A STUDY ON CHARACTERISTICS AND TRANSPORTATION MANAGEMENT POLICIES OF ON-STREET-PARKING IN C.B.D.

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Abstract: This paper aims 1) to clarify the characteristics of On-Street-Parking cars in a study area, 2) to suggest a simple method which can visualize the characteristics and 3) to develop a simulation system which can evaluate transportation management policies. Finally, we focus on ability of Transportation Demand (or System) Management policies to disperse congested time and location. Using the visualizing method or the simulation model, we discuss some policies that should be introduced into the studied area.

1. RESEARCH PROCESS

Traffic congestion is a serious problem in Tokyo Metropolitan Area. One of the factors of the congestion is a bottleneck caused by On-Street-Parking cars. Especially, there are not enough parking lots in C.B.D. (Central Business District) and the demand exceeds parking supply. Therefore, appropriate management policies are required to relieve the heavy traffic congestion.

On-Street-Parking cars are classified into two categories such as passenger cars and trucks. The characteristics of these categories are different so that the policies should be discussed by quantitative analyses considering their behavior. This paper aims 1) to clarify the characteristics of On-Street-Parking cars in a study area, 2) to suggest a simple method which can visualize the characteristics and 3) to develop a simulation system which can evaluate transportation management policies. Detail of the research process according to the above items is as follows.

1) The study area is Chiba-city where is one of the major C.B.D. in Tokyo Metropolitan Area. The survey was conducted in 1995, and about 500 trucks' and passenger cars' behavior in a day was recorded. The data covers the parking location, parking time, its duration and characteristics of each car.
2) Using the above data, we can show the distribution of parking duration and the location. The characteristics are visualized by "Parking-Location & Time (PLT)" chart which is suggested in this paper. We represent that the PLT chart can show the time and space occupancy of each road and its efficiency as a tool for the decision support.
3) A simulation system of On-Street-Parking cars is composed of three sub-models; the Poisson arrival model, parking location choice model (Logit model) and parking duration model. The simulation model can describe the observed behavior and we test several parking management policies.

Finally, we focus on ability of Transportation Demand (or System) Management policies to disperse congested time and location.

2. BACKGROUND AND OBJECTIVES

2.1 Parking demand and supply in Japanese C.B.D.

In metropolitan area in Japan, about 40% of parking actions use road space as parking space for free (Figure-1). 90% of them are illegal parking and they worsen traffic congestion, increase traffic accidents and disturb emergency vehicles operation. Especially in C.B.D., insufficient supply of parking facilities has accelerated the situation. Provision of parking facilities made only slow progress because of its low profitability and physical difficulties to construct parking facilities in small building lots. In addition to the imbalance between parking demand and parking facilities, people do not want pay for parking and still have strong preference to load/unload goods at frontage streets at destinations. Therefore, some Transportation Demand Management (TDM) policies should be introduced to relieve the congestion, and modeling systems to evaluate the policies are required.

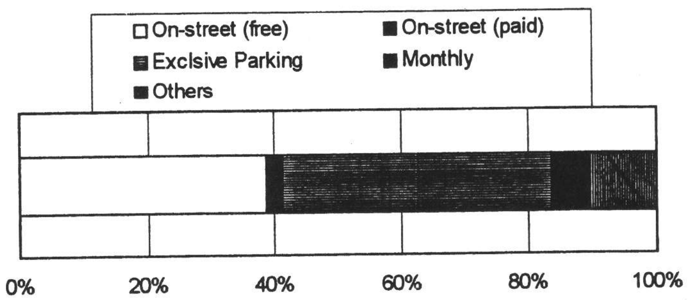

Figure-1 Type of parking facilities in metropolitan areas in Japan

2.2 Objectives

In this paper, we develop several methodologies that can clarify characteristics of parking behavior, particularly on-street-parking. In metropolitan cities in Japan, a half of on-street-parking cars is trucks, and the parking behavior would be different between trucks and passenger cars. We classify the parking cars into passenger cars and trucks and examine their behavior separately. A simulation system which can describe actual parking activities is proposed and some TDM policies are evaluated by the system.

