A STUDY ON THE ESTIMATION OF GOODS VEHICLES PARKING DEMAND AND PLANNING OF GOODS VEHICLES PARKING SPACES BASED UPON BUILDING USES IN THE CBD

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abstract: Nearly half of traffic made in an urban area is caused by movements of trucks and vans for pick-up and delivery services of various goods. Pick-up and delivery services has become an important component of the social and economic activities of every major cities in the world. Thus, the need for a careful investigation of goods movement is necessary to clarify the relation between the generation/concentration volume of goods vehicle and building use.

1.INTRODUCTION

The continuing increase in goods movements has caused several problems such as traffic congestion, traffic accidents, and environmental problems. Thus, a countermeasure against these problems has become an urgent and important issues in urban areas. Among these problems which needs to be addressed is the loading and unloading activities mainly carried out at on-street parking facilities of business, commercial, and wholesale districts due to the shortage of parking facilities and/or loading and unloading facilities.

In this paper, a survey was conducted to determine the generation/concentration volume of goods and goods vehicles at the Ginza district in Tokyo. An estimation method on generation/concentration volume of goods vehicles was presented and the amount of gross floor area and the composition rate of the gross floor area by use in a block was determined. Finally, the methodology was applied for the actual commercial blocks located at Ginza district.

2.THE CHARACTERISTICS AND THE PROCEDURE OF THE STUDY

2.1 Existing studies and aim of the study

Existing studies on parking demand of goods vehicles in Japan are the following:

1) studies which presented the number of truck- loading space according to the scale of the building (*Mori, et al, 1983, 1985*)
2) studies which clarified pick-up and delivery activities and actual parking condition of commercial district at the metropolitan area(*Takada, 1988*)
3) studies which analyzed the relation between freight volume and building uses. (*Nemoto, 1992, Tsukaguchi, ei al, 1989*)

As for the parking policy of goods vehicles, many designated parking lots for goods vehicles can be found in the CBD of Paris, Seattle and other major cities. On the other hand, there are only few cities in Japan where designated parking is established.

This paper aims to clarify the relation between the generation/concentration volume of goods vehicle and building use, and will try to establish an estimation method based on a sampling survey done at Ginza district.

2.2 The procedure of this study

The procedure of this study was conducted as follows;

a) The background and the purpose of this study was first clarified.
b) A questionnaire survey on goods movements at the Ginza district was conducted.
c) Based on the questionnaire survey, the standard unit of generation/concentration volume of goods and goods vehicles was calculated, and the synthesis standard unit of the generation/concentration volume of goods vehicles was deduced.
d) A sampling survey at the Ginza district was conducted.
e) The modeling formula was applied and a plan for on-street parking was made.

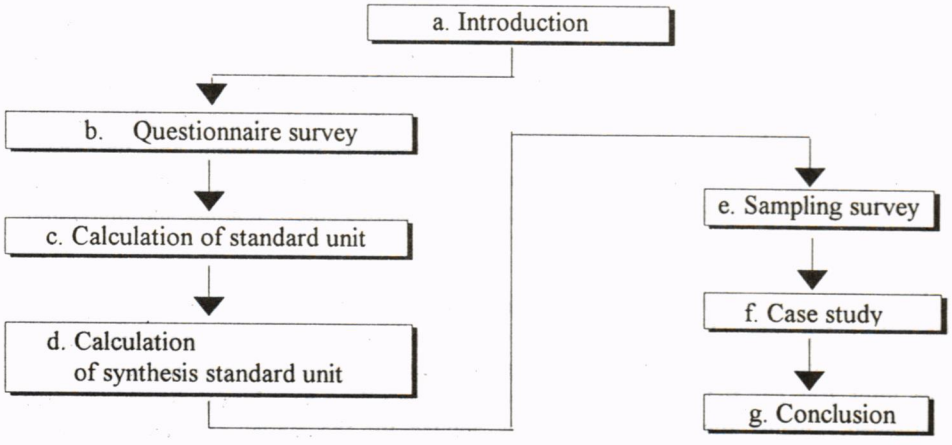

Figure -1 Flow chart of this study

3.CALCULATION OF THE STANDARD UNIT OF GOODS AND GOODS VEHICLE

3.1 Questionnaire survey at Ginza district

A questionnaire survey was conducted at Ginza district in order to determine the standard unit of goods and goods vehicle. Ginza district is the biggest business and commercial district in Tokyo. It has a land area of 86 hectares and a gross floor area of 241 hectares is dedicated for business and commercial use.(Figure - 2)

Generation/concentration volume of goods and goods vehicles were also obtained through the survey conducted on March 1993. The survey area consisted of offices, shop and stores, and restaurants which totaled 218 business firms. The response rate of the survey was approximately 76%.

