STUDY ON TRIP GENERATION AND ATTRACTION MODELS OF TRAVEL DEMAND FORECASTING BASED ON THE STRUCTURE OF TIME DISTRIBUTION

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Abstract: This study aims to make a time distribution of trip generations in urban area clear, and a model for the time distribution is built up, if a distribution of travel demand is a random phenomenon with a few peaks. First, the personal attributes of persons are categorized under a consideration of the characteristics of travel demand and the social structural change in the future: the increase of aged persons, the advancement of females' social participation, etc. It is seen that the time distribution of trip demand in each group of persons is steady through years, and that the changing structure of trip demand is presented by the time distribution pattern of trips. Next, relations between zones and the departure time distributions are examined. In addition, the pattern of the departure time distribution on one day is assumed that there is the distribution in each peak from the analysis by the order of trips.

Key Words: Time distribution of travel demand, Trip generation models, Person trip survey.

1. INTRODUCTION

The traditional 4 steps approach has been applied essentially to forecast the daily travel demand, using the Person Trip data. In addition, this model is still used in many cases for analyzing and forecasting urban travel demand in the planning of urban transportation. However, the consideration of the time distribution of travel demand is required for a travel demand management or a planning of traffic facilities, because the traffic jams happen in such rush hours for the commuting in the morning and evening. Traffic congestion may be also seen at the daytime in busy urban central districts. In other words, it is necessary to construct a travel demand model based on the time distribution of trips, in addition to the consideration of their spatial distribution. Future trends of the increase of aged persons, the advancement of social participation of women, the changes of working styles, etc. are guessed. And these facts will largely influence the structure of travel demand in the urban area. Therefore, it is seen that the structure of time distribution of travel demands must be analyzed in the relation between the social and economic conditions.

To allot the total trips in a day to the travel demand on every time zone, a reliable method is not established yet. Therefore, the time distributions of travel demand in a day are firstly analyzed in this study, using data of the person trip surveys in 1972, 1983 and 1993, in Northern Kyushu Area of Japan. These surveys are briefly called PT72, PT83 and PT93 hereafter. Then, the construction of the time distribution model for trip generations and attractions is attempted according to the classification of trip purposes and personal attributes.

2. CHARACTERISTICS OF FUKUOKA URBAN AREA

The difference in travel behaviors appears apparently depending on the spatial and social characteristics of the city. In addition, because the region features become tacitly an assumption when analyzing travel demand, it is necessary to know the features of urban area. Therefore, based on the map and the data of PT survey, the geographical features of Fukuoka urban area are outlined here, preceding the discussion of subjects.

2.1. Geographical features

Fukuoka urban area is the largest city area in the Japanese west-southern part and the hub-city in the Kyushu area. A geographical structure of the area is to have mountains by which travels to the southern and eastern areas are limited to some extent. Therefore, the basic structure of the travel flows of Y-type network is formed, in which Route 202 extends from the center of the city to the west and Route 3 joins the south and the north districts to the central urban area. Route 263 supplements the travel flow from the southwest to the center, and Route 201 links the central districts and the east as a complement of Route 3. In the east boundary of urban area, an expressway goes through. Route 385 leads locally traffic from the center of city to the south. Railways exist mostly along main roads above-mentioned.

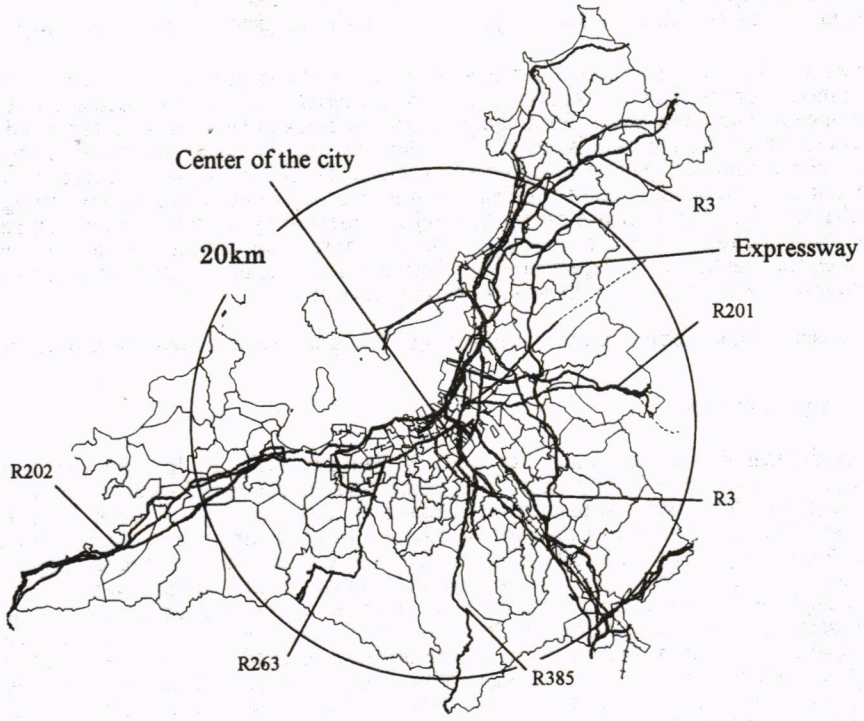


Figure 1. Map of Fukuoka urban area and the skeleton of road network

2.2. Characteristics of travel demand

We can see that bed towns were expanded into the suburb districts around main routes and the railways, when the urban structure is examined on the map and the PT data. Therefore, the main traffic flows are shown among the central urban district and bed towns. Further suburbs extend around the bed-town, and border districts of the Fukuoka urban area are the agricultural lands, where the traffic volume is somewhat few. Many houses spread in districts surrounding the city core and along Route 3, according to PT72 data. Housings are also

spreading along Route 202 year by year. Because of such spreading of housings and the fact that the urban area faces directly the Hakata bay, it can be said that the Fukuoka urban area has a fan type of spatial structure and a Y type of skeleton. It is natural that the distribution of travel demand depends on these geographical characteristics of urban area. Figure 2 shows the spider network chart of travel demand in Fukuoka urban area.

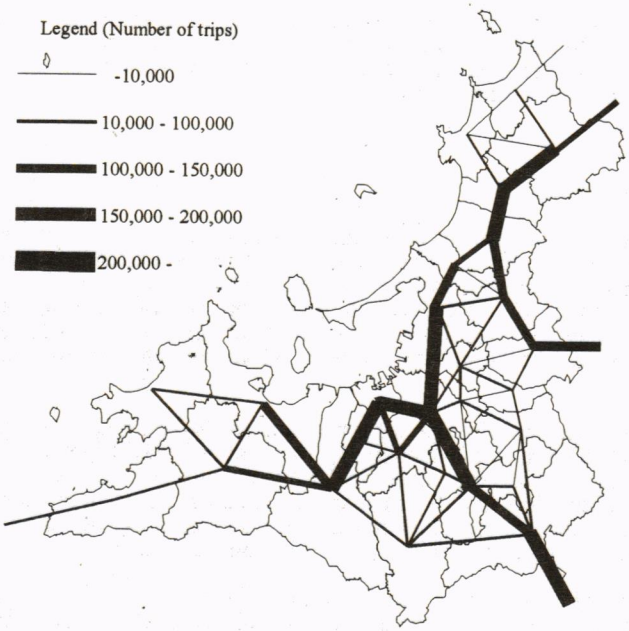


Figure 2. Spider network of travel demand in Fukuoka urban area

2.3. Population of Fukuoka urban area

The population in Fukuoka urban area is shown in Table 1. The population has rapidly increased from the 1960s to the early 1970s, which was the period of high economic growth, and from the latter half of 1980s, the increasing rate of population has gradually been down. It can be said that the population doubled in the past 30 years, in addition, social economic situations changed, too. For instance, increasing rates for female workers and the aged population are almost constant. Moreover, these situations of increase will continue for a while.

