A SIMULATION MODEL OF THE DELIVERY TRUCK'S MOVEMENT IN THE CBD OF OSAKA

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abstract : This study makes clear the mechanism how the delivery men decide the cycles or visiting sequences. Then the delivery men's route choice behavior from one sojourn to the next is analyzed. Based on the above analysis, a simulation model of the delivery truck's movement is developed, which can be used to estimate traffic volume of delivery trucks in each street in order to improve the traffic condition in commercial areas.

1. INTRODUCTION

In many central business districts of Japanese cities, a large volume of delivery trucks has become one of the most severe reasons of the traffic congestion, because most of the trucks park on curbsides for loading and unloading and thus obstruct the road traffic.

Since there is few detailed traffic census about delivery trucks in a limited area such as a CBD of a city, it is very difficult for planners to consider the measures to improve the condition. Therefore, for estimating the traffic flow of delivery trucks, it becomes an important theme to explore the behavior of delivery trucks on the road network. There are many studies on the characteristics of truck loading and unloading activities and planning of facilities dealing with goods in central business districts, for example, Marconi(1971), Ahrens (1977), Chistiansen (1978) , Habib et al.(1976, 1978), and Tsukaguchi et al.(1985), but there are few studies on the detailed characteristics of delivery and pick-up truck's movement such as route choice and parking location choice behavior related to delivery and pick-up activities based on a precise investigation.

The purpose of the study is to clarify the mechanism of delivery truck's movement and to make a model which can be used to estimate traffic volume of delivery trucks in each street in order to improve the traffic condition in commercial areas. We have investigated the delivery men's behavior in the CBD of Osaka by the methods of a on-site record and a stated

preference survey. By analyzing the data of the SP survey, this study firstly makes clear how the delivery men decide the cycles or visiting sequences when the sojourns or shipper's addresses are given. Then the delivery men's route choice behavior from one sojourn to the next is analyzed. Based on the above analysis, a simulation model of the delivery truck's movement is developed.

2. METHODOLOGY

2.1 Methodology

Generally speaking, in order to obtain data of goods movement in urban areas, questionnaire sheets are delivered to subjects who are engaged in goods movement, that is, persons in charge of goods movement in shippers, and persons in carriers such as truck drivers etc., and they are asked to answer the questions by themselves. However, it is difficult to make this kind of survey when goods movement in a limited area such as a commercial center of a city is investigated, because a trip length is very short, number of trips are very large, and duration of loading and unloading activities is very short since they are usually carried out on streets and so on. Under the circumstances, this study take a different way to obtain data on delivery truck's movement. The investigation in this study consists of two parts. One is a survey in which truck's practical movement is recorded by a surveyor who rides in a truck nest to the driver. Another is a stated preference survey in which drivers are asked to answer in their office such questions as a mechanism of decision making of the order of sojourns, the route at that time, their principles related to these activities and so on.

2.2 Data Collection

This study chooses Semba district as the study area, which is one of the traditional commercial center in Osaka. We chose a carrier whose head office is located near Semba district. In cooperation with the company, the following surveys were conducted. Since the carrier divided Semba district into several zones for their daily activities, we use the zones shown in Fig.1. This area is divided into four zones, that is a, b, c, and d zone, in which one truck delivers goods to shippers in half a day.

The on-site survey was done in October 1994. The four surveyors who rode in four trucks respectively, recorded sojourns, arriving and departure times, exact parking places, routes of the trips and so on. Based on the on-site survey, characteristics of truck movement in Semba district has been indicated. The data obtained here are used to make a stated preference survey described later, and to confirm the significance of the simulation model on delivery truck's movement.