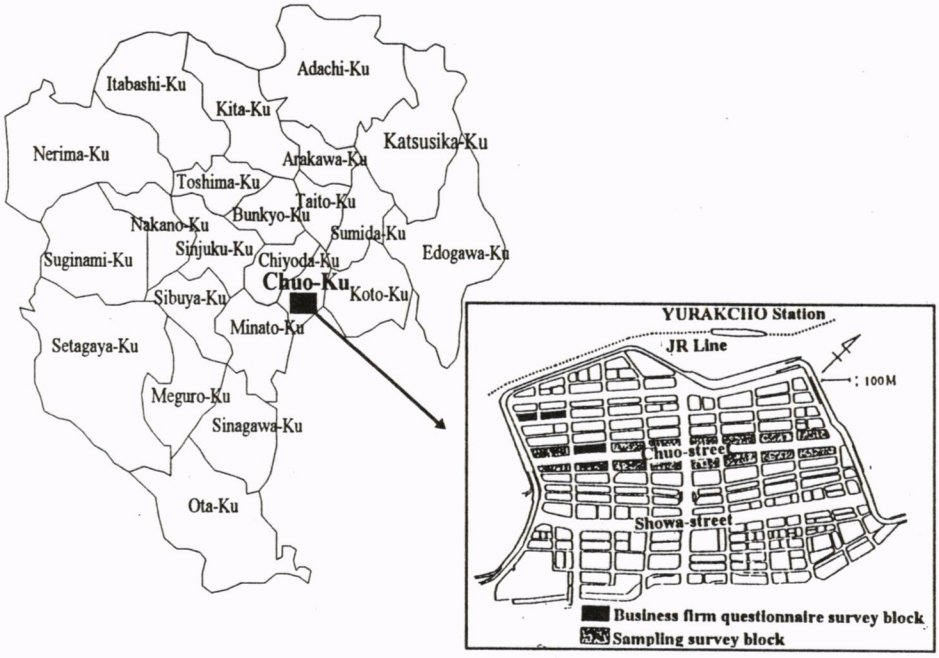

Figure - 2 Ginza district in Tokyo

3.2 Calculation of standard unit of goods and goods vehicles

The standard unit of goods by floor uses was calculated by dividing the generation/concentration volume of goods by the gross floor area of each use. (Table - 1)

This standard unit was derived from the results of questionnaire survey. So, it means average volume of goods by each floor use.

Table - 1 The standard unit of goods by floor uses [piece/(ha · day)]

floor use	generation	concentration
office	192.9	105.2
shop and store	35.3	62.3
restaurant	106.5	140.1

The standard unit of goods vehicles by floor uses was calculated by dividing the generation/concentration volume of goods vehicles by gross floor area of each use. (Table - 2)

Table - 2 Standard unit of goods vehicle by floor uses [number of vehicles/(ha · day)]

	office	shop and store	restaurant	average
standard unit	29.2	45.7	167.1	52.4

4.CALCULATION OF THE SYNTHESIS STANDARD UNIT OF GOODS VEHICLES

4.1 Calculation of the generation/concentration volume of goods vehicles

Planning of parking facilities for goods vehicles should consider both the volume of parking space and the parking demand of each block, instead of the individual buildings.