Table 1. Population of Fukuoka urban area

	Population					
	1970	1975	1980	1985	1990	1995
Fukuoka urban area	1,280,452	1,515,369	1,705,257	1,847,232	1,988,460	2,117,856
	Increasing rate	0.16	0.11	0.08	0.07	0.06
Male workers	376,995	418,944	474,278	502,507	550,580	604,028
	Increasing rate	0.10	0.12	0.06	0.09	0.09
Female workers	236,913	254,929	284,679	319,185	369,167	419,282
	Increasing rate	0.07	0.10	0.11	0.14	0.12
65 years and over		98,518	124,264	152,128	191,015	242,812
	Increasing rate		0.21	0.18	0.20	0.21

3. CLASSIFICATION OF TRIP PURPOSES AND PERSONAL ATTRIBUTES

Characteristics of travel behavior are different among personal attributes. Therefore, personal attributes must be grouped based on the similarity of travel behaviors. At that case, factors, which influence the trip generations at peak hours, should be investigated in particular. In other words, it aims to exactly analyze the complicated time distribution by the use of these factors.

First, the classification of trip purpose is carried out, using the time distribution of travel demand. Next, based on the similarity of time distribution of travel demand in each purpose, personal attributes are classified. In addition, the time distributions of the travel demand in each group are examined. Features of the time distribution of trip generations in each zone are examined, too.

3.1. Setting of time zones

To understand the characteristics of peak and off-peak of time distribution for trip generations in every purpose, setting of time zones in the time distribution of trips is important. Although the short time zone is required to analyze the detailed fluctuation of travel demand, there is the case that characteristics of time distribution for trip generations can hardly understand. Because understanding of travel time is fuzzy, most of persons are apt to give an answer of time that is easy to judge at the survey. Therefore, an appropriate time zone must be set for the study.

In a questionnaire of person trip, the departure time and arrival time of a trip are filled out in unit of a minute from 3 a.m. in the midnight to 3 a.m. of next day. From a result of survey, it is clear that a person recognizes the travel time at five minutes steps as a minimum, except for a part of fixed travel behaviors in a day such as a commuting trip or an attending-to-school trip. Moreover, the recognition of the travel time in a trip is guessed as every 30 minute because the cycle of the travel time in one trip is about every 30 minutes step.

As another method of evaluation, a class interval is checked by the formula of Sturges as the following equation. If the number of data is n, the following value k is adopted as number of time zones.

$$k = 1 + \frac{\log_{10} n}{\log_{10} 2} \tag{1}$$

A distribution of trips is decomposed into two parts by the off-peak travel demand, because each trip purpose has peaks of travel demand in the afternoon and the morning. If a number k is obtained from the number of data of each distribution, the number $2 \times k$ becomes about 40 in a trip purpose.

Therefore, an appropriate time zone is about 30 minutes in which 24 hours are divided into about 40. A time zone is established at every 30 minutes as 3:00-3:29 and 3:30-3:59, etc. for this study.

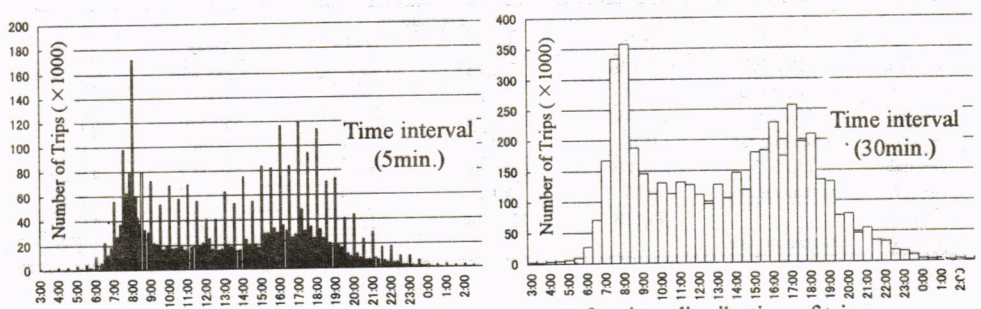


Figure 3. Comparison of two time zone type for time distribution of trips

3.2. Time distribution of trip generations in each trip purpose

Though going-home trips are put together usually as a group of trip purposes, the subdivisions of going-home trips might be different each other at a shape of time distribution. Therefore, trip purposes are classified again by the use of cluster analysis on the time distribution of trip generations. As a result, trip purposes are classified into 16 groups as shown in Table 2. As subdivisions of trip purpose for business are different in the PT72, PT83 and PT93 surveys, business purposes are summarized into two purposes, No.3 (business) and No.5 (other business), according to the cluster analysis of time distribution of trips.

Table 2. Classification of trip purposes and the rate of trips in each purpose

Purpose code	Converted trip purposes	PT72	(%)	PT83	(%)	PT93	(%)
		16 purposes	Rate	18 purposes	Rate	16 purposes	Rate
1	Commuting	Go for work	11.5	Go for work	13.3	Go for work	15.4
2	Attending to school	Attend to school	9.0	Attend to school	10.1	Attend to school	9.2
3	Business	Goods delivery and stocking	14.4	Goods delivery	7.5	Goods delivery	8.4
				Bring document			
		Meeting		Meeting		Meeting	
		Back to office		Back to office		Back to office	
4	Go for repairing	Go for repairing	1.8	Go for repairing	1.6	Go for repairing	2.0
5	Other business	Other business	0.1	Investigation	6.2	Other business	4.8
				Other business			
6	Go for agriculture	Agriculture	1.4	Go for agriculture	0.7	Go for agriculture	0.4
7	Go shopping	Go shopping	9.5	Go shopping	7.7	Go shopping	7.2
8	Recreation	Recreation	5.2	Recreation	4.7	Recreation	4.7
9	Go for other trip	Back to school	8.4	Back to school	9.6	Back to school	9.1
		Go for other private trip		Go for other private trip		Go for other private trip	
10	Back from commuting	Back from work	9.7	Back from work	11.2	Back from work	13.5
11	Back from attending	Back from school	8.4	Back from school	9.5	Back from school	8.7
12	Business (Back)	(Going home)	2.7	(Back from other trip)	1.1	(Back from other trip)	1.5
13	Agriculture (Back)	(Agriculture)	1.2	Back from agriculture	0.5	Back from agriculture	0.3
14	Shopping (Back)	Going home	8.3	Back from other trip	6.6	Back from other trip	5.9
15	Recreation (Back)		3.1		3.1		2.9
16	Other trip (Back)		5.0		6.4		6.1

Time distributions of trip generations for each trip purposes are shown in Figure 4. In every age, correlation coefficients are about 0.95, except for purposes of No.12 (Returning home from business). About purposes No.12, time distributions of trips are different among surveyed years of three times. The ratio data is the main cause of the difference. When the PT83 data are compared with PT93, PT72, it seems that a peak shifts at night. However, a peak time can be considered the same as 3 periods by the quantitative data. Moreover, there is the shrewd peak in PT72 data for the purpose No.1 and the purpose No.10. This is the influence of the flextime system introduction. However, there is no big difference as a departure probability on a day. In

