STUDY ON SIMULATION MODEL AND MEASURES OF EXCLUSIVE ON-STREET PARKING SPACES FOR LOADING & UNLOADING IN CBD

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Abstract: The measures to lower illegal parking cars in the exclusive use of parking lots for loading and unloading are examined through the simulation of the present situation at Central Business District. At first, the present data on goods vehicles in Fukuoka are surveyed, which shows the characteristics of on-street parking for loading and unloading such as short-time and small amount of goods as well. Secondly, the theoretical models of distributions such as pick-up and delivery(P.U.D.), parking meter section and arrival time interval of goods vehicles. Then, the forecasting models of P.U.D. distance, number of goods and on-street parking time for loading and unloading are also constructed. Thirdly, a simulation model on the park of goods vehicles at the exclusive on-street parking lots are proposed. And, simulating the management of parking lots, the way of arranging parking space for goods vehicles, some measures for the regulation of on-street parking are considered.

1. INTRODUCTION

The on-street parking of goods vehicles for loading and unloading in Central Business District(CBD) comes to the front as a social problem, while the rapid development of urban economy diversifies needs of goods shippers. In other words, the narrow streets in CBD cause the lack of on-street parking facilities, which blocks the loading and unloading on the street. On the other hand, it will bring some problems such as traffic congestion and traffic safety. Therefore, to solve these traffic issues, some spaces for loading and unloading in CBD should be expanded or some restrictions for goods vehicles are required.

The rotation rate of on-street parking lots for loading and unloading in CBD is higher than the one of off-street parking lots in daytime. However, the goods vehicles are not operated at all times during a day. There are both of busy time zones and unbusy time zones. Due to the characteristics of loading and unloading such as small amount, Just-In-Time and frequency, parking time tends to be short. It is the fact that the vehicles for loading and unloading are preferred to park illegally on the street even in the full use

of parking space. The overall measures need to be examined after consideration about every arrival time zone of loading and unloading vehicles.

So far many issues in terms of loading and unloading in CBD by Takada K(1988), Nemoto T(1992) and Ieda H(1992), and loading and unloading facilities by Dohgaki E(1991) and Asano M(1991) have been studied. One of them studied by Tsukaguchi H(1992) investigated on the arrival time zone, in which it was found that the parking time and the arrival time were applied to the exponential distribution. However, there were a lot of vehicles of "0" in the parking time and the distribution models were not suitable for the data.

In this study, the characteristics of on-street parking for loading and unloading based on the arrival time zone is investigated by the date observed at Tenjin district in Fukuoka City. Then, the simulation model for appropriate estimation of parking will be proposed. That simulation model can be considered about various factors such as types of vehicle, types of business, types of P.U.D., parking meter sections, arrival time interval, P.U.D. distance, the number of goods and the time for loading and unloading parking. Applying this simulation model, the parking measures for goods vehicles are also discussed.

2. CHARACTERISTICS OF ON-STREET PARKING FOR LOADING AND UNLOADING

2.1 Outline of Survey

The actual situations of on-street parking lots for goods vehicles set up at 1-chome Tenjin are investigated, because Tenjin district is the CBD of Fukuoka city and there are busy activities for business and commerce. At Tenjin district, on-street parking of goods vehicles as well as passenger cars causes serious urban traffic issues. So, the parking lots for the exclusive use of goods vehicles are settled up on one-way street. In this study, two sections on road with 5 parking meters and 8 parking meters are surveyed.

Loading and unloading issues on goods vehicles are basically consisted of the situation of P.U.D., goods, using vehicles, conditions of P.U.D. and surrounding of parking (See Figure 1). Type of business, arrival time, day / weather, type of vehicles, number of goods, type of P.U.D., distance of P.U.D., parking time, parking meter section and legal / illegal parking are items of the investigation.

The outlines of observations are shown as in Table 1. 650 vehicles were observed for a series of three days which are sunny weekday, rainy weekday and sunny holiday.

2.2 Characteristics of Parking for Loading and Unloading

The number of vehicles which arrive at the parking meter section for loading and unloading changes on the time zone as in Table 2. The first peak occurs between 9 am and 10 am, the off-peak, in the daytime and the second peak, between 2 pm and 3 pm.

On the other hand, the exponential distribution or the logarithmic normal distribution on arrival intervals may be applicable, although the arrival interval at time becomes a problem related with the arrival of the vehicles at every hour (See Table 3). Besides, it is found that there are two or three entrances in sections 1 and 2 and the arrival of vehicles can happen simultaneously. So, in this study the exponential distribution is applied for the distribution on the intervals of arrival vehicles.

The type of business is given in relation to the arrival time zone and the type of vehicles. The rate of loading and unloading vehicles in the commerce facilities is 60-90% at Tenjin district on the weekday. On the other hand, the rate of trucks is high in the morning time zones and the rates of van and truck are high in the daytimes.

The distribution of the type of vehicles on every time zone is shown as in Table 4. The rate of truck is high between 9 am and 10 am, and the rate of van is surpassing of the truck between 11 am and 15 am. Moreover, the rate of passenger car is exceeded with 20% in the time zones of 11,14,16 and 17 o'clock, although its rate is lower than that of van and truck.

Figure 2 shows the distribution of the number of goods being picked up and delivered at Tenjin district. The average number of P.U.D. per vehicle is 7.3 pieces. The rate of business, receipts checking, waiting, meeting and eating is 16.5%, and the rate of one piece of goods accounts for the highest percentage, 24.3%. Compared with these facts, the rate of over 51 pieces of goods is a little bit lower than 3% and the rate under 5 goods is the highest, 77.4%. These results show that small amount of P.U.D. happens rather than large amount of P.U.D..