The standard unit of generation/concentration of goods vehicles for a block was calculated as follows;

$$P = a_1F_1 + a_2F_2 + a_3F_3 \quad (1)$$

P : The standard unit of generation/concentration volume of goods vehicle for a block [number of vehicles/day]

a_1 : The standard unit of generation/concentration volume of goods vehicle by offices [number of vehicles/(ha · day)]

a_2 : The standard unit of generation/concentration volume of goods vehicle by shops and stores [number of vehicles/(ha · day)]

a_3 : The standard unit of generation/concentration volume of goods vehicle by restaurants [number of vehicles/(ha · day)]

F_1 : The gross floor area by offices [ha]

F_2 : The gross floor area by shops and stores [ha]

F_3 : The gross floor area by restaurants [ha]

4.2 Calculation of the synthesis standard unit of goods vehicles

The generation/concentration volume of goods vehicles depends according to the size of the gross floor area for each use (that is, offices, shop and stores, and restaurants).

By means of equation (1), the synthesis standard unit(W) of generation/concentration volume of goods vehicles can be obtained using the composition ratio of floor uses of

each type instead of the gross floor area.(*Takahashi, et al, 1994*)

$$W = a_1X + a_2Y + a_3Z \tag{2}$$

where, $W = P / F$
$X = F_1 / F$、$Y = F_2 / F$、$Z = F_3 / F$
$X + Y + Z = 1.0$
$F = F_1 + F_2 + F_3$

W : The synthesis standard unit of generation/concentration volume for goods vehicles [number of vehicles/(ha・day)]
F : The total gross floor area of the block [ha]
X : The composition ratio to gross floor area of office [$0 \leqq X \leqq 1$]
Y : The composition ratio to gross floor area of shop and store [$0 \leqq Y \leqq 1$]
Z : The composition ratio to gross floor area of restaurant [$0 \leqq Z \leqq 1$]

4.3 Calculation of the synthesis standard unit per unit time

Planning of parking facilities for a block should take into account the generation/concentration volume of goods vehicles as well per day as per unit time. In this paper, the volume of parking facilities for a block was combined with the middle parking demand volume of 12 hours.

The synthesis standard unit(W') of generation/concentration volume of goods vehicles for a block per unit time can be defined by the next equation;

$$W' = \lambda W \tag{3}$$

where
W' : The synthesis standard unit per unit time [number of vehicles/(ha・hour)]
λ : The ratio of the medium of hourly parking
This λ is 0.099 by this survey [$0 \leqq \lambda \leqq 1$]

5.PLANNING FOR THE PARKING FACILITIES OF GOODS VEHICLES BY BLOCK

5.1 Concept of planning of parking facilities

When parking facilities for goods vehicles are not enough to meet the demand, the following methods are employed: a) advanced utilization of existing parking facilities, b) control the parking demand, and c) increase the number of parking facilities.

In Japan, because parking facilities for goods vehicles were not planned sufficiently, existing parking facilities are remarkably low. Because of this, policies of allowing parking inside the building, off-street parking and on-street parking are very common. Among these policies, the construction of parking facilities inside the building can be a

long-term solution. Meanwhile, off-street parking facilities can be a short-term solution as long as an area is available in the district which can be converted to a temporary parking lot. On the other hand, on-street parking facilities can be a short-term solution in order to optimize existing road capacity.

However, for long-term planning, it is recommended that parking facilities should be constructed inside the buildings and vacant areas be converted to off-street parking since the capacity of roads are insufficient to accommodate demands for on-street parking.

Table - 3 period of time demanded on planning of parking facilities

	Short-term	Middle-term	Long-term
Parking spaces inside building		◎———	◎
Off-street parking facilities	◎———	◎———	◎
On-street parking facilities	◎———	◎	

5.2 Planning of parking facilities for the insufficient volume of goods vehicles

The insufficient volumes of parking for goods vehicles on a block wanting to park can be calculated as the difference between the parking demand and the capacity of the parking facilities. In this paper, we focus on goods vehicles, so we did not treat passenger cars.

