A GEOGRAPHICAL STUDY ON THE TYPES OF AUTOMOTIVE TRAFFIC REGION AND THEIR DISTRIBUTION IN THE KANTO DISTRICT, JAPAN

BY

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

1. The Problems

The present study considers the types of automotive traffic region centering around each city in the Kanto district, East-central Japan, and also their distributions in order to clarify the nodal regions of this district.

With the progress of motorization during the high economic growth of our country, interregional automobile traffic has remarkably increased its importance in the movement of persons and goods. As networks of paved roads linking a city with its surrounding areas were developed, many automotive traffic regions centering around each of cities were formed throughout the country. In general, such traffic regions have a common feature in that each of them consists of three component parts, i.e., the focus (city), its surrounding areas and automobile flows between them. But they are multifarious in respect to the elements such as the size, the shape, the internal traffic volume and so forth. It is considered that various automotive traffic regions in a district come together to form the organization of nodal regions.

Nowadays, many problems on the automotive traffic region centering around a city are examined in the field of urban and transportation geography. Some examples of such problems are as follows : (1) What is the appropriate method for delimiting automotive traffic regions? (2) By what kind of criterion and by what method are the various automotive traffic regions classified? (3) How can the difference between the types of automotive traffic region be interpreted? (4) Is there any regularity in the distribution of the types of automotive traffic region? It is the primary objectives of this study to clarify the nodal regions of the Kanto district through solving these problems.

2. Previous Studies on the Automotive Traffic Region

We will review previous studies on the automotive traffic region in this section. And also we will point out the unsolved problems in them. First of all, the concept of traffic region and the terminology are briefly reviewed.

As early as in the first half of 1930's, the Japanese geographers used the term of "jidosha-ken (automobile region)" which referred to the areal extents of bus line network centering around a city in the Kanto district (Iiyama and Sasaki,1933). This was one of the earliest attempts to arrive at the conception of traffic region. In the second half of 1950's studies on the traffic region as well as on the trading area, the sphere of living, the city region and so forth progressed, so that the concept of traffic region was made clearer. Arisue (1953a), in his study of traffic regions established by railway passengers, tried to define the concept of traffic region. He defined the traffic region as a region surrounded by traffic devides within which the flow of passengers is directed to a certain place. Moreover, he said, " When traffic region is discussed, it is necessary to specify the traffic facilities, the level of traffic centers (city, block, station and so on), and the critical magnitude of flows contributing to the formation of the traffic region." His definition of traffic region was one of the earliest attempts in the field of traffic region in the world.

So far many researchers have used different terminology to imply the automotive traffic region. Some examples of such terminology are as follows. Green (1950), one of the leading geographers who were concerned with the traffic region, referred to bus service area centering around a fourth-order center in England and Wales as urban sphere of influence or hinterland. Godlund (1951,1956), a Swedish geographer, referred to bus service area centering around a built-up area in his country as umland. By umland it meant, he said, that part of the field in which the strength of a certain place dominates over that of all other places. Brush (1953), in his study of the hierarchy of central places in the Middle West, used the term traffic area. Within the traffic area centering around a town or a village, the attraction is clearly exerted most strongly by the center. In this way, although the different terms have been used, they have a common feature in that the nodal region consists of a focus (center), its surrounding areas and traffic flows between them.

In the early days, Green (1950) and Godlund (1951,1956) just cited, delimited the bus service areas in England and Wales and in Sweden respectively. The method Green used becomes known as a bus service technique. From timetables for the ordinary local bus services he determined the towns from which at least some buses were operated that serve no place larger than themselves. For each of these towns he depicted a diagram showing bus lines radiating from the center. Then, placing the diagrams in their relative positions on a map, he drew the hinterland boundaries. Total number of the centers determined was approximately 700. Furthermore, he investigated physical,economic and social factors affecting the extents and the shape of bus service areas. Similarly, Godlund (1956) delimited bus traffic umlands centering around each of built-up areas in some counties in Sweden. The bus traffic umlands were determined on the basis of traveller frequency data by using the bus service technique. His study was focused on the examination of cross-temporal (dynamic) relationships between the extent of bus traffic umland centering around a built-up area and its theoretical centrality which was calculated based on similar equation to the telephone method by Christaller (1933). Both of the research works adopted bus traffic as an index of interaction between an urban center and its region, because it was considered that bus service might give a good measure of the degree to which the urban center dominated its surrounding areas in Northwestern Europe at that time.