According to the on-site survey, the number of sojourns in half a day is about twenty five. Therefore twenty five sojourns are chosen for a stated preference survey which was carried out in November 1995. The sojourns are chosen from a view point of their location and volume of goods. Here, six drivers who are engaged in delivery and pick-up activities every day in this district and two office workers who are in charge of making a schedule of delivery and pickup activities participated. They were given the question sheets and maps in their office and asked to answer the order to visit the sojourns and the route at that time considering the traffic rules in that area. The subjects were also asked to answer the questions based on their usual behavior. Therefore some persons might regard as of major importance

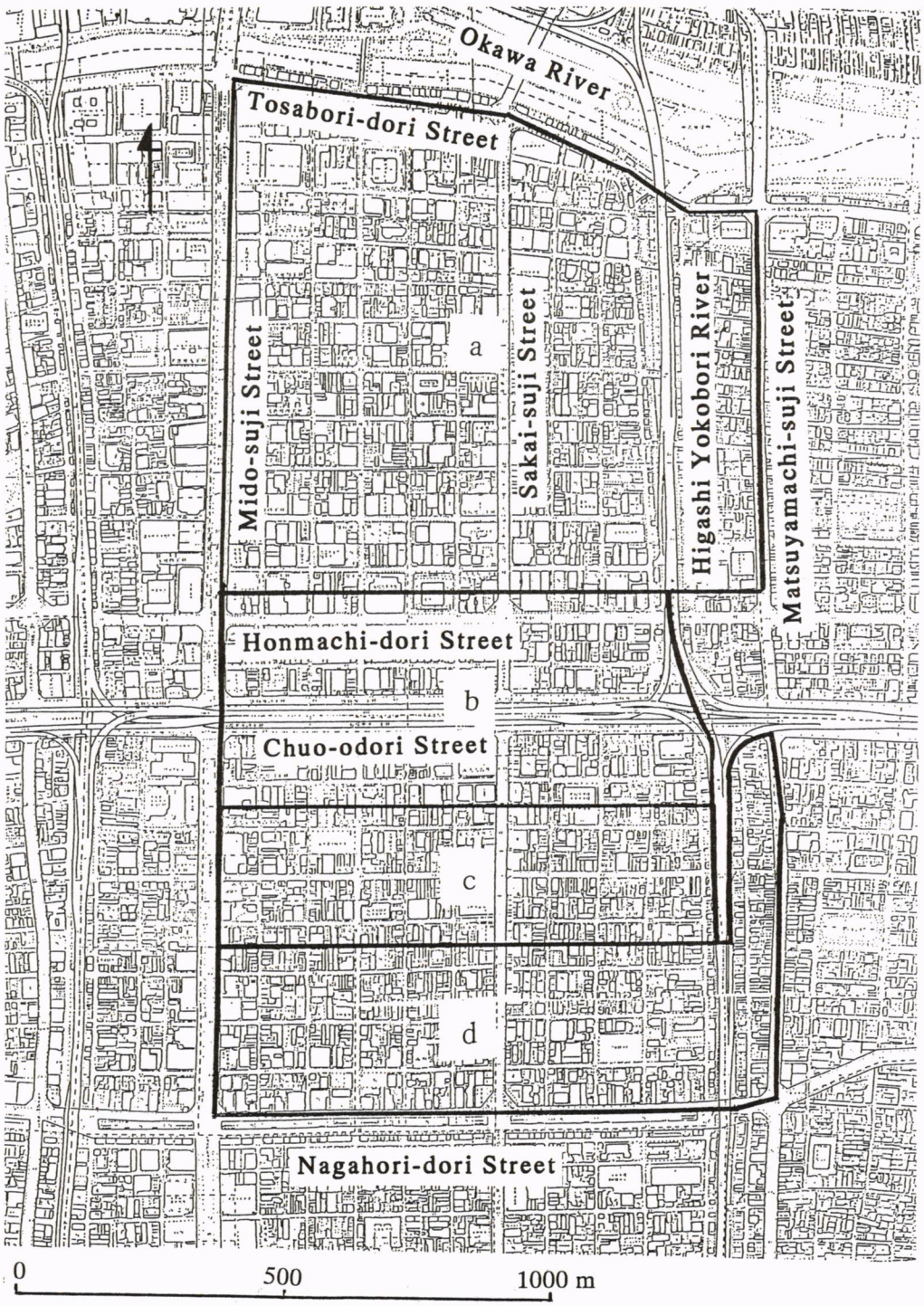


Fig. 1 Study Area

the overall route optimality rather than the relation between the present sojourn and the alternative next sojourn. On the other hand, other persons might attach importance to the relation between the present sojourn and the alternative next sojourn. In the survey, six types of delivery activities in which the zone and sojourns are different were prepared for one subject. When more than two shipper's location are very close each other, a subject is apt to choose one sojourn for these shippers. Therefore, in the following sections, we treat only sojourns to make an analysis Addition to this, in order to make an analysis more systematically, every sojourn is replaced by the nearest node in the road network.