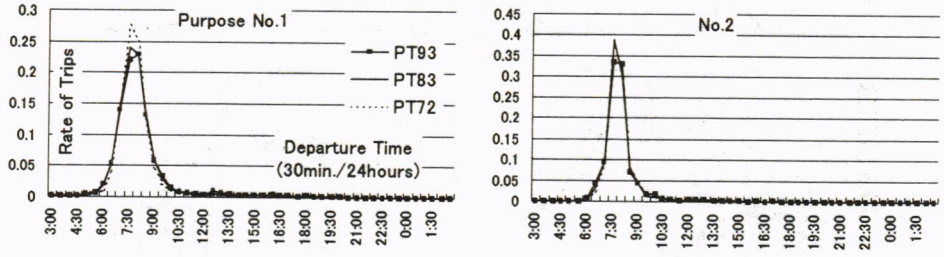


Figure 4. Time distributions of each trip purpose for time series

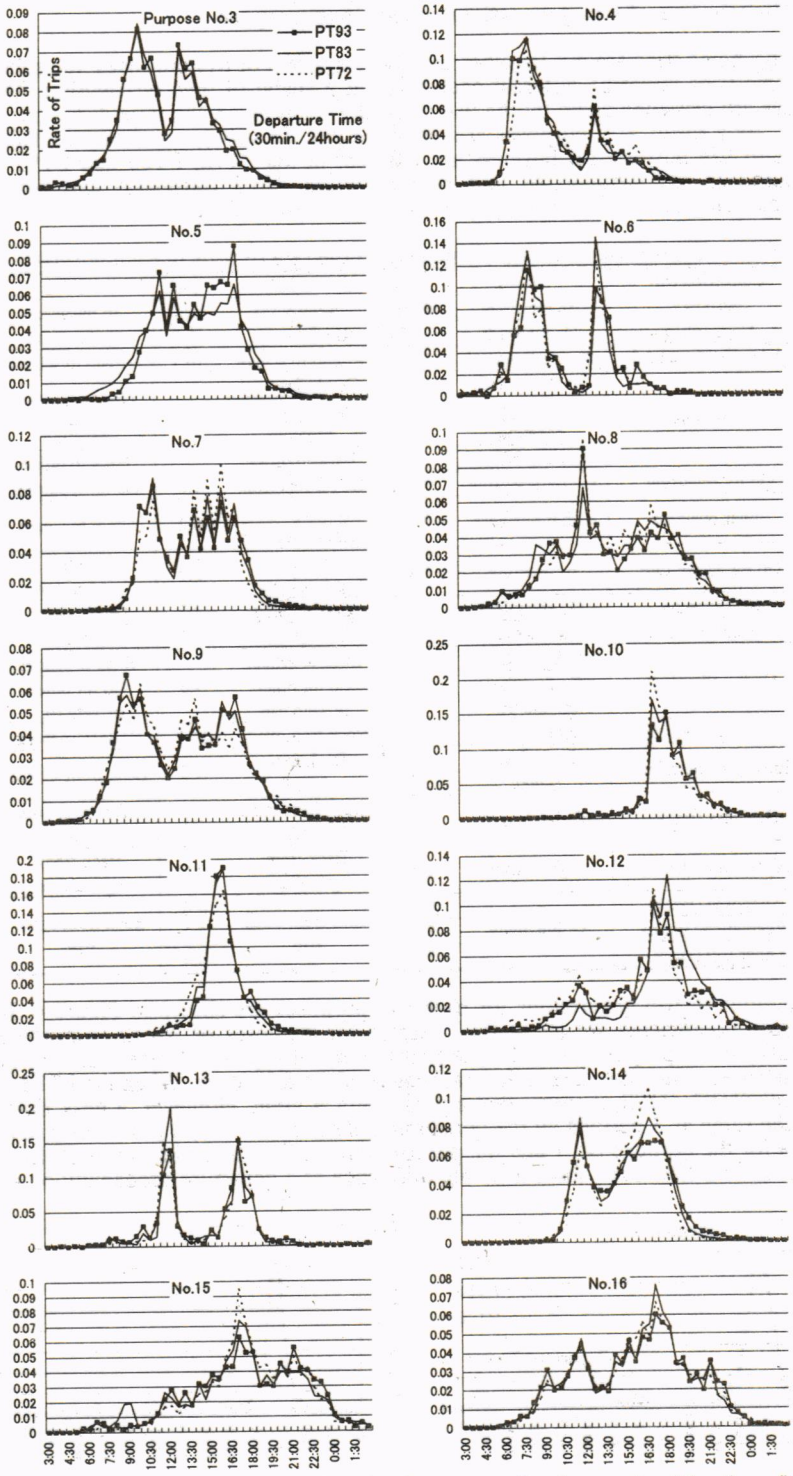


Figure 4. Time distributions of each trip purpose for time series (Continued)

addition, the time distribution of the purpose No.14 (Going home (shopping)) for PT72 is different from the other distribution because the data structure is different from the other data.

3.3. Time distribution of trip generations in each personal attribute

Difference of time distributions for trip generations in each purpose among personal attributes is examined. Personal attributes are sex, age and occupation in the PT data. Personal attributes are split originally into 2 categories in sex, into 17 categories in age, and into 14 categories in occupation as in Table 3.

Table 3. Original categories of personal attributes

Sex	2 groups	Male, Female
Age	17groups	Divided into 5 years
Occupation	14groups	Agricultural workers, Mining workers, Production process workers, Sales workers, Service workers, Workers in transport occupation, Security workers, Clerical workers, Technical workers, Managers and officials, Student, Child, Wife and Unemployed

To get groups on personal attributes, cluster analysis based on the correlation coefficients among every time distribution for the personal attribute is applied. The similarity of time distributions among pair of various categories of attributes is also investigated by Kolmogorov-Smirnov test. On the other hand, the increase of aged persons, the social participation of women, the change of working styles etc. must be considered in the classification of personal attributes. Under these considerations, personal attributes are divided into some groups as shown in Table 4, and details of groups in each personal attribute are expressed as follows:

Table 4. Classification of personal attributes

Sex	2 groups	1:Male, 2:Female
Age	3 groups	1:Young (-14), 2:Middle (15-64), 3:Aged (65-)
Occupation	3 groups	1:Worker, 2:Student (and Child), 3:Unemployed (and Wife)

(a) Sex. Though the correlation coefficient between male and female is large, the significant difference by KS test is seen only in the purpose No.10 (Returning home from work). On the other hand, as it can be guessed that women travel behavior will change more in the future by social participation of women. From these viewpoints, sex keeps 2 groups: male and female. If it is compared with a man, the woman's characteristics are the acting avoiding a night.

(b) Age. Because of the analysis, the age is fundamentally classified into 3 groups of young persons (14 years old and under), middle age persons (15-64 years old) and aged persons (65 years old and over). However, there is a special case in the classification of ages. That is, in private purpose of trips, the 50 years old and over is included in the aged groups. The distribution pattern of the aged person is comparatively similar to the middle age. However, if it is compared with the middle age, the aged person acts in daytime avoiding the peak time and leaves in the morning.

(c) Occupation. From results of analysis, occupations are classified into 3 groups: workers, students and the unemployed. Students include children and housewives are included into the unemployed. Trips by workers have already been classified into 4 groups in trip purposes. In addition, the difference of time distributions among occupations in each trip purpose cannot be seen. Therefore, workers' group does not need to be subdivided. However, as for the agricultural workers, business purpose is classified into the worker group, and private purpose is classified into the unemployed group, from the viewpoint of the similarity of time distribution.