The distribution of P.U.D. types is obtained as in Table 5 concerning the arrival time, type of vehicles and type of business. Basically the rate of delivery is high in trucks and vans, and the rate of others is high in passenger car.

The distribution of the walking distance for P.U.D. on the street is found as in Figure 3. The average distance of P.U.D. is 15.3 meter. 29% of P.U.D. is 5 meter and less, 56%, 10 meter and less and 82%, 20 meter and less. These results show that P.U.D. vehicles tend to park near to the destination. The cases of parking over 51 meter far away from the destination are a little bit under 1%. In other words, on-street parking for loading and unloading in CBD prefers short-distance walking for delivery and pick-up.

Figure 4 shows the distribution of on-street parking time for loading and unloading. The short parking time less than 10 minutes occupies 40.3%. Among them less than 5 minutes parking is 20.8%, which means that the time of the on-street parking for loading and unloading trends to be short.

The distribution in the use of parking meter sections based on the type of vehicles and the type of P.U.D. are obtained. Truck and van tends to use section 1 for delivery, and section 2 for pick-up. Passenger cars tend to use almost section 2, because it is the front of commercial facilities and it is easy to access.

The illegal parking can be defined as parking outside the given cell, not using the parking meter, not

paying the parking fee and over-time parking. Most parking is regarded as legal. However, it is difficult to check paying of parking fee or over-time parking. Therefore, the illegal parking in this study is simply defined as parking outside the given cell and the legal parking, as parking in the cell correctly.

The rate of illegal parking is higher than the legal parking. The reason is the lack of cells of on-street parking for loading and unloading and the concentration of on-street parking vehicles in the particular time zones. Moreover, the requirement of convenience for short-time parking can be one of the reasons to park illegally, too. Although the construction of more off-road parking facilities as a hard measure or the more rigid regulation for parking as a soft measure can be one of the solutions, it is also needed to think about expanding the current on-street parking space as well.

In a nutshell, each probability distribution in relation to arrival time zones, type of business, type of vehicles, type of pick-up and delivery and parking meter section is represented categorically, which is suffering from modeling. However, these data could be used as beforehand information to construct the forecasting models of parking characteristics, and the probability distributions of these data practically surveyed can be helpful for the simulation.

3. FORECASTING MODELS FOR THE CHARACTERISTICS OF ON-STREET PARKING AND SIMULATION MODEL FOR LOADING AND UNLOADING AT THE EXCLUSIVE LOTS

3.1 Construction of Forecasting Models for the Characteristics of On-Street Parking

The models to discriminate each category of good's number are built as in Table 6 in the application of quantification analysis 2. On account of limited space, one figure is presented in this paper. It is also possible to guess the number of goods concretely based on the discriminating probability at each step in the hierarchical system as in Figure 5. That is, the probability at each step ($p_1 \sim p_6$) is obtained by assuming the concept as in Figure 6 with the use of the discrimination scores.

If the distinction probability is defined, m pieces of the explanatory variables($z_1 \sim z_m$) are obtained, which are the category scores of discrimination. Two groups are G 1 and G 2, and the two groups' probability density functions are $f_1(z)$ and $f_2(z)(z = [z_1 z_2 \cdots z_m])$. Then, the problem of the discrimination of two groups is to fix the boundary based on z. If z is put in the right side of the boundary, it belongs to G 1. If z is put in the left side, it belongs to G 2. However it is true that there is overlap between both groups as in the Figure. Concerning these facts, the discriminating probability of each group is defined.

The quantification theory 1 makes the model related with the forecasting distance of P.U.D. as in Table 7. It is seen that the arrival time zone, the type of vehicle, the type of P.U.D., the parking meter section, the type of business and the number of goods influence as explanatory variables. This model can't be enough proper because the multiple correlation coefficient is low. Therefore the theoretical values are regarded as

the fundamental components and the residuals are obtained by the use of theoretical normal distribution.

The parking time is predicted by the use of the model as in Table 8. The type of business, the time zone, the type of vehicle, the number of goods, type of P.U.D. and P.U.D. distance become explanatory factors according to the model. It is why the parking time becomes the last set in vehicle various characteristics.

3.2 Development of Simulation Model of On-Street Parking for Loading and Unloading

Based on the distributions of various characteristics of loading and unloading and their forecasting models, the simulation procedure of on-street parking for loading and unloading is established as in Figures 7 and 8. Necessary various data are mentioned in the forgoing paragraph (§2.2) such as each probability distribution of the type of business, P.U.D., time zones, arrival interval in time, the type of vehicle and parking meter section. The discrimination models of each category of number of goods, forecasting model for P.U.D. distance and parking time (§3.1) and the number of arrival vehicle for a day are also used as data for the simulation. The arrival time of vehicle can be simulated after the time is set. Then the characteristics of loading and unloading and the parking are given for every arrival vehicle.

The calculation algorithm as in Figure 8 is a system that forecasts various characteristics of on-street parking for loading and unloading under the use of beforehand information. Supposing that the vehicle parks in the parking cell as soon as it arrives in the case of the existence of room to park and outside the parking cell in case of no room to park at the cell, the simulation is carried out. This simulation is based on the investigation that none of vehicles waits for the empty when the parking lots are full and that most of the cars stop to before and behind of the parking section or the opposite side of road.

The parking time can be defined as the time from the arrival to finishing the loading and unloading and the vehicle leaves after the parking time is over.