3. FACTORS RELATED TO DELIVERY TRUCK'S MOVEMENT

3.1 Influence of Distance

Since the study area is small, the percentage of trips less than 100 meter is 22.4%, that of trips less than 500 meter is 77.6% and the average trip length is 370 meter. As for trip time, the percentage of trips less than 1 minute is 32.5% and average trip time is 3.3 minuets.

The percentage of drivers who choose the nearest sojourn as the next visiting place is 74.4 %. Regarding the other 25.4 % of sojourns, Fig.3 shows the accumulation of the difference of distance between the nearest sojourn and the practically chosen sojourn, and Fig.4 shows the accumulation of the ratio between the nearest sojourn and the practically chosen sojourn by the driver. According to these figures, the gradient changes at about 80 percentile point in both figures, which correspond to 2.0 in the case of the ratio, and 200 meter in the case of the difference. Also Fig. 5 shows that 68 % of sojourns satisfies the region less than 2.0 in the case of the ratio and 200 meter in the case of the difference. Therefore it can be said that the distance is the most important factor to choose the next visiting place.

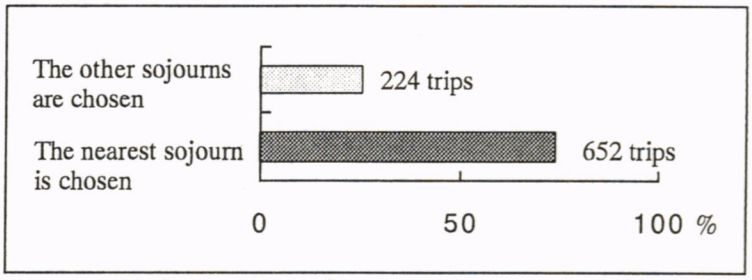


Fig.2 Percentage of the nearest sojourn chosen

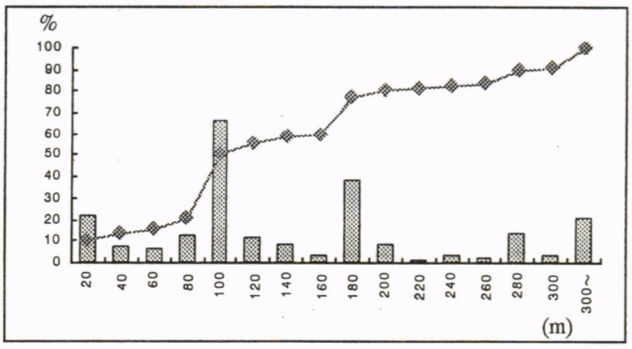


Fig.3 Accumulation of difference between the nearest and practically chosen sojourn