The capacity of the parking facility is equal to the total capacity of the three policies which are parking inside the building, off-street parking, and on-street parking.

$$\begin{aligned} V &= Q - C \\ &= Q - (C1 + C2 + C3) \\ &= W' \cdot F/r - (\theta \cdot F \cdot N + C2 + L/k) \end{aligned} \tag{4}$$

where

V : The insufficient volumes of parking facilities for goods vehicles [number of vehicles]
Q : The parking demand volumes [(W・F) / r] [number of vehicles]
C : The capacity of parking facilities [number of vehicles]
C1 : The capacity of parking spaces in side the building [number of vehicles]
C2 : The capacity of off-street parking facilities [number of vehicles]
C3 : The capacity of on-street parking facilities [number of vehicles]
F : The total gross floor area of the block [ha]
W' : The synthesis standard unit per unit time [number of vehicles / (ha・hour)]
N : The criterion on the planning of parking spaces for goods vehicles inside building 1.0 lots / 0.3ha [number of vehicles / ha]
r : The turnover of parking per unit time
θ : The ratio of the gross floor area of building above 0.2ha(the minimum annexed-establishment-duty floor area for loading and unloading activities to a total gross floor area of the block
L : The possible distance of the on-street parking facilities establishment outside the circuit part of the block [m]
k : The length needed for parking space for a standard goods vehicle [m]

This paper aims to focus on the short-term solution of on-street parking wherein it tries to maximize the available capacity of the road since planning of off-street and inside building parking requires a lot of capital investment.

Transforming equation (4);

$$V = (W' \cdot F/r - \theta \cdot F \cdot N - C2) - L/k \quad (5)$$

The right side parenthesis of equation (5) is the parking demand volumes of goods vehicle that could not use the off-street and inside the building parking facilities. The second member of the right side parenthesis is the on-street parking volumes at present. From equation (5), the amount of on-street parking space needed can be predicted in the future.

6.SAMPLING SURVEY FOR THE CASE STUDY

6.1 Sampling survey

In order to concretely examine the applicability of the formula, a sampling survey was conducted on three blocks of the Ginza district from 8:00 *a.m.* to 8:00 *p.m.* on March 24, 1993 (Wed.). These are 7 Chome 8-No.1 Block-and 8 Chome 5-No. 2 Block-(North Sides), 8 Chome 5-No. 3 Block-(South Side).

The main survey items recorded were the following:

a) Volume, shape and form of goods entering and exiting the building entrances, and the time of entrance and exit.
b) Type of vehicle, parking space number, parking time, and duration of parking.

Block 1 mainly consists of offices, shop and stores, while Block 2 and Block 3 mainly consist of restaurants.

6.2 Centralization times, on-street parking times of vehicles and goods vehicles

The peak-hour total parking volume of goods vehicles for the three blocks was during the period 10:00 *a.m.* to 11:00 *a.m.* (light vans, small sized truck, large sized trucks). However, peak-hour volumes for each block were different.

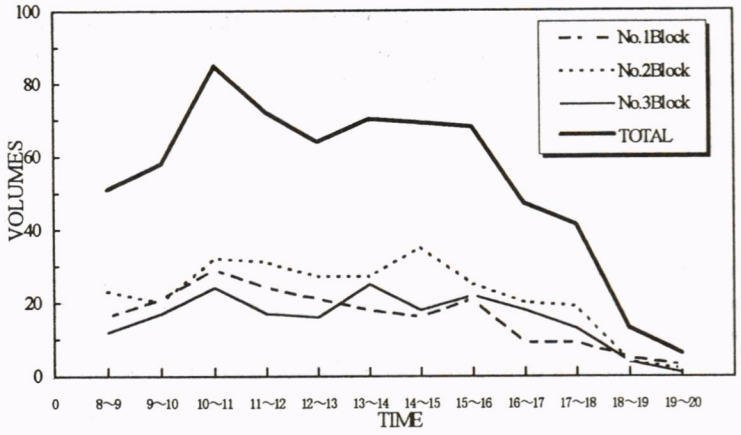

Figure - 3 Parking vehicles of goods vehicles by time

Figure 4 shows the peak-hour volume of parking vehicles (goods vehicles and passenger cars). Peak-hour volume of goods vehicles was from 10:00 *a.m.* to 11:00 *a.m.*, while for passenger cars, from 4:00 *p.m.* to 5:00 *p.m.*