3. THE FEATURE OF STUDIED AREA

The studied area is a C.B.D. in Chiba-city where lies eastern part in Tokyo Metropolitan Area. The population of Chiba-city is about 900,000, and the studied C.B.D. is a capital city of Chiba prefecture. The area's size is about 150m × 400m and it has two railway stations. Figure-2 illustrates the map of the studied area. The area consists of 9 blocks. The numbered intervals in each block are surveyed. The abstract of the survey is summarized in Table-1.

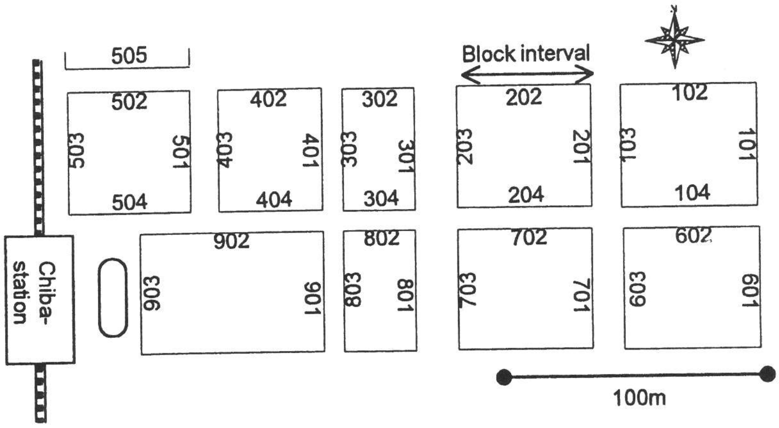

Figure-2 Illustration of studied area

Table-1 Principal items of Chiba-city survey

-Survey method: Counting by examiners
-Year/Month: 1994, October
-Duration: a.m.8:00 – 11:00 and p.m.1:00 – 4:00 (total 6 hours)
-Number of observed parking cars: 1,238 cars
-Principal survey items: time, duration and location of parking, attribution of car (commercial or private, large or small etc.), destination building of each carry, mode of carry (by hands or hand-truck), number of baggage, figure of baggage (box or envelope etc.)

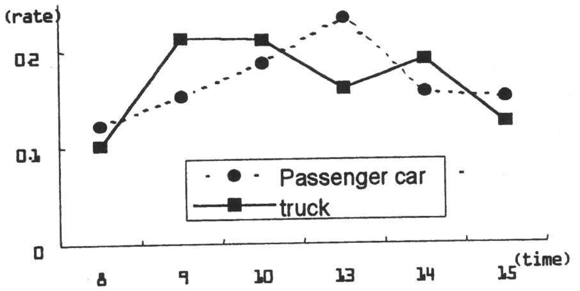

Figure-3 Temporal density of samples (total)