3.3 Test of Simulation Model

The simulation model as in Figures 7 and 8 is applied to 396 vehicles observed in a weekday, and the reproducibility of the situation of on-street parking for loading and unloading is examined. That is, the distribution of arrival time zones under various factors is checked by Chisquare test for factor analysis of theoretical results as in Table 9. The type of business, type of vehicle, the number of goods and the type of P.U.D. are significant at the level of 5% and 10%, respectively. The P.U.D. distance and the parking time and the parking meter section are not significant at the level of 10%. Such results agree with the examination based on the investigated data even though it is not strict because of the influence of making categorically the distribution of the number of goods.

The distribution of time zones for arrival vehicles has a peak between 9 am and 10 am, and another peak, between 2 pm and 3 pm as in Table 10. In the distribution of the type of business, the parking in commercial facilities composes of large rate in all time zones. Comparing the commercial and business sections, the parking happens much more at commercial section in the morning or daytime, and at

business section, in the afternoon.

According to the type of vehicle, the trucks in the morning park much more. And the vans also park much between 10 am and 11 am, between 1 pm and 2 pm and between 3 pm and 4 pm. On the other hand, the passenger cars tend to park much more between 11 am and noon and afternoon. In terms of the distinction of P.U.D., delivery composes of large amount of the rate and next is other purposes. The parking for the simultaneous purpose of pick-up and delivery happens and pick-up is the last. Other purposes for parking happen much more between 11 am and noon and in the afternoon, and it is corresponding to the parking time zones of the passenger car. These results on the probability distributions and characteristics of parking can be seen to match to the observed weekday data.

The situations of such legal and illegal parking in each section and each time zone are shown as in Figure 9. In section 1, the number of illegal parking vehicles is large from 9 am to 10 am and is rapidly decreasing after 10 am. It begins again increasing from 3 pm and then starts decreasing after that time. In section 2, there are a lot of number of illegal parking vehicles at noon from the later half of 10 am, and the number of illegal parking vehicles starts decreasing after noon except 3 pm and 4 pm. In general, it can be found that the number of illegal parking cars at the section 1 is larger than at the section 2.

Table 10 shows the distribution of P.U.D. distance based on the arrival time zones. It is seen that the rate of P.U.D. distance is high in 20 meter or less. In details, 5 m or less for P.U.D. distance is high from 9 am to10 am and from 2 pm to 3 pm. The rate of 11-20 m is high from 9 am to10 am and from 2 pm to 3 pm, and 41 m or more, from 9 am to 10 am and from 5 pm to 6 pm. In addition, if the average distance obtained by the forecast model of P.U.D. distance is requested, it is 16.3 meter and the standard deviation is 10.6 meter. These results agree with the data practically observed.

It is seen that the rate of 5 pieces of goods or less is high in all time zones as in Table 10. The pick-up and delivery system tends to be small amount and to serve frequently. Moreover, the average number of goods is 6.2 pieces and it is corresponding to the one in the observation.

The rate of 30 minutes or less in the parking time distribution is high and parking for 2 hours or more is high between 9 am and 10 am. The average parking time is calculated as 28.2 minutes and the standard deviation is 23.6 minutes in order to examine the accuracy of the forecast model of the parking time as in Table 8 and these results are corresponding to the observed data.

It can be said that the theoretical values predicted by the simulation are almost corresponding to the data and enough reproducibility is obtained. So, proposed model has no problem for simulation.

4. THE PROPOSAL OF PARKING MEASURES BY SIMULATION

4.1 Measures Against Increasing Demand of Parking

The proposed simulation model was developed to study the measures of the on-street parking for loading

and unloading and was appropriate enough from the consideration of the results as in § 3-3. Then the variations of a legal parking and an illegal parking are calculated by the use of this model to see the increase of the parking demand in the future as in Figure 10. Even though the demand of parking vehicles doesn't decrease in reality, it is also illustrated for the comparison.

With the view of weekday data (396 vehicles), the illegal parking rate gets higher if the parking demand increases and the illegal parking rate gets lower in case that the parking demand decreases.

The parking cells and parking lots are not enough for the current parking demand. It is guessed that the on-street parking lots for loading and unloading in CBD will be needed further if the urban activities become complicated. It can be found that the increase of the parking cells is necessary to solve this congestion fundamentally. Otherwise, 20% of present parking demand is needed to eliminate through some drastic parking restrictions.

4.2 Simulation for the Measure of Elimination of Passenger Car

Basically the passenger cars are not allowed to park at the on-street parking lots for exclusive use of goods vehicles. However, in fact, many passenger cars park at those lots, which make the on-street parking of goods vehicles difficulty. In order to solve such serious problem, the effectiveness of improvement of the parking environment in such a case to park on-street only the goods vehicles should be simulated. The results are shown as in Figure 11, and the rate of legal or illegal parking is obtained.

If the passenger cars are allowed to park at on-street parking lots, the rate of illegal parking is high in all of the morning time zones except between 11 am and noon. On the contrary, if the passenger cars are prohibited from parking on street, the rate of legal parking is high all the morning time except between 9 am and 10 am, which can be understood that the on-street parking situation is improved. In the case of prohibiting the passenger cars from parking on street, the rate of illegal parking is 10% lower than in the opposite case. As a whole, the rate of illegal parking is decreased except between 1 pm and 2 pm. Moreover, the big improvement is seen from 10 am to 11 am and from noon to 1 pm.

4.3 Strategies to Increase the On–Street Parking Cells

When the on-street parking condition was simulated in the case of the elimination of the passenger cars as above mentioned, illegal parking rate still exceeded 50% between 9 am and 10 am, which means that the parking time was not improved. On the other hand, due to the characteristics of on-street parking for loading and unloading such as short-time, small amount, frequency and insufficient off-street exclusive parking facilities for goods vehicles, the parking vehicles hardly change from on-street lots to off-street facilities. The drivers of goods vehicles tend to park on-street and to pick-up and delivery by running to escape from the control of illegal parking, which will cause some obstacles to the pedestrian and even dangerous traffic accidents. Therefore, dealing with on-street parking for loading and unloading by only the viewpoint of controlling the illegal parking is doubtful. The improvement of off-street parking facilities needs long term. So, it is desirable to induce the method of increasing parking cells on roads as a

short term plan. In this paper, the following three cases of on-street parking cells are examined on the assumption that there are spaces in the road section.