For the above classification, a resemblance between each attribute of the purpose 2,6,11,13 (attending to school and agriculture (go and back)) is especially high because these attributes difference between the sexes or between the ages.

For an example, the ratio of each traveler's attribute in total trip demand of a trip purpose in PT93 is shown in Table 5. In sex, most of trips for business account for males, while most of trips for going shopping are done by females. It is easily seen that occupations are limited to the worker group or student group in every trip purpose except for private purposes. In age groups, the young group does not exist in business purposes, because 15 years old and under is the compulsory education period. Trips of the aged persons for the purpose No.2 (attending to school) and No 11 (Back from school) can be assumed as 0 for very small ratio, though a small amount of trips are observed. Rates of 22 groups in 48 groups in occupations are 0 or almost 0. Rates of 19 groups in 48 groups in age are 0 or almost 0, too.

Difference of time distributions of trips in proposed groups on three times of PT surveys was examined by the use of KS-test. As a result, all distributions in proposed groups among the three times can be assumed to be almost same at significant level of 5% except for the business purpose, although the population in Fukuoka urban area has doubled during three times of PT survey. Moreover, the correlation coefficients of each personal attribute for each purpose are more than 0.95 except for a part of the aged person that it is short of the number of data.

Table 5. Ratio of trips of each personal attribute for each purpose

Purpose No.	Sex		Occupation			Age		
	No.1	No.2	No.1	No.2	No.3	No.1	No.2	No.3
	Male	Female	Worker	Student	Unemployed	14 and under	14 - 64	65 and over
1	0.597	0.403	1	0	0	0	0.975	0.025
2	0.535	0.465	0	1	0	0.592	0.408	0
3	0.830	0.170	1	0	0	0	0.973	0.027
4	0.940	0.060	1	0	0	0	0.975	0.025
5	0.850	0.150	1	0	0	0	0.983	0.017
6	0.601	0.399	1	0	0	0	0.697	0.303
7	0.179	0.821	0.286	0.088	0.626	0.034	0.834	0.132
8	0.511	0.489	0.456	0.192	0.353	0.098	0.788	0.115
9	0.311	0.689	0.254	0.212	0.534	0.125	0.732	0.142
10	0.615	0.385	1	0	0	0	0.971	0.029
11	0.538	0.462	0	1	0	0.615	0.385	0
12	0.784	0.216	1	0	0	0	0.932	0.068
13	0.626	0.374	1	0	0	0	0.723	0.277
14	0.161	0.839	0.260	0.087	0.653	0.036	0.825	0.139
15	0.494	0.506	0.389	0.208	0.404	0.115	0.736	0.149
16	0.308	0.692	0.208	0.236	0.555	0.149	0.694	0.158

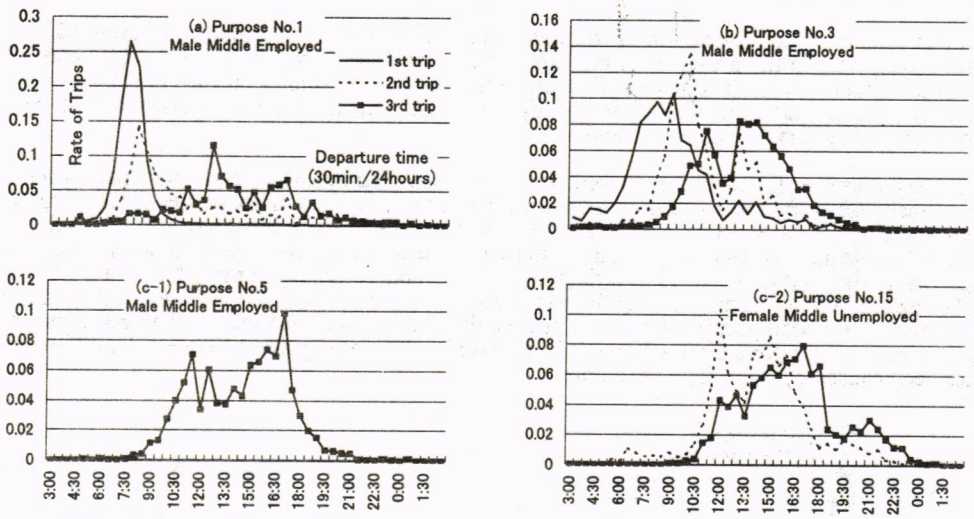
(For details of the trip purpose Nos., see Table 2.)

3.4 Generating time distributions in the order of trips

In the previous chapter, each group subdivided by personal attributes will be able to say that it has the almost same distribution in generating trips. However, their distributions can't be represented by a theoretical function simply from a viewpoint of the probability, because they have a complex form. Therefore, the generating time distributions in every purpose of personal attributes on a day should be analyzed in detail on an additional viewpoint.

The generating order of trips can be seen as a factor that influences on their departure time. Therefore, the time distributions of generating trips are divided by the order of trips. Every pattern of the time distributions based on the order of trips is shown in Figure 5, in accordance with which trips are classified into the groups of first trips, second trips, and third trips or over. In these cases, the first trip doesn't exist in the purpose of going home (purpose Nos.10, ・・・,16). In addition, the time distribution of trips in aged persons isn't the subject of the analysis, because there are few trips on them and the difference in the distribution cannot be found clearly. The characteristics on each time distribution of generating trips can be found as follows.

(a) Distribution with single peak: These types of distributions are seen in first trips with purpose Nos. 1, 2, 10, 11, 6 and 13, and it is also found in all of distributions on trips generating in the groups of young persons and students. Going home trips of above purpose Nos. are presented by a distribution with single peak, too.



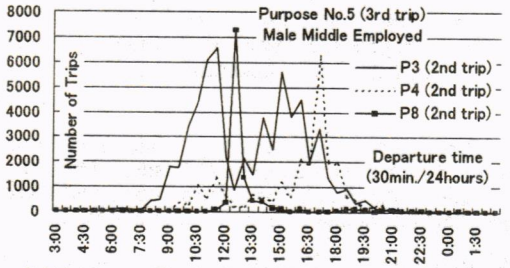
(For details of trip purpose Nos., see Table 2.)

Figure 5. Patterns of time distribution based on the order of trips

(b) Distribution with twin peak: The second trips or over of the purpose Nos.3, 4, 7, 14 and so on are shown by the distribution with twin peak. Almost these distributions have peaks in both of morning and afternoon.

(c) Other type of distribution: In purposes of Nos.5, 8 and 15, distributions have a weak peak in the noon in addition to both peaks in morning and afternoon. This type of distribution may be seen to be same to the twin peak type in the classification of distributions. In addition, there are some distributions in the night time zones as shown in Fig. 5 (c-2), or in the early morning time zones. However, they are ignored, because the number of trips is less than 100 and we can't distinguish them from accidental errors at the investigation. (For the details of the trip purpose Nos., see Table 2.)

In addition, the departure time distribution of each trip order is separated by preceding trip purpose. Figure 6 shows the example of the time distribution by the preceding trip for each trip order. This example is the time distribution by preceding trips for third trip of the trip purpose. The time distribution is separated in every peak in comparison with Figure 5(c-1) clearly. For other distributions, the distribution is separated in every peak time in the same to the example.



P: Trip purpose (For details, see Table 2.)

Figure 6. Time distributions of the trip purpose by the preceding trip purposes

As a result, the following facts were found by the above considerations.