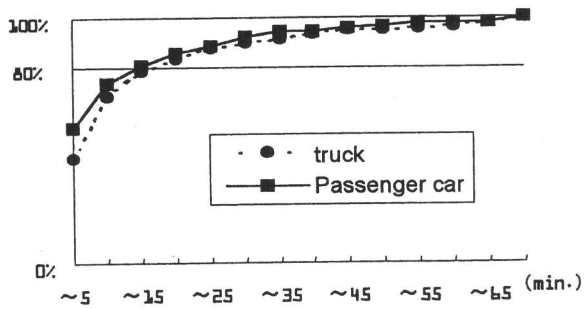

Figure-4 Distribution of parking duration

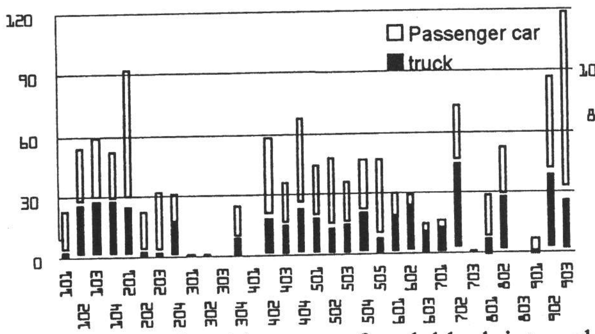

Figure-5 # of parking cars of each block interval

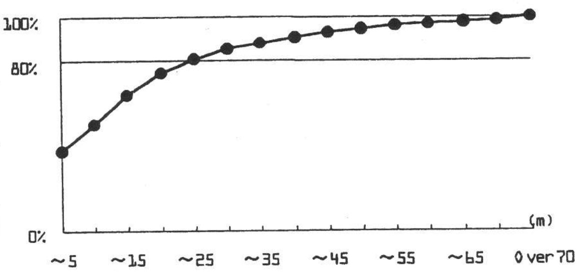

Figure-6 Distribution of conveyance distance

Over ten examiners observed on-street-parking cars during 6 hours, and they recorded activities of each car in detail. If a parked car carried baggage, they checked the mode, the figure etc. Here, we call the cars that carried baggage as "truck" and the others as "passenger car". Figure-3 shows the density of on-street-parking cars. Trucks have two peaks and passenger cars concentrates in a p.m. hour. The distribution of parking duration is resulted in Figure-4. The curves are quite similar between truck and passenger car, however average parking duration of truck car is 13.1 minutes and the passenger cars' duration is 10.8 minutes.
Total number of on-street-parking cars on each block interval is summarized in Figure-5. The block interval number in Figure-5 is same as the number in Figure-2. Figure-5 represents that the ratio of truck to passenger car is quite different, because the ratio depends on the attributions of block interval. For example, block intervals near railway station have large number of passenger cars and trucks concentrates in central area where has larger business and commercial buildings. Figure-6 shows distribution of conveyance distance of truck's baggage. About a half trucks parked in front of the destination buildings so that the distance was under 5 meters. However, 20% truck drivers carried their baggage over 25m. This is because of the time-space concentration of parking cars. Transportation demand management policies should be applied to disperse it.
The studied area has only 10 tolled on-street-parking lots. They are called "Parking Meter Lot" or "Parking Ticket Lot" and the fee is about $1 per 10 minutes. There are little number of the parking lots and the fee is very high, therefore, almost cars park illegally (Figure-7).

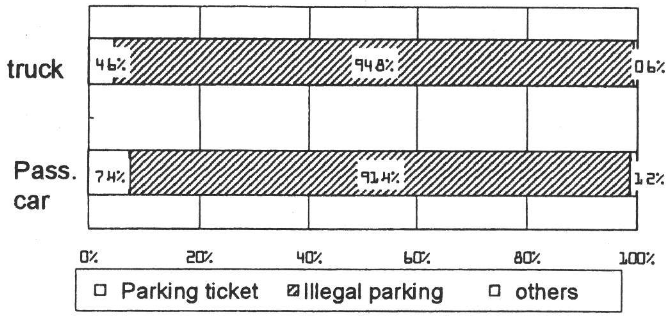

Figure-7 Type of parking facilities of the samples

4. TIME-SPACE OCCUPANCY ANALYSIS BY PLT CHART

4.1 Definition of PLT chart

On-street-parking activity should be analyzed by time & space dimension. Because the principal variables which can describe parking car's behavior are parking time, duration, location and its attributions such as size of car, truck or not etc. Here, we propose a method which can display the parking cars' behavior of each block interval easily. The proposed chart has location axis (horizontal axis) and time axis (vertical axis) as in Figure-8, and observed on-street-parking car is located in the chart as a bar. The chart can also show unavailable parking locations such as a pedestrian crossing or a fire hydrant etc. We name the chart PLT (Parking Location & Time) chart.
Figure-8 displays a PLT chart of block interval 103 during a.m.8:00 – a.m.10:30. The chart represents that parking cars concentrated limited space and time, especially some cars parked over one hour and they disturbed parking behavior of other cars.

One of an important indices calculated by PLT chart is parking occupancy of each block interval. The parking occupancy is a ratio of total bars' area to total area of the PLT chart, and it defined as

$$O_k^i = \frac{\Sigma_j \left(l_j^i \times T_{kj}^i\right)}{\left(L_k - C_k\right) \times UT}, \quad (1)$$

where,

O_k^i : parking occupancy of the k-th block interval and the i-type car (i=1: truck, i=2: passenger),

L_k : length of the k-th block interval (m),

C_k : length of unavailable parking space on the k-th block interval (m),

l_j^i : length of parking space of the i-type car (i=1: 6m, i=2: 4m),

T_{kj}^i : parking duration of the j-th car (min.),

UT : observed duration (min.).