Case 1 : One parking cell is increased at sections 1 and 2 respectively.
Case 2 : 2 cells are increased at both sections 1 and one cell is increased at section 2.
Case 3 : Two parking cells at both of sections 1 and 2 are increased respectively
The rates of legal and illegal parking vehicles in each case are found as in Figure 12 as results of the simulation. Three cases show that the rates of the illegal parking vehicles are lower in all time zones except between 9 am and 10 am. 6.6% decreases in case 1, 10.3%, in case 2, and in case 3, 12.9%. Moreover, it can be seen that the effect of case 1 is lower than the case of elimination of the passenger cars, case 2 has the same effect and case 3 is more effective.

The whole rates of illegal parking vehicles are as follows; 46.2% in weekday, 39.6% in case 1, 36.1% in the elimination of passenger cars, 35.9% in case 2, and 33.3% in case 3. If the parking cells are added as a temporary measure of parking strategies in CBD, the rate of illegal parking cars can be lowered and the difficulty of on-street parking for loading and unloading can be somewhat resolved.

5. CONCLUSION

In this study, some prediction models of the characteristics of on-street parking for loading and unloading and the simulation model to examine the parking situation at on-street parking lots in CBD was proposed and some measures of the on-street parking for loading and unloading were studied. The results are summarized, as follows:

1) As the factors which influence the arrival time of on-street parking for loading and unloading, the type of business, the type of vehicle, the number of goods and the type of P.U.D are obtained. It can be also found that the factors such as the parking meter section, P.U.D. distance and the parking time hardly influence. These facts are roughly corresponding to the results examined by simulation.

2) The distribution of the arrival time interval at every hour can be givens by the exponential distribution and the logarithmic normal distribution. The exponential distribution is assumed in this simulation because of two reasons. One is the fact that the simultaneous arrival can be observed because there are 2 and 3 entrances at parking meter sections 1 and 2, and another is that the exponential distribution can be easily handle to simulate.

3) Using the obtained data, various distributions such as type of vehicles, type of business, type of P.U.D., parking meter section and arrival time interval were made clear. The forecasting models of P.U.D. distance, the number of goods and the on-street parking time for loading and unloading were also obtained. The simulation model concerning on–street parking for loading and unloading in case of two or more parking sections was developed by the use of the distributions and forecasting models. And the reproducibility was enough. Moreover this simulation model can be useful for the examination of various parking measures in CBD.

4) The first being raised as a strategy to improve the conditions of on-street parking in CBD is to eliminate completely the passenger car from the use of parking lots. Then, it can be said as a whole that there has been some improvement of illegal parking. However, the effect of the improvement can not be seen from 9 am to 10 am

5) It is possible to increase the on-street parking cells as a measure for parking problem at Tenjin district. The increase of parking cells is effective if there is space of about two cells at sections 1 and 2, though it is not flawless.

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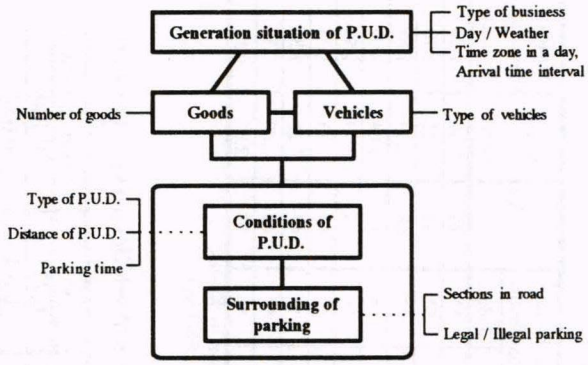

Fig. 1 Elemental factors of the issues on parking lots for the exclusive use of loading and unloading

Table 1 Outline of investigation

Description		Time zone	Vehicles	Investigation point
Sunny weekday	3/19/96 Tuesday	09:00 - 18:00	139 vehicles	Parking meter 8 (Section 1)
Rainy weekday	3/21/96 Thursday	09:00 - 18:00	152 vehicles 244 vehicles	Parking meter 5 Parking meter 8
Holiday(sunny)	3/20/96 Wednesday	09:00 - 18:00	115 vehicles	Parking meter 5 (Section 2)

Note : March 20 is holiday on the Vernal Equinox

Table 2 Distribution of arrival vehicles in time zones

9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
0.177	0.136	0.121	0.078	0.083	0.134	0.119	0.109	0.043

Table 3 Interval of arrival time

Time zone	Exponential distribution		Logarithmic normal distribution		Vehicles	Means	Standard deviation
	R-Max.	Judge.	R-Max.	Judge.		(Minute)	(Minute)
9h.	0.2031	**	0.1623	**	70	0.86	1.29
10h.	0.1874	**	0.1387	**	54	1.11	1.10
11h.	0.1770	**	0.1470	**	48	1.33	1.61
12h.	0.2327	**	0.1124	**	31	1.84	2.02
13h.	0.1954	**	0.0522	**	33	1.79	1.59
14h.	0.1382	**	0.1140	**	53	1.13	1.21
15h.	0.1210	**	0.1245	**	47	1.28	1.38
16h.	0.1676	**	0.1762	**	43	1.40	1.33
17h.	0.2516	**	0.1443	**	17	2.35	2.81