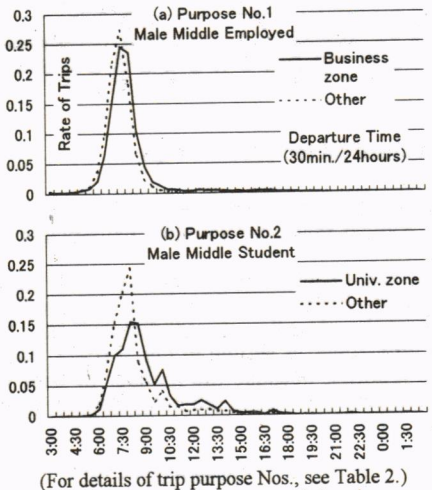
(a) There are some time distributions of generating trips on a day; the distribution with single peak, the one with twin peak and so on. Although the explanation factor of peaks in the morning and afternoon for distribution with two peaks cannot be found clearly, most of other distributions are separated by personal distribution in each peak. Therefore, it is assumed that it is composed of two distributions in the morning and the afternoon.

(b) The peak time that can happen on a day is several times in the morning, in the afternoon, at noon, and at night. The time distribution is formed corresponding to the purpose, the personal attributes. On that occasion, the departure time becomes the probability distribution restricted by the various conditions such as the arrival time or the schedule of transportation, staying time at the facilities and so on.

3.5. Time distribution patterns of trip generations in each zone

In this chapter, time distribution of trip generations in each zone is examined. Supposing that travel behaviors in the group are same, we examine whether there would be the difference of time distributions in each zone or not. Because the number of samples on trips in C zones (197 zones) is not enough, time distribution of trips in each B zone (27 zones in units of award, city, town and village) is the subject of study.

In every purpose, the similarity among zones on time distribution in each personal attribute was analyzed, using the correlation analysis. As a result, the time distributions of the purpose No.1 (Going for work, Male, Middle age, Worker) and the purpose No.2 (Attending to school, Male, Middle age (14-64), Student) are different as shown in Figure 7, depending on zones. As for the purposes No.6, No.13 (Agriculture, Going and returning home), No.8, and No.15 (Recreation, Going and returning home), time distributions are not different significantly among the proposed groups of zones. The time distribution in each zone for the aged persons' group cannot be assumed the same, but it is treated as the same pattern because the difference has been caused by a shortage of samples.



(For details of trip purpose Nos., see Table 2.)

Figure 7. Patterns of the time distribution by generating zones

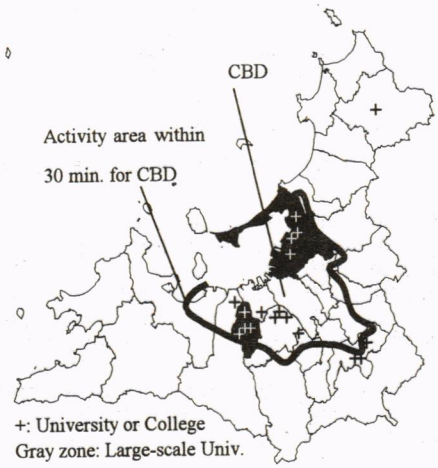


Figure 8. Activity area within 30 min for CBD and university's area

(a) Purpose No.1 (Commuting, Male, Middle age, Worker). The peak of travel demand in zones, which are in the Central Business District (CBD) within about 30 minutes at travel time, is smaller than the one of suburb zones, and there is wide range in time zone. The rate of trips that start late is higher than in other zones.

(b) Purpose No.2 (Attending to school, Male, Middle age, Student). In Fukuoka region, there are many universities and colleges more than 20. However, the difference of time distributions is shown in two zones with a large-scale university as shown in Figure 8 (gray zones). Time distributions for attending-to-school distribute over considerable wide time zones, in addition, the rate of trips starting time is late is higher than other zones.

After all, in both trip purposes of No.1 and No.2, it is understood that trips may be generated at late time because of the short distance from the generation zone to the destination zone. In addition, time distributions are difference in attracting force of zones such as the large-scale universities or the CBD.

4. MODELING OF TIME DISTRIBUTION FOR GENERATION TRIPS

The model of the time distribution may be constructed based on trip purposes and personal

attributes proposed in this study. In addition, it is assumed that the time distribution is composed some probability distributions.

The precise model of total trip generations on a day has been constructed. Therefore, the composition ratio of the personal attribute is already given, too. In this study, given that these values are already calculated, the model is constructed.

4.1. Concept of the modeling

The focus of this section is how to model the time distribution. If the number of trips of purpose j (for details of this classification, see the Table 2.) at a time zone t in the zone m is presented by $F_m^j(t)$, it is given by the following expression:

$$F_m^j(t) = U_m^j \times \sum_{k=1}^{n} \left(C_m^{jk} f_m^{jk}(t) \right) \tag{2}$$

where U_m^j = Travel demand in generating zone m of a day for the trip purpose j,

C_m^{jk} = Rate of trips in generating zone m for the trip purpose j and personal attribute k,

$f_m^{jk}(\cdot)$ = Probability density function of time distribution pattern in generating zone m for the trip purpose j and personal attribute k.

Next, the form of the model is decided. From the previous sections, the modeling of the time distribution is assumed the following as:

(a) The time distribution of personal attributes in every purpose is integrated by the probability distribution on every peak. In this study, time distributions of personal attribute in every purpose are assumed to have 3 peaks in the morning, in the evening and at noon.
(b) The pattern of time distributions by personal attributes in every purpose is stable for the 3 times of PT survey (1972,1983,1993). In other words, the patterns of the time distribution do not change by age. Their changes are expressed on the number of trips.
(c) The patterns of the time distributions in each generating zone are the same except for the time distribution as explained in details below. The zonal characteristics such as the distance between the zones may be introduced in the change of the average and variance in each distribution.

4.2. Difference of time distributions among zonal characteristics

Models of time distributions for the purposes No.1 (Commuting, Male, Middle, Employed) and No.2 (Attending to school, Male, Middle, Student) are built based on results of the differences of time distributions on zones. As described in the previous chapter, the difference of the time distributions by trip generations is affected by the CBD, the large-scale university and so on. In this study, the model for time distributions in each zone characteristics is constructed using peculiar $f_m^{jk}(\cdot)$ to the zone because it is considered that the place of the CBD or the university is immovable, except for the their move by large-scale developments. However, someday, the attracting force or connection of zones may be treated as the variable in the function $f_m^{jk}(\cdot)$.

4.3. Building the model of the departure time distribution

First, there is a quantitative problem of the data. For a group of the aged person, a part of the distribution will be regarded as the abnormal value for a small amount of travel demand. Its distribution is integrated into the one of middle age group, because the distribution pattern is comparatively alike.

The time distribution of trips can be approximated by a beta function with the upper and lower

limits in the definition domain. It is convenient to reproduce traffic demand during a day, and there is reasonable in the reproduction compared with normal distribution. The model is represented as follows when the equation (2) was subdivided by each personal attribute for each peak time:

$$F_m^{jklh}(t) = U_m^j \times \sum_{k=1}\sum_{l=1}\sum_{h=1}\left(C_m^{jklh} \sum_{i=1} a_i^{jklh} f_i^{jklh}(t) \right) \tag{3}$$

where $F_m^{jklh}(t)$ = Travel demand in generating zone m at a time zone t by personal attributes k, l and h in the trip purpose j,

k = Sex (k=1,2),

l = Age (l=1,2,3),

h = Occupation (h=1,2,3) (For details of these groups, see Table 4.),

a_i^{jklh} = Parameter of $f_i^{jklh}(t)$ $(1 = \sum_{i=1} a_i^{jklh})$,

$f_i^{jklh}(t)$ = Pdf. ($\sum_{i=1} a_i^{jklh} f_i^{jklh}(t)$ = Time distribution by personal attributes in the trip purpose j.)