This index will be examined in the following subsection.

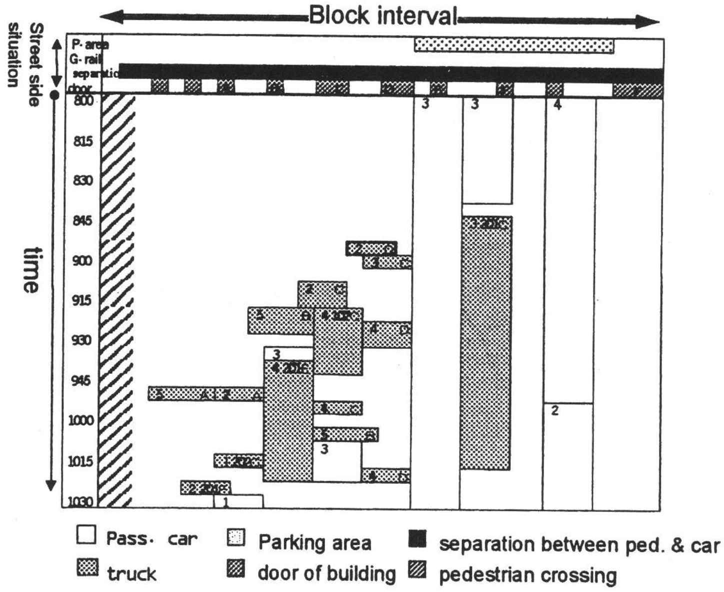

Figure-8 An example of PLT chart

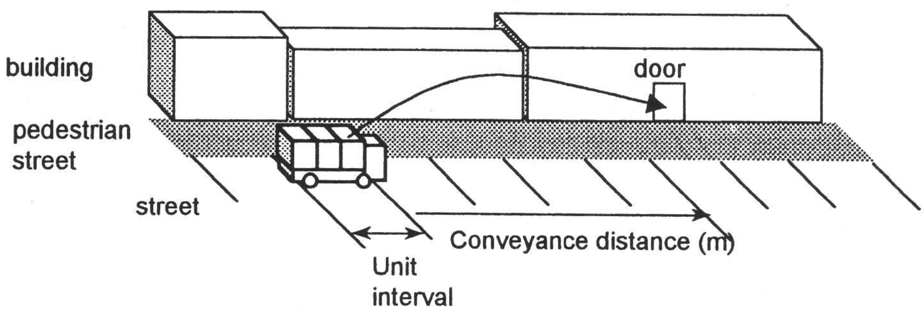

Figure-9 Illustration of truck's conveyance

4.2 Calculation of parking occupancy of each block interval

The parking occupancy index can show important characteristics of on-street-parking behavior. It would be of help to discussing transportation demand management policies.
Here, we calculate the parking occupancy for each block interval and each car-type, truck or passenger car. Some TDM policies will be suggested by the result.
The calculation result of 33 block intervals is summarized in Figure-10. The occupancy in observed duration, *UT* in equation (1) is 360 minutes, is calculated by truck and passenger car. Block interval 802 gives the maximum occupancy value 0.45, and it can be divided into two indices as follows.

$$O_{802} = O^1_{802} + O^2_{802} = 0.15 + 0.3 = 0.45 \tag{2}$$

It is supposed that the high occupancy block intervals have serious problems by the on-street-parking cars, therefore, we are focused on two block intervals, 802 and 504, and discuss some TDM policies to relieve them (see Figure-11, 12).

Block interval 802 faces many commercial & business buildings which generate & attribute many goods. The truck's parking occupancy is constantly high, therefore, the parking demand should be dispersed to other block intervals. Some demand switching policies to block interval 803 or 303 would be considered. For example, building parking lots on 803 or 303, strengthening regulation to illegal parking for all day should be introduced.
On the other hand, on-street-parking cars on block interval 504 concentrate during a.m.9:00-a.m.10:00. Especially, parking occupancy of passenger car is very high. Block interval 504 fronts on a railway station so that there are crowded with people who come to see off or welcome their family members. Of course policies to disperse the demand to other block intervals should be introduced, moreover, temporal dispersion policies should be conducted.