Note 1. R-Max : Residual maximum by KS-test
2. ** : Adopted by KS-test in 5% level

Table 4 Distribution of the types of vehicles in every time zone

Time zone	Truck	van	Passenger car
9h.	0.529	0.371	0.100
10h.	0.519	0.444	0.037
11h.	0.292	0.417	0.292
12h.	0.290	0.613	0.097
13h.	0.424	0.485	0.091
14h.	0.340	0.434	0.226
15h.	0.362	0.468	0.170
16h.	0.372	0.395	0.233
17h.	0.294	0.412	0.294

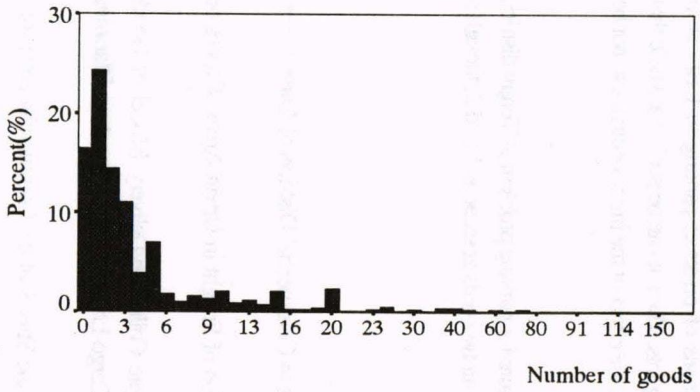

Fig. 2 Distribution on the number of goods

Table 5 Distribution of the type of pick-up and delivery

Description			Delivery	Pick-up	P.U.D.	Others
9h.-10h.	Truck	Commercial	0.737	0.070	0.193	0.000
		Business	0.875	0.000	0.125	0.000
	van	Commercial	0.941	0.000	0.059	0.000
		Business	0.500	0.000	0.125	0.375
	Passenger car	Commercial	1.000	0.000	0.000	0.000
		Business	0.000	0.000	0.000	1.000
11h.-13h.	Truck	Commercial	0.781	0.094	0.125	0.000
		Business	0.600	0.000	0.200	0.200
	van	Commercial	0.841	0.023	0.136	0.000
		Business	0.545	0.000	0.091	0.364
	Passenger car	Commercial	0.778	0.111	0.111	0.000
		Business	0.182	0.000	0.000	0.818
14h.-17h.	Truck	Commercial	0.750	0.050	0.200	0.000
		Business	0.313	0.000	0.125	0.563
	van	Commercial	0.792	0.146	0.063	0.000
		Business	0.476	0.095	0.143	0.286
	Passenger car	Commercial	1.000	0.000	0.000	0.000
		Business	0.217	0.043	0.000	0.739

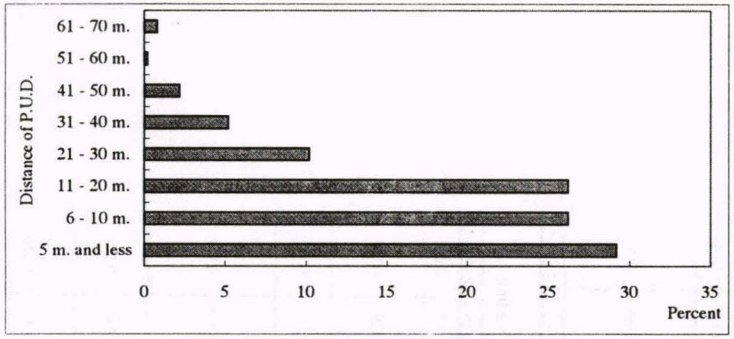

Fig. 3 Distribution for distance of pick up and delivery on on-street parking

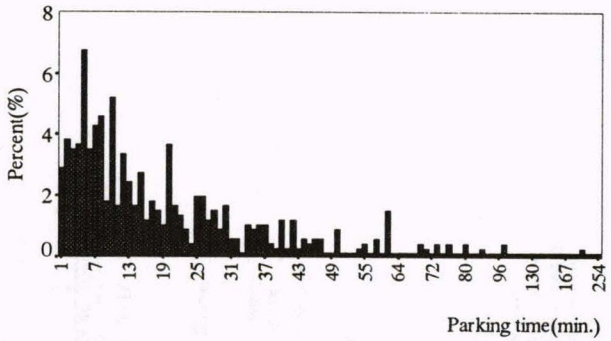

Fig. 4 Distribution of on-street parking time at Tenjin district

Table 6 Quantification analysis 2 for 0 pc. of goods & others

Description		Vehicles	Cat. Score	Range / Partial cor.
Type of business	Commercial	281	-0.527	1.813
	Business	115	1.287	0.602
Time zone	9h.	70	-0.163	0.431
	10h. - 11h.	102	0.072	0.143
	12h.	31	-0.204	
	13h. - 14h.	86	-0.056	
	15h. - 16h.	90	0.210	
	17h.	17	-0.221	
Type of vehicles	Truck	158	-0.121	0.810
	van	174	-0.138	0.256
	Passenger car	64	0.672	
Parking meter section	Parking meter 5	152	0.249	0.404
	Parking meter 8	244	-0.155	0.181
External criterion	0 pc.	56	1.720	
	Others	340	-0.283	
Percentage of correct	0 pc.	56	100.0%	R^2 = 0.488
	Others	340	82.6%	
	Total	396	85.1%	