The parameter a_i^{jklh} is the composition rate of the each probability distribution, which is divided by peak time in the time distribution by each personal attribute in each purpose. The estimated parameters are above the parameter a_i^{jklh}, lower and upper limits A and B and the parameters of the beta function α and β. The estimated parameters from the PT93 data are shown in Table 6.

Table 6. Parameters of the generating time distribution model by personal attributes in every purpose

No.	Male (k=1)					Female (k=2)				
PjAlOh-i	a_i	A	B	α	β	a_i	A	B	α	β
P1A2O1-1	0.95	6	14	3.19	2.92	0.96	7	16	2.93	3.30
P1A2O1-2	0.05	19	42	1.05	2.30	0.04	24	41	1.42	3.03
P2A1O2	1	9	12	1.90	1.90					
P2A2O2	1	6	14	2.89	2.26	1	6	14	3.02	2.86
P3A2O1-1	0.51	5	20	3.52	2.15	0.54	5	21	4.04	2.25
P3A2O1-2	0.49	19	48	1.54	6.87	0.46	20	46	1.17	5.09
P4A2O1-1	0.69	7	36	2.69	13.74	0.71	8	41	3.01	18.90
P4A2O1-2	0.31	17	48	2.34	8.68	0.29	19	48	1.03	6.77
P5A2O1-1	0.27	1	20	8.54	1.86	0.25	1	20	8.28	1.51
P5A2O1-2	0.68	19	21	2.51	2.01	0.55	19	48	2.26	8.33
P5A2O1-3	0.06	12	34	6.23	3.11	0.20	18	23	1.44	1.67
P6A2O1-1	0.63	8	22	1.90	5.30					
P6A2O1-2	0.37	20	48	0.96	5.79					
P7A2O1-1	0.35	2	23	4.95	1.75	0.19	2	21	10.24	2.72
P7A2O1-2	0.10	21	27	4.52	5.86	0.11	19	24	2.57	1.62
P7A2O1-3	0.55	24	48	1.97	4.74	0.70	8	34	16.06	3.87
P7A1O2	1	24	41	2.46	6.80					
P7A2O2-1	0.22	1	22	6.34	1.35	0.42	13	26	1.59	0.77
P7A2O2-2	0.78	21	48	1.83	3.90	0.58	26	48	1.04	5.40
P7A2O3-1	0.43	10	20	5.76	4.03	0.49	13	48	3.70	29.34
P7A2O3-2	0.57	18	44	2.51	7.17	0.51	20	34	2.05	3.32
P8A2O1-1	0.27	16	48	2.96	21.99	0.28	1	26	4.83	2.16
P8A2O1-2	0.18	17	20	4.14	2.35	0.12	18	20	1.60	1.49
P8A2O1-3	0.55	28	44	1.58	3.40	0.60	27	44	1.93	3.69
P8A1O2-1	0.16	11	48	2.05	22.39					
P8A1O2-2	0.84	1	30	18.36	2.54					
P8A2O2-1	0.22	1	22	5.18	1.22	0.20	15	22	2.25	1.22
P8A2O2-2	0.78	21	48	2.14	3.97	0.80	21	48	2.37	5.20
P8A2O3-1	0.45	1	18	2.15	1.03	0.49	10	20	2.64	2.12
P8A2O3-2	0.55	18	48	1.04	3.17	0.51	18	48	1.46	4.86
P9A2O1-1	0.30	6	20	2.24	2.88	0.34	8	14	2.10	1.37
P9A2O1-2	0.29	7	26	2.88	1.78	0.21	6	25	2.92	1.21
P9A2O1-3	0.41	24	47	2.03	4.03	0.45	24	36	2.47	2.81
P9A1O2	1	24	48	2.60	11.09					
P9A2O2-1	0.31	1	24	2.30	1.00	0.18	8	20	1.04	1.05
P9A2O2-2	0.69	22	34	3.09	2.23	0.82	1	44	21.50	12.51
P9A2O3-1	0.61	4	21	4.79	3.82	0.53	8	23	3.59	5.15
P9A2O3-2	0.39	19	40	1.20	2.98	0.47	19	48	1.51	5.80

No.	Male (k=1)					Female (k=2)				
PjAlOh-i	a_i	A	B	α	β	a_i	A	B	α	β
P10A2O1	1	28	46	1.48	3.76	1	28	38	1.00	2.23
P11A1O2	1	21	30	3.04	2.30					
P11A2O2-1	0.08	12	22	5.35	2.35	0.07	11	22	6.68	2.32
P11A2O2-2	0.92	24	47	1.41	5.01	0.93	25	48	1.33	6.72
P12A2O1-1	0.16	1	20	3.19	0.98	0.20	1	20	3.43	0.94
P12A2O1-2	0.84	14	48	6.10	6.27	0.80	17	45	3.21	4.03
P13A2O1-1	0.39	16	48	3.76	33.94					
P13A2O1-2	0.61	26	33	2.05	2.17					
P14A2O1-1	0.20	14	24	1.19	0.97	0.11	14	21	2.32	1.59
P14A2O1-2	0.80	19	48	4.83	5.95	0.89	1	36	13.50	3.04
P14A1O2	1	25	34	1.95	2.10					
P14A2O2-1	0.23	8	26	3.18	1.24	0.16	13	25	3.28	1.50
P14A2O2-2	0.77	25	48	1.79	3.28	0.84	25	48	2.06	5.26
P14A2O3-1	0.40	13	48	6.91	39.79	0.36	12	26	9.64	12.41
P14A2O3-2	0.60	21	45	2.08	5.98	0.64	19	34	2.76	2.91
P15A2O1-1	0.17	2	30	3.30	1.04	0.28	13	32	1.93	1.02
P15A2O1-2	0.83	27	46	3.30	2.61	0.72	30	46	3.18	3.44
P15A1O2	1	27	32	2.11	1.62					
P15A2O2-1	0.12	1	27	3.18	0.78	0.51	1	34	7.79	1.22
P15A2O2-2	0.88	26	43	1.55	1.23	0.49	33	48	2.56	4.87
P15A2O3-1	0.35	2	24	1.97	0.85	0.28	15	23	2.97	2.66
P15A2O3-2	0.65	24	47	1.04	1.92	0.72	21	48	1.51	3.91
P16A2O1-1	0.22	3	20	2.79	1.31	0.22	8	22	1.32	1.30
P16A2O1-2	0.78	8	46	6.21	3.53	0.78	20	48	3.35	5.02
P16A1O2	1	26	48	2.12	5.25					
P16A2O2-1	0.30	1	32	1.80	0.63	0.41	20	34	2.45	1.04
P16A2O2-2	0.70	30	44	2.79	2.38	0.59	28	44	9.44	6.53
P16A2O3-1	0.38	13	21	2.41	2.52	0.17	1	15	8.31	2.12
P16A2O3-2	0.24	19	27	2.16	2.09	0.19	1	21	26.91	5.66
P16A2O3-3	0.38	25	48	1.30	3.70	0.64	19	47	2.06	5.18

P: Trip pupose, A: Age, O: Occupation (For details of these classifications, see Table 2. and Table 4.)