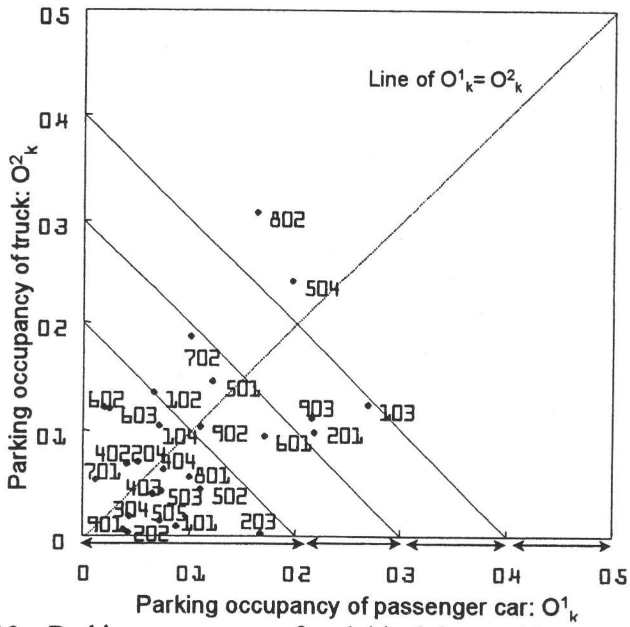

Figure-10 Parking occupancy of each block interval by type of car

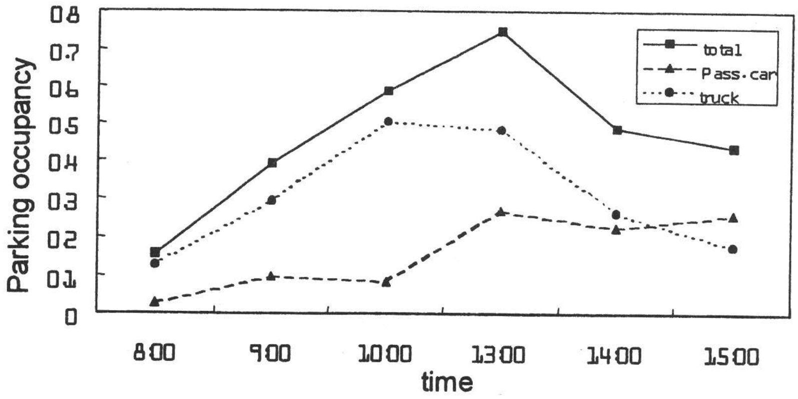

Figure-11 Parking occupancy of interval 802

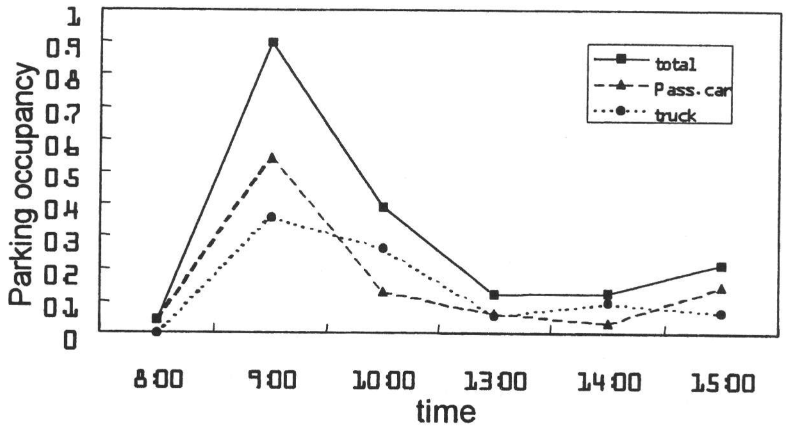

Figure-12 Parking occupancy of interval 504

5 SIMULATION ANALYSIS FOR TRANSPORTATION MANAGEMENT POLICIES

5.1 Hypothesis and models of simulation analysis

To evaluate TDM policies for on-street-parking, we develop a simulation system to describe each on-street-parking car by space and time. The simulation system has three models; 1) arrival model, 2) duration model and 3) parking location choice model. The simulation's flow is illustrated in Figure-13. The detail of each model is explained as follows.