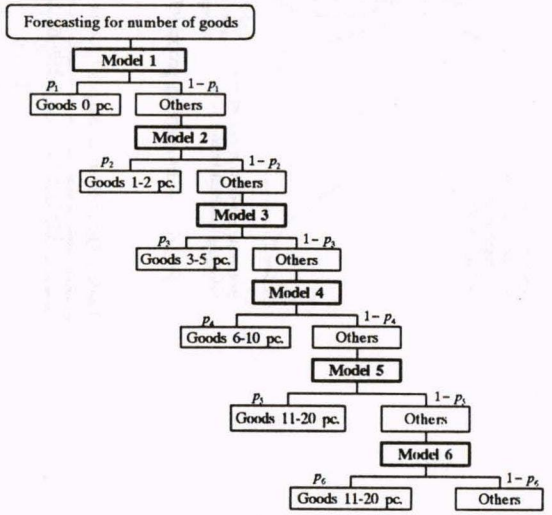

Fig. 5 Prediction system by discrimination models for the number of goods

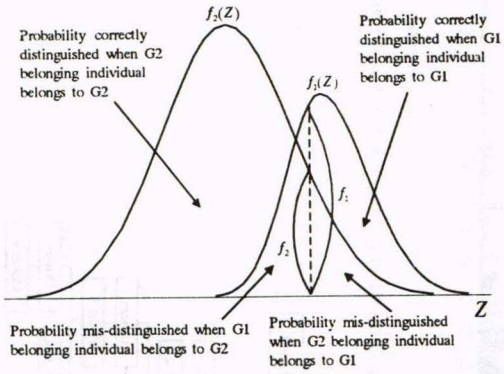

Fig. 6 Discriminanting probabilities of two groups

Table 7 Quantification analysis 1 for the distance of P.U.D.

Description		Vehicles	Cat. score	Range	Partial cor.
Time zone	9h.	70	1.809	5.042	0.126
	10h.-11h.	102	-1.637		
	12h.	31	0.516		
	13h.-14h.	86	0.469		
	15h.-16h.	90	-0.820		
	17h.	17	3.405		
Type of vehicles	Truck	158	-0.089	2.852	0.081
	van	174	0.826		
	Passenger car	64	-2.026		
Type of P.U.D.	Delivery	274	-1.809	13.385	0.160
	Pick-up	21	-1.888		
	P.U.D.	45	-2.122		
	Others	56	11.264		
Parking meter section	Parking meter 5	152	4.067	6.601	0.265
	Parking meter 8	244	-2.534		
Type of business	Commercial	281	-0.759	2.613	0.081
	Business	115	1.854		
Number of goods	0 pc.	56	-14.017	29.385	0.226
	1 - 2 pc.	180	1.030		
	3 - 5 pc.	89	2.137		
	6 - 10 pc.	23	5.841		
	11 - 20 pc.	30	4.805		
	21 - 50 pc.	8	-2.856		
	51 pc. and more	10	15.368		
Constant = 15.354		$R^2 = 0.363$			

Table 8 Quantification analysis 1 of the on-street parking time

Description		Vehicles	Cat. Score	Range	Partial cor.
Type of business	Commercial	281	-4.100	14.117	0.236
	Business	115	10.017		
Time zone	9h.	70	7.229	11.429	0.169
	10h.	54	-4.200		
	11h.-13h.	112	-0.616		
	14h.-16h.	143	-1.689		
	17h.	17	1.833		
Type of vehicles	Truck	158	-2.516	6.151	0.101
	van	174	0.947		
	Passenger car	64	3.635		
Number of goods	0 pc.	56	12.806	134.613	0.711
	1 - 2 pc.	180	-10.985		
	3 - 5 pc.	89	-3.619		
	6 - 10 pc.	23	2.628		
	11 - 20 pc.	30	2.228		
	21 - 50 pc.	8	27.350		
	51 pc. and more	10	123.628		
Type of P.U.D.	Delivery	274	2.497	31.645	0.284
	Pick-up	21	12.132		
	P.U.D.	45	3.416		
	Others	56	-19.513		
Distance of P.U.D.	5m. and less	104	-3.952	8.106	0.156
	6 - 10m.	121	-1.824		
	11 - 20m.	102	4.154		
	21 - 40m.	55	3.148		
	41m. and more	14	2.493		
Constant = 23.568		$R^2 = 0.742$			