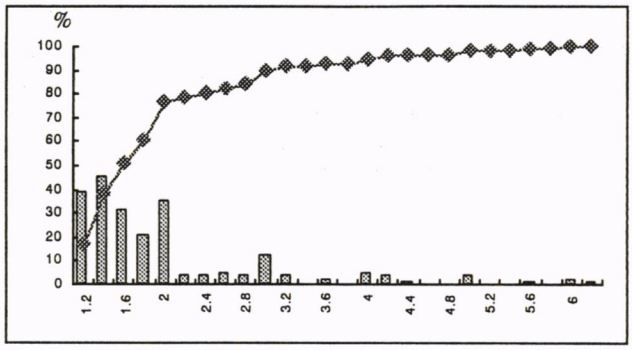


Fig.4 Accumulation of ratio between the nearest and practically chosen sojourn

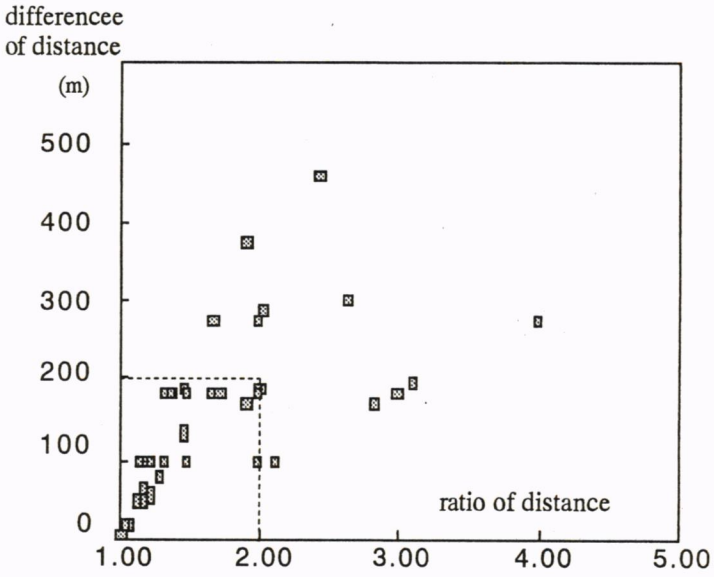


Fig.5 Relation between the difference and ratio of distance

3.2 Influence of Street Characteristics

Here, firstly this study divided sojourns into two groups. When the practically chosen sojourn is the nearest one, this sojourn belongs to group 1, and if that is not the nearest one, this sojourn belongs to group 2. Secondly, streets are ranked by two levels, that is, rank 1 means arterial streets, that is, Mido-suji Street, Sakai-suji Street, Matsuyamachi-suji Street, Chuo-odori Street and Nagahori-Street shown in Fig.1, and rank 2 means the other streets.

In order to find out the influence of the characteristics of streets, the following procedure was adopted. In the case of sojourns which belong to group 1, the sojourns are compared with all alternatives. On the other hand, in the case of sojourns which belong to group 2, two kinds of comparison were done, that is, the comparison between the nearest sojourn and the practical chosen sojourn (case 1), and the comparison between the nearest sojourn and all sojourns which were not chosen (case 2).

The detailed procedure of comparison is as follows. Regarding street width, when a length of a street of rank 1 increases comparing with that of the nearest sojourn, and a length of a street

of rank 2 decreases comparing with that of the nearest sojourn, rank 1 obtains one point. Also, when a length of a street of rank 2 increases comparing with that of the nearest sojourn, and a length of a street of rank 1 decreases comparing with that of the nearest sojourn, rank 2 obtains one point. When rank 1 or rank 2 increases but the other does not change, rank 1 and rank 2 do not obtain any point. If both of rank 1 and rank 2 do not obtain any point, the dummy item obtains one point. Regarding number of right and left turn and going straight, when one or two items increase among one of the three values, and the other one or two values decrease, all items which increase obtain one point. If values of all items are zero, the dummy item obtains one point.

The result of the above consideration is shown in Fig.6 and Fig.7. In the case of group 2 (case 1), percentages of rank 1 and rank 2 are higher than those in group 1, but the value of the rank 1, and that of rank 2 is almost the same, so the street width does not play an important role to choose a destination rather than the nearest one. Fig.7 shows that the number of going straight in group 2 (case 1) is larger than that in group 1 by more than 15%, and this value is larger than that in right and left turn. Accordingly, a sojourn which can reach without any turn is apt to be chosen even if the distance is a little longer. In group 1, the value in every item is small. It may be said that since there does not exist any efficient factor, the nearest sojourn is chosen. According to the analysis described above, distance from the present sojourn to the next sojourn, number of right and left turn are the effective factors when the next visiting place is chosen.