1) Arrival model
The Poisson distribution is applied to the arrival model. We calculate average arrival rate, number of vehicles per minutes, from the observed data. The average of each block interval and car type (truck or passenger car) is calculated and it is used as the Poisson distribution's parameter.

2) Duration model
Duration model gives parking duration of each car. We assume the Weibull function as the statistical duration. The distribution function is expressed as

$$F(t) = 1 - \exp\left[-(\gamma t)^{\rho}\right]. \qquad (3)$$

(γ and ρ : parameter)

Unknown parameters, γ and ρ, are estimated by using observed data and the result is shown in Table-2.

3) Parking location choice model

We could not observe destination of each passenger car's driver, therefore, we assume that the drivers choose parking location among their arrival block interval. The choice probabilities of each driver are same. However, truck driver's destination was recorded, and we apply conventional Logit model to the choice model. To simplify the calculation of the simulation, we divide a block interval into 10 sub-intervals and assume that a driver has 10 alternatives in the choice set. Of course a sub-interval which other car has already parked is excluded from the choice set. Here, only conveyance distance between parking location and destination building is used as an independent variable. Table-3 is the parameter of the Logit model.

Table-2 Estimated parameters of duration model

Type of car	Parameter		t-value
Passenger car	γ	7.6354	30.3
	ρ	0.8918	24.6
truck	γ	2.0949	21.3
	ρ	0.8125	18.2

Table-3 Estimated parameter of parking choice model

	parameter (t-value)
conveyance distance (m)	−0.11556 (14.1)
Likelihood ratio	0.283
Hit ratio	45.7%
Number of samples	332

The simulation is conducted on 24 block intervals during 6 hours. Random numbers distributed uniformly are generated and they are used to choose an output of each model. The results of the simulation depend on the initial random numbers so that they are different each other. We repeat the simulation 100 times and calculate the average as the final result. The statistical comparison between observed data and the final result passed χ^2 test, consequently we judge that the simulation system can describe the parking behavior well.

5.2 TDM policy analysis by the simulation system

We evaluated several TDM policies to relieve traffic congestion due to on-street-parking cars. Here, strengthening regulation of parking duration is examined as one of the policies. The assumptions are as follows.

1) Maximum parking duration of passenger car is regulated to X minutes strictly.
2) Passenger cars which parks over X minutes would park in private or public parking lot. Hence, they are excluded from on-street-parking demand.
3) No regulations as for truck.

We consider that truck supports commercial & business activity in a city, and the drivers would not switch their parking location to parking lot because of the hardship of carrying baggage. Figure-14 is the simulated result regarding the regulation policy. An average conveyance distance is calculated for an index to represent efficiency of truck activity. The maximum parking duration of passenger car is changed from 30 minutes to 5 minutes. As the regulated duration is shorter, the average conveyance distance also decreases. However, the distance changes only from 7.45 [m] to 7.2 [m]. Although this policy reduces passenger car parking, it would not be efficient for freight truck. This is because of the randomness of parking location choice.