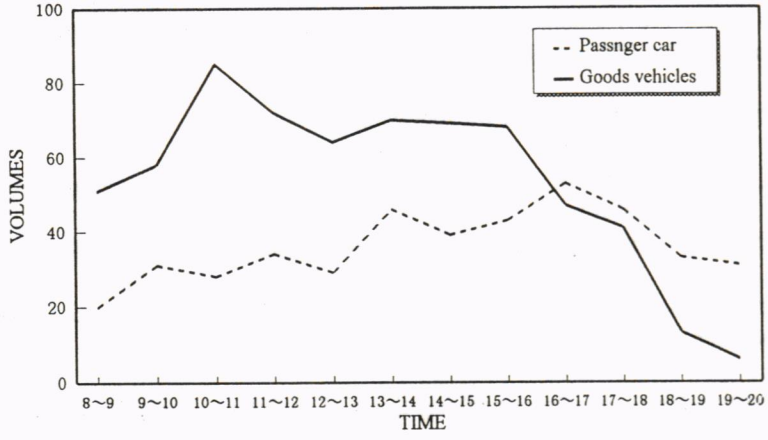

Figure - 4 Parking time of goods vehicles and passenger cars

Above 60% of small-sized and large-sized trucks had parking times under 10 minutes, while for passenger cars, it is a little over 30%. Meanwhile, passenger cars which parked above 1 hour consists 30 %.

Comparatively, the parking time of goods vehicles is considered to be short. (Table - 4)

Table - 4 Average parking time for type of vehicle

	1.Passenger car	2.Light van	3.small-sized truck	4.large-sized truck
average parking hours(min)	31.4	19.9	20.2	19.1
sample numbers of vehicle	320	251	16	213
a composition ratio	29.6	23.2	1.5	19.7

	5.Motorbike · bike	6.others	7.total no. of vehicles	8.goods vehicles Total of 2,3,4
average parking hours(min)	19.7	13.9	20.7	20.4
sample numbers of vehicle	258	23	1081	480
a composition ratio	23.9	2.1	100.0	44.4

7.CASE STUDY

7.1 Application of the Formula

By using the theoretical equation obtained in the former sections, the volume of on-street parking facilities in the Ginza district can be estimated. Then, a plan for the on-street parking facilities of passenger cars and goods vehicles can be made. Perceiving that the peak hour time of passenger cars is different from the peak-hour time of goods vehicles, the following two cases are set;

Case Ⅰ : Space-Sharing System
This is a plan to divide the street spatially into two, one for passenger cars and one for goods vehicles. Some parts of the street are also dedicated for common use.

Case Ⅱ : Time-sharing System
This is a plan which assigns different time of usage of on-street parking facilities by passenger cars and goods vehicles.

7.2 Case Ⅰ : Space-Sharing System

1) The turnover, the number of cars which can park in one on-street parking space per day, was calculated based on the number of cars and the average parking time of passenger cars and goods vehicles. Also, the demand of on-street parking spaces for each time, as well as the total volume of on-street parking spaces was calculated . (Table - 5)

Table - 5 Demand of parking spaces for goods vehicles and passenger cars

Time(hour)	passenger cars turn-number : the 2nd time		goods vehicles turn-number : the 3rd time		the total
	parking volume	parking spaces	parking volume	parking spaces	parking spaces
8 ~ 9	20	10	51	17	27
9 ~ 10	31	16	58	20	36
10 ~ 11	28	14	85	29	43
11 ~ 12	34	17	72	24	41
12 ~ 13	29	15	64	22	37
13 ~ 14	46	23	70	24	47
14 ~ 15	39	20	69	23	43
15 ~ 16	43	22	68	23	45
16 ~ 17	53	27	47	16	43
17 ~ 18	46	23	41	14	37
18 ~ 19	33	17	13	5	22
19 ~ 20	31	16	6	2	18

2) The peak demand of parking spaces for passenger cars and goods vehicles were deducted from the total volume of on-street parking spaces, in order to get the respective exclusive on-street parking spaces for passenger cars and goods vehicles, as well as for the common-use parking spaces. The peak demand of parking spaces for passenger cars was 27 spaces from 4 *p.m.* to 5 *p.m.*, and, that for goods vehicles was 29 spaces during 10 *a.m.* to 11 *p.m.*. Thus, 29 parking spaces were assigned for the exclusive use of goods vehicles. The maximum demand of on-street parking spaces at peak hour for both passenger cars and goods vehicles was 47 lots from 1 *p.m.* to 2 *p.m.*. Hence, 47 on-street parking spaces must be supplied in this district.