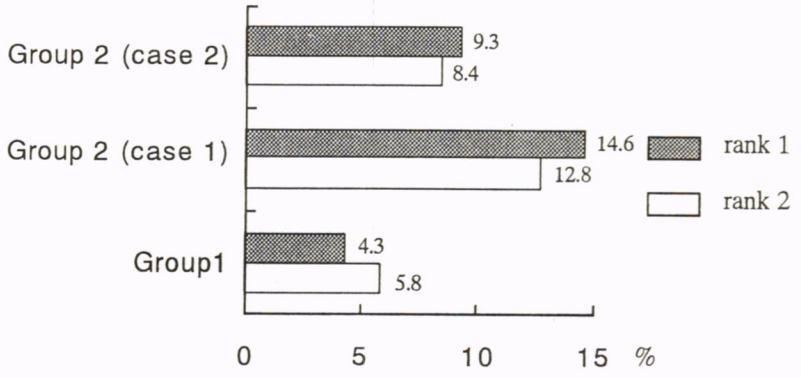


Fig.6 Influence of street width

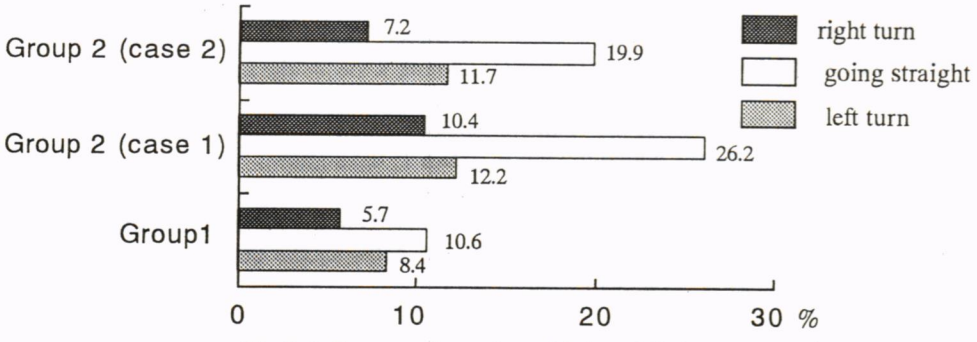


Fig.7 Influence of number of left and right turns

4. MODEL OF DELIVERY TRUCK'S MOVEMENT

As described before, there are some persons who regard as of major importance the overall route optimality, on the other hand, other persons might attach importance to the relation between the present sojourn and the alternative next sojourn. Here, since the subjects were the persons who are engaged in delivery and pick-up activities every day in the study area and the office workers who are in charge of making the schedule of the delivery and pick-up activities, the traffic condition of streets in the area has been considered. This study assumes that drivers consider the overall route optimality and the local route optimality, but they attach importance to the relation between the present and the alternative next sojourn, because it is very difficult to find out the overall optimal route. Based on the above analysis, a simulation model of delivery truck's movement in a commercial area is developed by two steps shown as follows.

4.1 Classification of Visiting Places

At every sojourn, the nearest visiting places are classified as a following way.

Step 1 : When the nearest sojourn is next to the present sojourn, the nearest sojourn is classified as type A.

Step 2 : Calculation of the percentage of number of going straight at every intersection for all trips to the unvisited sojourns.

Step 3 : If the percentage of the nearest sojourn in the step 2 is the largest, the sojourn is classified as type B, and if the percentages are the same, the sojourn is classified as type C. Also, others are classified as type D.

Step 4 : As to the trips in which the nearest sojourn are not chosen, the sojourn practically chosen is classified as the same way as described above. Here, the comparison is done between the practically chosen sojourns and all sojourns including the nearest one.

The result is shown in Table 1 and Table 2. From Table 1, it is clear that when a type of the nearest sojourn is A, B, or C, that is, the nearest sojourn is located next to the present sojourn, the rate of going straight is the largest, or all rates are the same, type A, B or C is chosen more frequently than type D. From Table 2, when the nearest sojourn is not chosen, it is clear which sojourn is chosen. In the case of type D in which the rate of the nearest sojourn is not high, B type sojourn is apt to be chosen, when the nearest sojourn was not chosen.