a: parameter, A: lower limit, B: upper limit, α, β: parameter

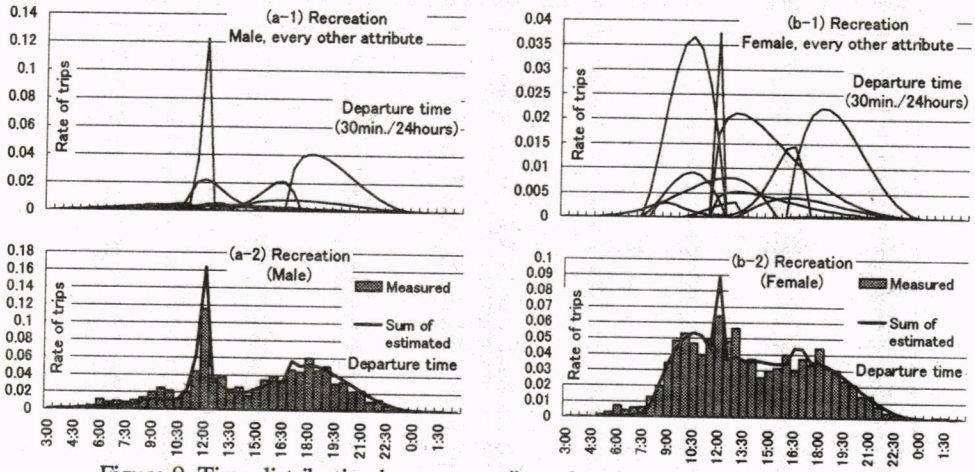


Figure 9. Time distribution by every attribute for trip purpose No.8 (example)

As an example of the visual examination, Figure 9 shows the time distribution by every attribute $f_i^{jkh}(t)$ for purpose No.8 (Recreation).

5. REAPPEARANCE AND TIME TRANSFABILITY OF MODEL

The reappearance and the time transferability by using the model built in the preceding chapter are examined. First, the reappearance of the model is examined in comparison between the actual value and the estimated value by PT93 data. Next, the time transferability is examined for the estimated value by PT83 data and parameters by Table 6. In addition, the number of trip generations by personal attributes in every purpose on a day is used each PT data. Table 7 shows the number of trips on a day by personal attributes in every purpose. In addition, these rates of trips are of each trip purpo se. C_m^{jkh}. Table 8 shows the correlation coefficients and the RMS errors of the each time distribution for PT93, PT83 and PT72. For lack of space, the Male group is only shown in this study.

First, the reappearance of the PT93 data is examined. Figure 10 shows the reappearance of the model by total purposes. For the total, the correlation coefficient is 0.978 and the RMS error is 17676.9. For the individual attributes in every purpose, especially, the time distribution of purpose No.8 (Recreation, Middle, Employed) is worse than the other model. The reason is that the distribution of this group, which has the sharp peak in noon, can't be reappeared precisely. In addition, the reappearance of the time distribution by the Aged persons group (A3 group) and Middle-Student group (A2O2 group) is low; the reason is that there are only a small sized data of Aged persons group and Middle-Student group. Therefore, it shouldn't be evaluated only from the correlation coefficient and the RMS error. R eappearance of time distributions is worse in groups, which have a few numbers of trips (50-100).

Next, the estimated values of each year are examined. The tendency to PT72 and PT83 of each attribute is similar to PT93. PT72 is a reference value because the structure of the data is partly different. The numbers of trips on a day by individual attributes in every purpose in PT93 are shown in Table 8, to compare with those of PT83. Though the number of trips between PT83 and PT93 change, both the correlation coefficient and the RMS error of PT83 shown in Table 7 are similar to PT93. Figure 11 shows the time transferability of the model by total purposes for PT83. Middle-Student group (A2O2 group, see Table 8.) is worse than other groups in the precision of the time distributions in every purpose. This reason is that number of trips in this group is a few (about 50).

Table 7. Number of trips on a day and rate of trips on a day for each purpose (Male)

	PT93		PT83			PT93		PT83	
	Number	Rate	Number	Rate		Number	Rate	Number	Rate
P1A2O1	419,750	0.970	339,666	0.975	P10A2O1	377,386	0.967	289,730	0.973
P1A3O1	12,817	0.030	6,893	0.020	P10A3O1	12,793	0.033	6,502	0.022
P2A1O2	131,117	0.564	138,326	0.614	P11A1O2	129,355	0.587	134,724	0.637
P2A2O2	101,543	0.436	86,909	0.386	P11A2O2	90,837	0.413	76,539	0.362
P3A2O1	317,425	0.972	260,297	0.968	P12A2O1	50,709	0.926	32,615	0.964
P3A3O1	9,247	0.028	5,110	0.019	P12A3O1	4,056	0.074	872	0.026
P4A2O1	85,005	0.977	58,696	0.964	P13A2O1	5,304	0.718	10,649	0.861
P4A3O1	2,006	0.023	826	0.014	P13A3O1	2,085	0.282	1,721	0.139
P5A2O1	189,638	0.982	204,034	0.962	P14A2O1	16,008	0.356	11,955	0.332
P5A3O1	3,556	0.018	4,112	0.019	P14A3O1	1,845	0.041	742	0.021
P6A2O1	7,560	0.668	14,026	0.837	P14A1O2	4,663	0.104	5,830	0.162
P6A3O1	3,750	0.332	1,898	0.118	P14A2O2	7,968	0.177	7,530	0.209
P7A2O1	24,784	0.409	17,857	0.374	P14A2O3	5,909	0.132	5,181	0.144
P7A3O1	2,524	0.042	786	0.016	P14A3O3	8,520	0.190	4,814	0.134
P7A1O2	5,278	0.087	6,383	0.134	P15A2O1	34,013	0.503	30,695	0.458
P7A2O2	10,534	0.174	10,886	0.228	P15A3O1	1,777	0.026	794	0.012
P7A2O3	7,078	0.117	6,440	0.135	P15A1O2	9,578	0.142	14,134	0.211
P7A3O3	10,340	0.171	5,420	0.113	P15A2O2	8,632	0.128	10,458	0.156
P8A2O1	65,167	0.580	56,384	0.533	P15A2O3	5,000	0.074	4,238	0.063
P8A3O1	2,665	0.024	1,596	0.015	P15A3O3	8,557	0.127	6,680	0.100
P8A1O2	12,875	0.115	16,260	0.154	P16A2O1	23,345	0.262	28,891	0.293
P8A2O2	14,661	0.130	18,016	0.170	P16A3O1	2,920	0.033	1,687	0.017
P8A2O3	6,700	0.060	6,060	0.057	P16A1O2	21,229	0.238	23,388	0.237
P8A3O3	10,324	0.092	7,447	0.070	P16A2O2	15,339	0.172	18,204	0.185
P9A2O1	44,245	0.330	49,761	0.337	P16A2O3	8,886	0.100	12,989	0.132
P9A3O1	4,749	0.035	2,416	0.016	P16A3O3	17,477	0.196	13,309	0.135
P9A1O2	26,853	0.200	28,523	0.193	Total	2,464,479		2,176,955	
P9A2O2	23,692	0.177	34,222	0.232					
P9A2O3	12,004	0.090	16,668	0.113					
P9A3O3	22,401	0.167	16,166	0.109					

P: Trip pupose, A: Age, O: Occupation
(For details of these classifications, see Table 2. and Table 4.)

