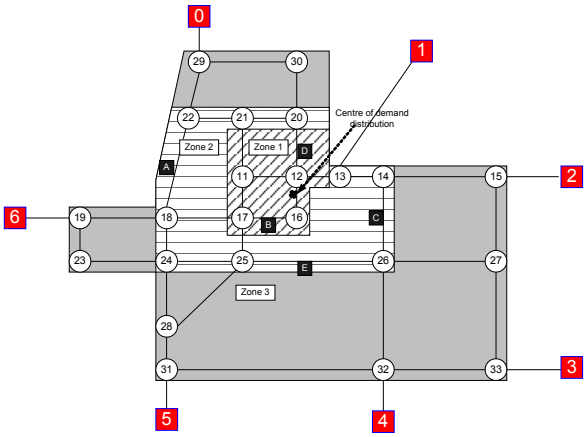


Figure 1 Ibaraki Network

Table 4 Settings of the simulation

Overall	
Scanning time interval	1 seconds
Time simulated within day	6:00～21:00 (54000seconds)
Days simulated	30 days
Demand	3,000 veh. / day (1,500 parking vehicles, 1,500 through traffic)
Demand distribution	Normally distributed with standard deviation of 400m for N-S and E-S directions
Parking	
Maximum number of queuing spaces for waiting to enter	10veh. (for all car parks)
Parking fee for 30 minutes	¥125 (Res.), ¥100(Reg.)
Vehicle	
Max. acceleration	$1m/s^2$
Max. deceleration	$2m/s^2$
Min. distance headway	5m
Min. time headway	1second
Velocity while searching alternative car park	50% of regulated speed

Table 5 Study cases

Case Name	Reserved Car parks					Ratio of people accessing to PR system	Ratio (number) of reserved spaces
	A	B	C	D	E		
N						-	0.00 (0)
A(0.5)	X					0.5	0.36 (180)
B(0.5)		X				0.5	0.10 (50)
BCD(0.5)		X	X	X		0.5	0.40 (200)

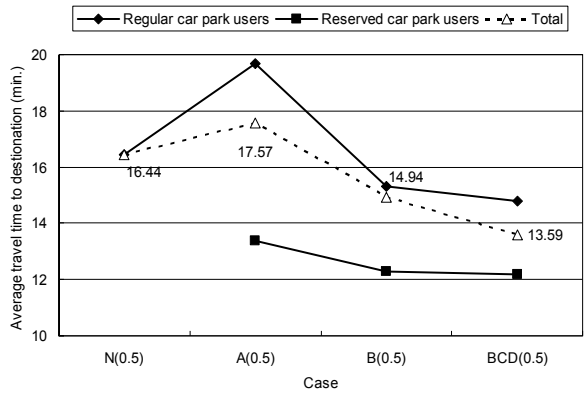
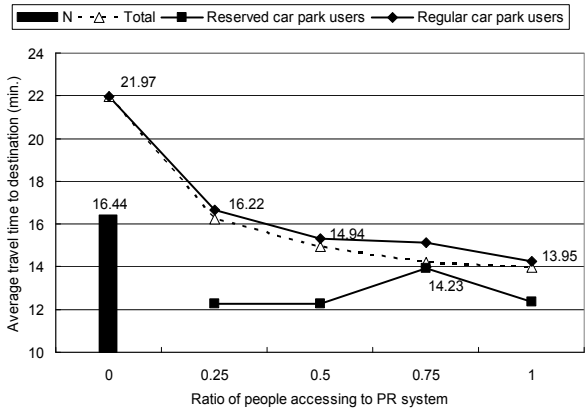


Figure 2 Effect of PR system vs. locations of car parks

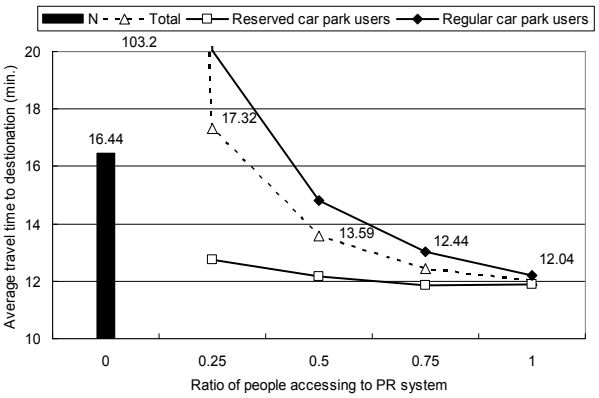
users and social points of views. Key findings of this study can be summarised as follows.

1. The effect of PR system may vary when the locations of reserved car parks are different.
2. Unlike information provision, the effect of installing the system may not decrease when large proportions of drivers consider using reserved car parks.
3. It is preferable to set a small number of car park spaces in downtown as reserved at first, and then by looking at the balances between demands and supplies, we should consider increasing the number of reserved car parks.
4. It is possible by location reserved car parks strategically to control the traffic flow entering into the city. Therefore, PR system may work as one of the advanced traffic management schemes in the city.

The major defect of this study is that parking demand is fixed. In reality many people with time constraints will travel by rail in reality. If PR system helps to reduce the uncertainty of travel time, the public transport users may as well think about using reserved car parks. This effect may reduce the effect of PR system, or the traffic condition may get worse by these additional demands. Second defect is that our simulation model does not consider the on-road parking behaviours.



(a) Case B



(b) Case BCD

Figure 3 Effect of PR system vs. ratio of reserving drivers

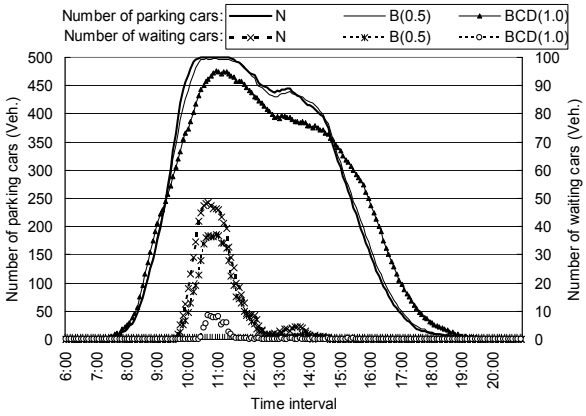


Figure 4 Number of parking and waiting cars

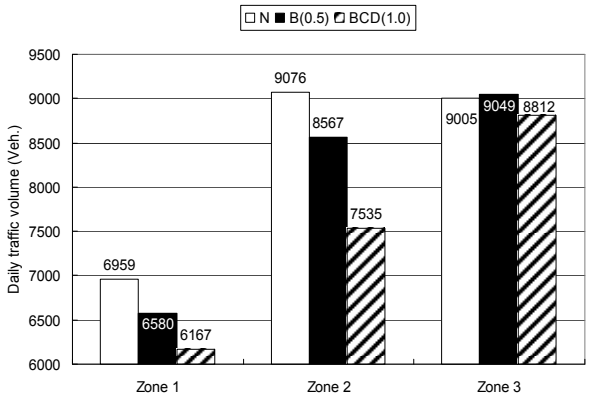


Figure 5 Road traffic volumes for each zone

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