Table 1 Number of nodes by type

type of the nearest node	A	B	C	D
number of trips in which the nearest node is chosen	121 (88.3)	154 (75.1)	36 (87.8)	140 (60.3)
number of trips in which the nearest node is not chosen	16 (11.7)	51 (22.9)	5 (12.2)	92 (39.7)
total	137 (100)	205 (100)	41 (100)	232 (100)

( ) : percentage of column total

Table 2 Relation between the nearest node and the node chosen practically

		type of the nearest node			
		A	B	C	D
number of trips by type when the nearest node was not chosen	A	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)
	B	5 (31.3)	8 (15.7)	0 (0.0)	48 (52.2)
	C	5 (31.3)	0 (0.0)	5 (100)	0 (0.0)
	D	5 (31.3)	43 (84.3)	0 (0.0)	44 (47.8)
	total	16 (100)	51 (100)	5 (100)	92 (100)

( ) : percentage of column total

4.2 Development of the Model

The simulation model is developed as shown in Fig.8.

Step 1 : Distance from the present sojourn P to all other sojourns, and number of going straight and turning right and left at that time are calculated.

Step 2 : At the present sojourn P, the existence of alternatives is checked, which is located within double distance to the nearest sojourn, and within 200 meter added to the distance to the nearest sojourn. If there is not such a sojourn, the nearest sojourn is chosen as the next visiting place, and after the present sojourn P is replaced by the sojourn, we go back to step 1. If there is such a sojourn, we go to step 3.

Step 3 : Type of the nearest sojourn and all other sojourns are examined.

Step 4 : Based on Table 1 and 2, the next visiting place is determined.

When the nearest sojourn belongs to type A and C, the next visiting place is the nearest one, because in most trips the nearest sojourn has been chosen as shown in Table 1.

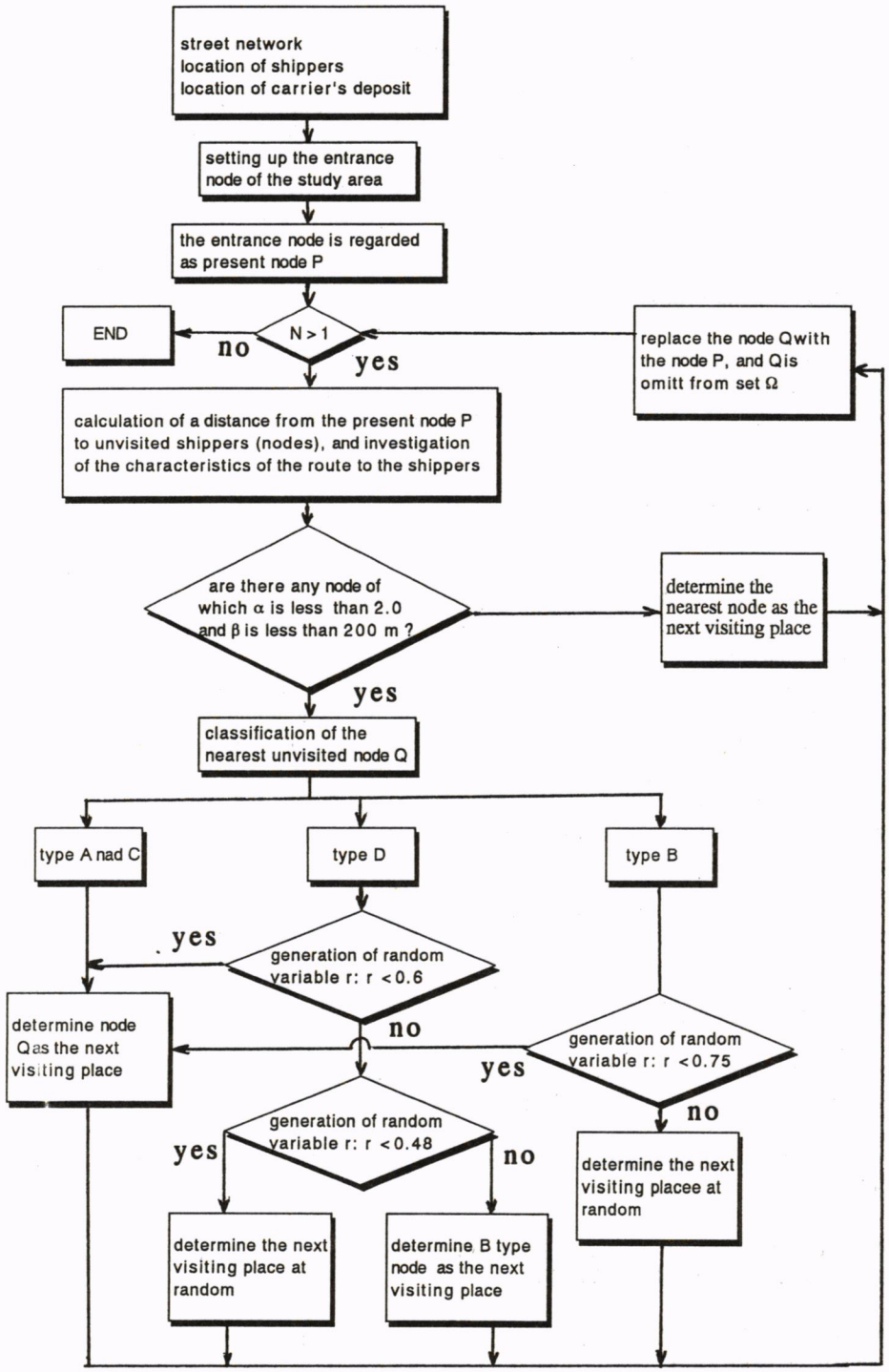
When the nearest sojourn belongs to type D, the probability of the nearest sojourn being chosen is 60 %, and as to others, 52 % of trips are determined to choose the sojourns which belong to type B, and the other 48 % are determined at random.