Table 8. Reappearance of trip generations by each attribute in each purpose (Male)

	Correlation coefficient			RMS error				Correlation coefficient			RMS error		
	PT93	PT83	PT72	PT93	PT83	PT72		PT93	PT83	PT72	PT93	PT83	PT72
P1A2O1	0.983	0.985	0.970	4230.8	3338.3	8467.5	P10A2O1	0.971	0.975	0.818	3487.8	2518.4	12920.6
P1A3O1	0.991	0.971	0.898	608.2	342.2	729.4	P10A3O1	0.928	0.916	0.823	551.9	330.2	641.7
P2A1O2	0.991	0.978	0.980	3280.0	3052.2	5962.4	P11A1O2	0.950	0.966	0.961	2712.6	2207.2	3471.0
P2A2O2	0.958	0.958	0.941	3074.6	3042.1	5773.8	P11A2O2	0.931	0.907	0.917	2443.2	2314.3	3951.9
P3A2O1	0.967	0.959	0.932	2030.1	1841.8	7860.9	P12A2O1	0.859	0.733	0.842	666.7	695.3	2033.1
P3A3O1	0.919	0.887	0.910	333.1	164.8	520.1	P12A3O1	0.689	0.788	0.741	130.6	33.2	184.1
P4A2O1	0.981	0.981	0.963	507.0	357.3	947.7	P13A2O1	0.887	0.840	0.865	87.3	253.2	795.1
P4A3O1	0.782	0.653	0.912	110.9	40.0	121.4	P13A3O1	0.773	0.759	0.879	86.8	79.1	412.9
P5A2O1	0.963	0.965	0.638	1364.0	1596.3	127.6	P14A2O1	0.910	0.820	0.819	442.3	385.2	1060.3
P5A3O1	0.696	0.876	0.479	139.0	126.4	9.9	P14A3O1	0.434	0.461	0.431	64.9	29.1	86.9
P6A2O1	0.864	0.873	0.869	135.8	263.7	1140.4	P14A1O2	0.975	0.963	0.935	219.6	269.3	589.6
P6A3O1	0.841	0.711	0.858	140.9	88.8	449.2	P14A2O2	0.934	0.796	0.853	244.3	260.6	316.0
P7A2O1	0.949	0.894	0.882	607.0	504.1	1475.3	P14A2O3	0.967	0.905	0.928	245.6	316.5	823.8
P7A3O1	0.595	0.507	0.689	89.9	31.6	113.8	P14A3O3	0.965	0.925	0.967	300.6	180.3	200.9
P7A1O2	0.953	0.916	0.926	243.8	290.6	613.5	P15A2O1	0.948	0.952	0.893	851.7	796.8	1645.0
P7A2O2	0.928	0.869	0.853	320.9	352.7	395.7	P15A3O1	0.155	0.005	0.105	54.5	27.0	67.3
P7A2O3	0.963	0.896	0.939	306.1	381.7	987.2	P15A1O2	0.966	0.952	0.880	537.3	718.2	1555.1
P7A3O3	0.963	0.931	0.914	375.9	216.3	245.8	P15A2O2	0.918	0.785	0.598	242.6	279.6	529.3
P8A2O1	0.967	0.913	0.920	2347.5	2042.0	4790.3	P15A2O3	0.821	0.797	0.774	53.4	61.7	119.9
P8A3O1	0.431	0.361	0.539	121.2	73.4	178.5	P15A3O3	0.864	0.892	0.895	249.2	200.4	176.7
P8A1O2	0.951	0.942	0.969	571.6	749.4	1497.9	P16A2O1	0.926	0.954	0.945	571.8	713.9	2341.2
P8A2O2	0.943	0.928	0.878	399.2	452.6	774.5	P16A3O1	0.529	0.364	0.487	88.2	57.5	223.5
P8A2O3	0.867	0.820	0.788	82.2	89.7	157.6	P16A1O2	0.982	0.927	0.877	857.2	944.1	976.4
P8A3O3	0.917	0.813	0.857	310.9	230.3	206.1	P16A2O2	0.886	0.824	0.677	458.4	507.0	475.1
P9A2O1	0.951	0.903	0.931	1005.5	1194.1	4179.7	P16A2O3	0.910	0.858	0.912	261.4	284.2	372.6
P9A3O1	0.717	0.593	0.711	151.0	87.2	361.6	P16A3O3	0.934	0.895	0.911	538.3	443.0	467.2
P9A1O2	0.935	0.951	0.906	1168.6	1156.8	1204.8	Total	0.979	0.983	0.935	17676.9	16821.4	41818.5
P9A2O2	0.896	0.908	0.884	703.2	862.3	733.3							
P9A2O3	0.960	0.945	0.936	328.1	316.2	420.5							
P9A3O3	0.975	0.913	0.928	782.7	605.1	710.1							

P: Trip purpose, O: Occupation, A: Age (For details of these classifications, see Table 2. and Table 4.)

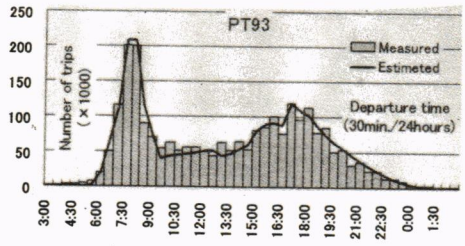


Figure 10. Reappearance of the model by total purposes

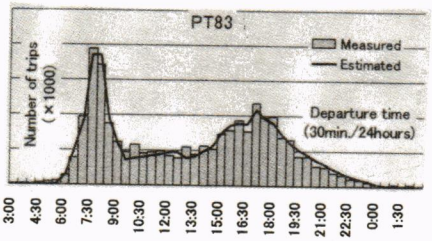


Figure 11. Time transferability of the model by total purposes

6. CONCLUSION

In this study, the time distribution of trip generations in urban area is cleared, and the model of the generating time distribution is built up, if a distribution of travel demand is a random phenomenon with some peaks. Then, the characteristics of the travel demand and the social structural change in the future: the increase of aged persons, the advancement of females' social participation and so on are considered. The results are shown as the following:

(a) The distribution patterns by personal attributes in every purpose were analyzed by the characteristics of the generating time distributions. It was classified new groups from the viewpoint of the time distribution pattern. On the other hand, it was shown that the time distributions were stable for the 3 times of PT survey (1972,1983,1993).
(b) The difference of time distributions among zones is not almost seen. However, for trips attracted in the specific zone such as commuting or attending to school, the difference of the generating time distribution is seen. Therefore, in building the model of the generating time distribution, the subject is how to deal with the distance between the zones, especially distance to the CBD and so on.
(c) Under consideration of the time distribution by the order of trips, it is cleared that the pattern of the time distribution on a day is made by combing the probability distributions in every peak.
(d) Models on the time distribution by personal attributes in every purpose are constructed based on the results of analysis as mentioned in the section 4.3. The reappearance and the time transferability of proposed models are examined from viewpoints of quantity and the 2 times of PT survey (1983,1993).

REFERENCES

Chishaki, T., Kusuda, M. Tatsumi, H. and Kikuchi, H. (1994) Spatial and Temporal Distribution Model of Car Trip. **Technology Reports of Kyushu University**, Japan, Vol.67, No.1, 17-23, January 1994.

Kubo, Y., Chishaki, T., Kajita, Y. and Kohara, T. (2001) Study on Zonal Characteristics based on the Time Distribution of Generating and Attractive trips. **Technology Reports of Kyushu University**, Japan, Vol.74, No.1, 33-40, January 2001.

Nakashima, H., Chishaki, T. and Kawano, M. (1987) Categorization of Traffic Purpose in Travel Demand Analysis. **Technology Reports of Kyushu University**, Japan, Vol.60, No.6, 695-703, December 1987.

Person Trip Data (1972, 1983, 1993) **Person Trip Survey**, Urban transport planning conference in Northern Kyushu area, Fukuoka, Japan

Population Data (1970-1995) **Population Census**, Statistics Bureau and Statistics Center, Japan