On the other hand, 20 parking spaces (i.e. 47-29=18) can be assigned for the exclusive use of goods vehicles. 18 parking spaces (i.e. 47-27=20) can be assigned for the exclusive use of passenger cars. 9 parking spaces (i.e. 47-18-20=9) can be assigned for common-use parking.

3) On-street parking at the Ginza district has a total of 12 lanes, five of which have 29 spaces which have parking meters for the exclusive use of passenger cars. From this, It is possible to install parking spaces for the exclusive use of goods vehicles on the remaining 7 lanes. The total length of these 7 lanes is 481meters, of which 355 meters can be utilized for on-street parking because the section within 5meters from the intersection and the pedestrian crossing, on-street parking is banned.

Assuming that one truck requires 15meters length for parking (length of the truck plus the turning radius), 23 spaces (i.e. 355÷15=23) can be assigned for goods vehicles parking. From these, the required 20 spaces for the exclusive use of parking spaces of goods vehicles) can be installed in the Ginza district.

7.3 Case Ⅱ: Time-Sharing System

1) The peak-hour volume of passenger cars was different from the peak-hour of goods

vehicles. Therefore, goods vehicles should have the first priority to park during these periods, i.e. 4 hours from 9 *a.m.* to 1 *p.m.* (goods vehicles hours). (Figure - 3)

2) 198 goods vehicles which parked on-street during the period 9 a.m. to 1 p.m. were supposed to park in the Ginza district between 9 *a.m.* to 13 *p.m.* for loading-unloading. So, the number of goods vehicles parking during the priority time for goods vehicles results in 353, i.e. 154goods vehicles actually parked during the priority time for goods vehicles plus 198 goods vehicles which were supposed to park during these hours. The hourly volume of goods vehicles that wanted to park was $353 \div 4 = 88$.

3) As the average parking time of goods vehicles was 20minutes, the parking space can be used 3 times. The number of the demand spaces for goods vehicles can be calculated to be the hourly volume of goods vehicles wanted to park divided by the number of times per hour the parking space was used,. $88 \div 3 = 29$.

Presently, there are 29 spaces which have parking meters and it is possible to install 23 additional parking spaces in the Ginza district as calculated in case I . From these, we were able to prepare enough spaces required for goods vehicle parking.

However, it is necessary to lengthen each lot to meet parking demand requirements of goods vehicles.

The same examination on passenger cars were done, and the result suggested that there are enough on-street parking spaces for passenger cars.

8.CONCLUSION

The purpose of this paper has been to present an estimation method of generation/ concentration volume on goods vehicles based on the survey conducted in Ginza district. It also aimed to find if the method is applicable for making of parking plans and loading-unloading plans of individual blocks. The following conclusion may be drawn from this study:

a) From the questionnaire survey, standard unit of generation/concentration volume for goods and goods vehicles was calculated.

b) The formula of the synthesis standard unit of goods vehicles per day, and the synthesis standard unit of goods vehicles per time were calculated.

c) Parking facilities for goods vehicles should be located inside the building, off-street and on-street. Among these policies, provision of on-street parking can be made short-term to optimize capacity of the existing road.

d) Based on the sampling survey, the average parking time for goods vehicles were 20.4 minutes, passenger cars; 31.4 minutes. Peak hour periods for goods vehicles was during the morning, whereas passenger cars was in the afternoon.

e) By using the equation obtained in Section 4 and 5, parking plans were done for the

Ginza area each for passenger cars and goods vehicles. Loading and unloading parking plans for goods vehicles were also made.

Thus, the method clearly demonstrates the applicability of it in the planning of parking spaces for goods vehicles and passenger cars. The application of the model on the case study suggested that Ginza, one of the busiest commercial and business districts in Japan, has enough on-street parking spaces and will satisfactorily handle the minimum parking or loading-unloading demands as long as parking and loading-unloading activities will be done systematically.

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