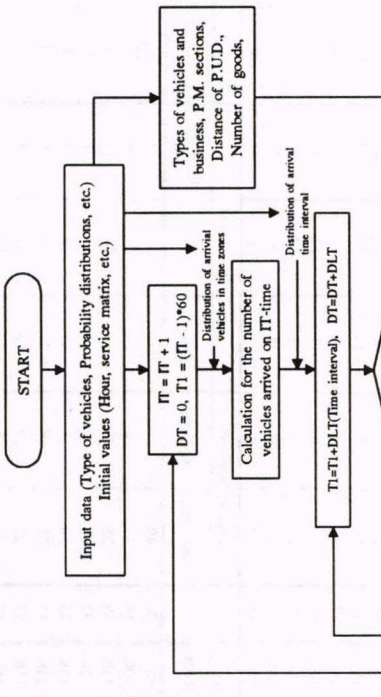

Fig. 7 Simulation model of the on-street parking for loading and unloading

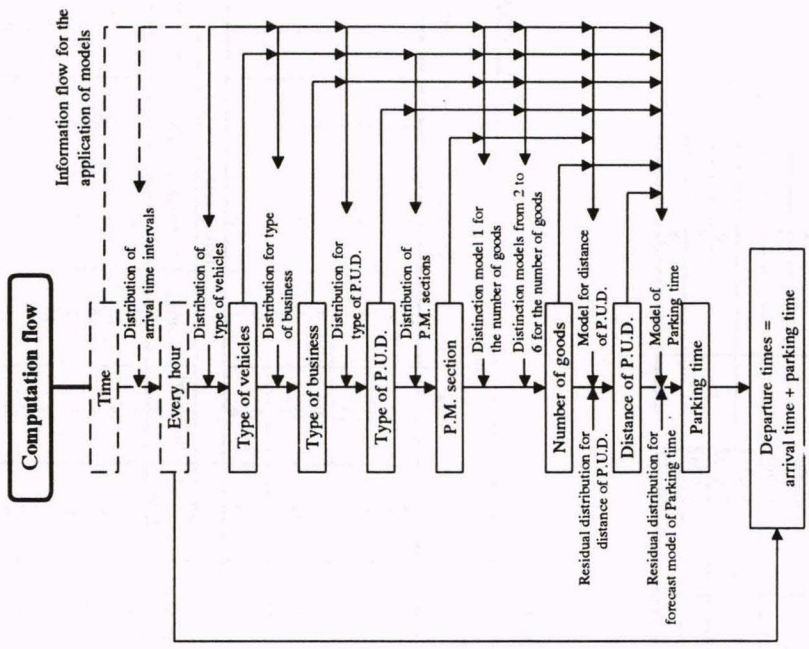

Fig. 8 Computation flow for informations of vehicles characteristics

Table 9 Chisquare test of the arrival time distributions under the various factors by simulated

Items	Values of chisquare test	Degree of freedom	Probability of significance	Judgment
Type of business	4.81	2	0.0903	*
Type of vehicles	7.92	4	0.0947	*
Number of goods	98.88	12	0.0000	**
Type of P.U.D.	13.63	6	0.0341	**
Distance of P.U.D.	4.36	8	0.8232	#
Parking time	11.24	8	0.1882	#
Parking meter section	1.88	2	0.3900	#

Note ** : Dismiss(5%), * : Dismiss(10%), # : Adoption(5%)

Tab.10 Cross table according to the results of simulation between time zone and various factors

Unit : Vehicles

Time zone	Total	Type of P.U.D.				Parking meter section		Legal / Illegal parking		Number of goods						
		Delivery	Pick-up	P.U.D.	Others	Section 1	Section 2	Legal	Illegal	0 pc.	1 - 2 pc.	3 - 5 pc.	6 - 10 pc.	11 - 20 pc.	21 - 50 pc.	51 - 200 pc.
9h.	70	56	1	6	7	43	27	27	43	7	14	17	27	1	1	3
10h.	54	39	1	11	3	33	21	24	30	3	6	36	2	1	6	0
11h.	48	24	1	6	17	21	27	25	23	17	5	21	3	1	1	0
12h.	31	14	3	11	3	17	14	15	16	3	2	12	2	8	4	0
13h.	33	27	1	4	1	21	12	28	5	1	1	26	0	5	0	0
14h.	53	31	4	7	11	30	23	30	23	11	12	21	3	6	0	0
15h.	47	25	5	5	12	28	19	24	23	12	19	7	4	3	2	0
16h.	43	30	0	8	5	27	16	27	16	5	24	8	0	0	6	0
17h.	17	13	0	3	1	9	8	13	4	1	9	6	1	0	0	0

Time zone	Total	Type of business		Type of vehicles			Distance of P.U.D.					Parking time				
		Commercial	Business	Truck	van	Passenger car	5m. and less	6 - 10m.	11 - 20m.	21 - 40m.	41m. and more	10min. and less	11-30min.	31-50min.	51-120min.	121min.and more
9h.	70	49	21	37	20	13	12	10	20	26	2	9	25	21	12	3
10h.	54	42	12	27	27	0	15	9	17	13	0	14	25	11	4	0
11h.	48	28	20	10	21	17	10	6	18	14	0	9	18	11	10	0
12h.	31	23	8	16	11	4	5	6	13	7	0	8	7	12	4	0
13h.	33	30	3	15	18	0	4	7	11	11	0	11	13	9	0	0
14h.	53	35	18	25	18	10	12	5	16	20	0	14	17	18	4	0
15h.	47	27	20	13	26	8	8	10	14	15	0	10	15	13	9	0
16h.	43	28	15	19	15	9	9	7	14	13	0	17	11	9	6	0
17h.	17	10	7	9	4	4	3	6	6	2	2	3	6	7	1	0

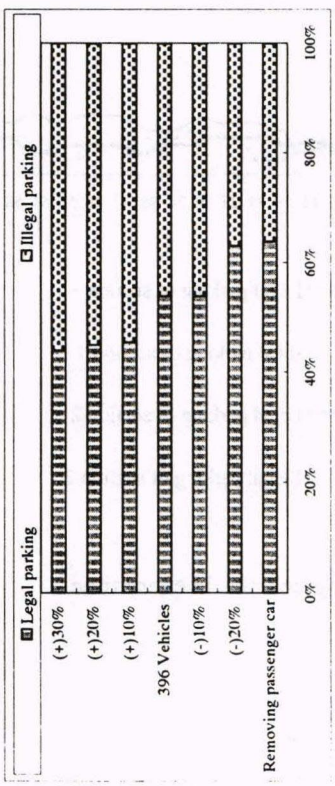

Fig. 10 Rates of legal parking and illegal parking in each case of the increase of demand

Fig. 11 Rates of legal and illegal parking vehicles at every hour in each case of passenger cars