When the nearest sojourn belongs to type B, the probability of the nearest sojourn being chosen is 75 % and the other 25 % are determined at random.

Step 5 : The present sojourn P is replaced by the sojourn determined at step 4, and the consideration described above continues until all sojourns have been visited.

4.3 Reproducibility of the Model

Using the model, we estimate the behavior of eight subjects, that is, six of delivery truck's drivers and two office workers who are in charge of making a schedule of delivery and pickup activities. Table 3 shows that the rate of reproducibility is 70.1 %, that is to say, as to 614 sojourns out of 876 sojourns, the same sojourns were chosen in an actual condition and estimation .



N : number of unvisiteed shippers

Ω : set of unvisited shippers

α : ratio of a distance to the nearest sojourn and that to the practically chosen sojourn

β : difference betwen a distance to the nearest sojourn and that to the practically chosen sojourn

Fig. 8 Flow chart of the model

Table 3 Reproducibility and Adaptability of the model

	total sojourns	no. of agreement
Reproducibility	876	614 (70.1 %)
Aduptability	268	164 (61.2 %)

4.4 Adaptability of the Model

This study obtained detailed data of delivery truck's behavior which were recorded by surveyors who had a seat beside the drivers. Therefore, we can examine the validity of the simulation model, using the data. Table 3 shows that the rate of adaptability is 61.2 %.

5. GENERAL CONCLUSION

The general conclusions of this study is as follows:

(1)This study has made clear the mechanism how the delivery men decide the cycles or visiting sequences. Then the delivery truck's route choice behavior from one sojourn to the next has been analyzed.

(2)Based on the above analysis, a simulation model of the delivery truck's movement has been developed. The reproducibility and the adaptability of the model is not so high, but it does not matter in practical application to estimate traffic volume of delivery trucks in each street in order to improve the traffic condition in commercial areas. It is necessary to make a model on pick-up truck's movement and finally to make a generalized model which can explain delivery and pick-up truck's movement in a central business district.

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