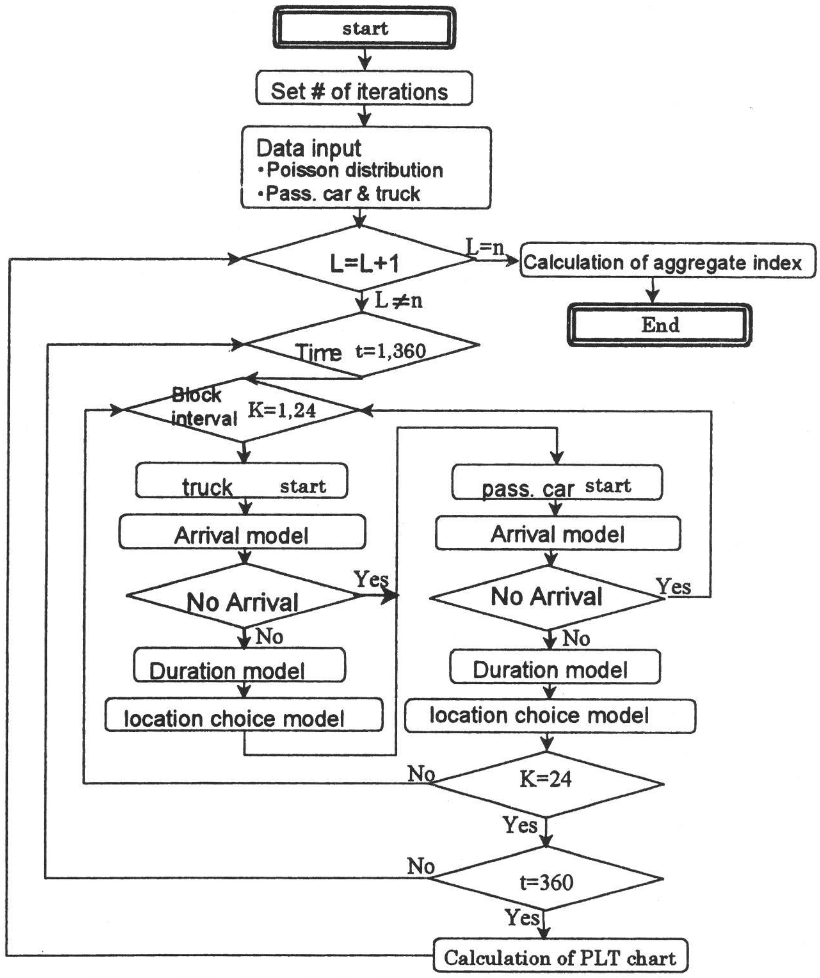

Figure-13 Calculation flow of the simulation system

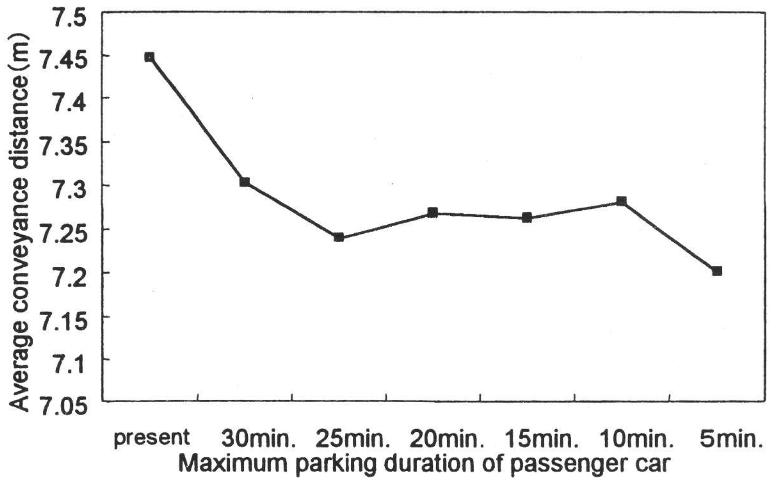

Figure-14 Relationship between conveyance distance & regulation of parking duration

6 CONCLUSION

This paper studied on-street-parking car's behavior based on actual data. A method to visualize feature of on-street-parking car, PLT chart, was proposed and it can clarify the observed samples' behavior at a glance. It is shown that some indices derived from PLT chart such as parking occupancy can summarize characteristics of parking.

The simulation system proposed in this paper includes several aspects of on-street-parking; arrival, duration and location choice. The structure of the simulation system would be essential but still primitive. More detail aspects should be included in the system. And this is one of the reasons that TMD policies discussed in this paper are limited.

Further topics to be studied are summarized as follows:

1) To observe drivers behavior of passenger car after park, because their destination also affect their parking location.
2) To increase the number of alternatives of parking location choice model. The observed data show that 20% of trucks does not park a block interval that has their destination. The choice set should include not only the destination's block but also neighbor block intervals.
3) To model arrival time. Some arrival time choice model is required to describe drivers temporal behavior. Especially, temporal regulations should be evaluated by the system including temporal behavioral change.

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