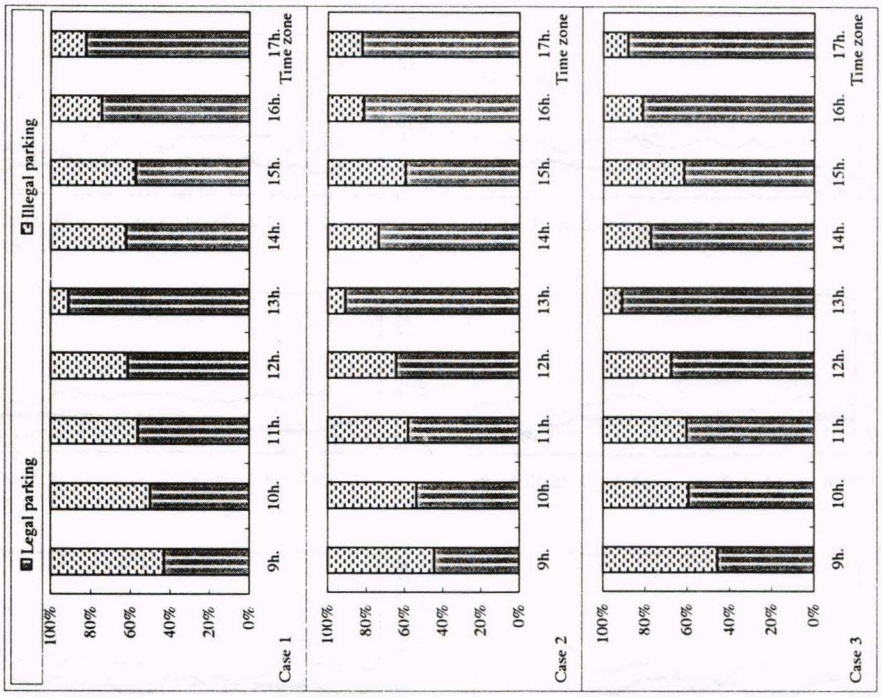

Fig. 12 Rates of legal and illegal praking vehicles in the cases incresing the parking cells

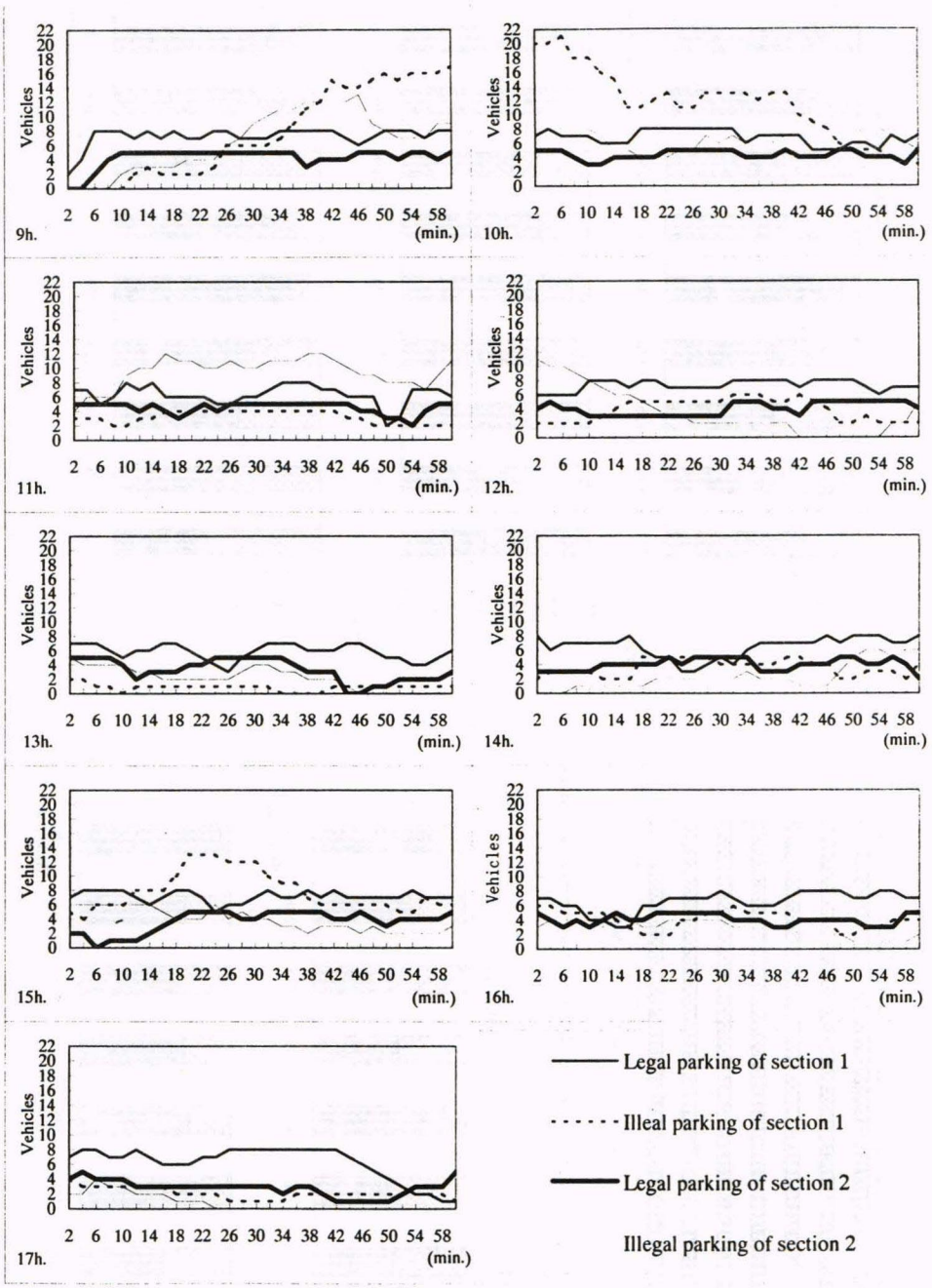

Fig. 9 Number of goods legal and illegal parking vehicles in every time