Brush (1953), in his study of the urban hierarchy in southwestern Wisconsin, delimited traffic areas of the lower-order central places, that is, towns and villages. The traffic areas were determined from a map showing average daily flows for roads carrying more than 100 vehicles, using state highway commission data. The boundaries of the traffic areas of towns and villages were traffic devides where few vehicle travelled. On the other hand, hamlets or the lowest order central places, even if they were far from main roads and from towns and villages, did not exhibit sufficient traffic convergence to form traffic areas. Measuring an area of each of the traffic areas and calculating the mean values of such areas for towns and villages separately, Brush showed the differences between towns, villages and hamlets, in terms of the extents of complementary areas as well as the central place functions. In the United States, the ratio of private automobile ownership was so high that automobile traffic could be a good measure of the degree to which central place dominated its surrounding areas.

Turning to single city's automotive traffic region, several studies on the subject have analyzed the two-way interactions between the city and its surrounding areas in detail. For example, Helvig (1964) analyzed daily motor truck movements entering and terminating within the Chicago Area, and distinguished four different hinterland levels centering around the city. Using the detailed information tabulated from Chicago Area Transportation Study's truck file, Helvig made the elabolate study of the subject. It is noteworthy that he could measure quantitatively the effect of distance factor on the magnitude of interaction between the Chicago Area and its hinterland by using the Pareto equation, one of the social gravity models, and that he indicated the great differences of the effects of distance factor between the aggregate levels of hinterland (the state, the county and the local levels) clearly.

In our country the geographical studies of the automotive traffic region have been done, since the first half of 1950's as early as the date Green, Godlund and Brush published the results of their researches. Shimizu (1952) investigated the motor truck traffic between the city of Tokyo and its surroundings, and then showed the city's trucking hinterland. Based on the material collected through roadside interviews by the Ministry of Transportation, he drew the boundaries of the trucking hinterland centering around Tokyo. In terms of the competition with freight trains and the kinds of goods, the hinterland was divided into five component parts in the order of distance from Tokyo : (1) the area in short distances; (2) the suburban area; (3) the middle distance area; (4) the long distance area; (5) the areas in far distances.

At that time, Arisue (1953b) investigated the number of passengers on bus line networks centering around several local towns in the southern part of Izu peninsula (Oku-izu) and elucidated the functional relationships between the local towns and their surroundings. Based on the bus traffic survey made for himself, he applied the Pareto equation model to the phenomenon of distance decay from the local towns, Shimoda-machi and Matsuzaki-machi. As a result, he found that in a mountainous area such as Oku-izu, the application of the Pareto equation must be divided into two parts : (1) one applied to the district surrounding a local town within which the rural-urban interaction is strong; (2) the other applied to the remote district where such interaction is weak. Through the use of mathematical method, the extents of bus traffic regions centering around each of the local towns become clear.

Arisue (1964a, 1964b), a few years later, depicted a nationwide map showing the automotive traffic regions in Japan.

This map formed a counterpart to the similar map showing the railway traffic regions (Arisue,1953a, 1957). Utilizing the Ministry of Construction's data of daily average number of vehicles passing temporary observation points which amounted to more than eight thousand in the whole country, he depicted a map of daily traffic flows along main roads, and determined the 794 first-order traffic regions from traffic devides. Furthermore, he set up a hierarchy from the first-order to the third-order traffic regions and then showed the hierarchical structure on a map as mentioned earlier. It is obvious that Arisue's study of the automotive traffic region in Japan is one of the transportation studies done from a viewpoint of nodal region.

Okuno (1969) also depicted a map showing automotive traffic regions in Japan on a nation-wide scale, using the material and operational procedure of the same kind with Arisue (1964a, 1964b). In this study, Okuno set up a hierarchy from the first-order to the third-order traffic regions. He expressed the relationships between the size of traffic regions at every order of the hierarchy and the size of their central cities, by means of three generalized equations. And then, introducing the basic-nonbasic concept of urban economic functions into these equations, he made the mechanism of the hierarchy clear.

Since motorization infiltrated into our country in the early 1970's, the interregional Origin-Destination (hereafter O-D) tables from the Ministry of Construction's Road Traffic Survey have been used as basic materials for delimiting automotive traffic regions. Through the application of mathematical method to the interregional O-D table, the traffic relation between each of unit areas of the table (administrative districts such as shi, ku, machi and mura) has become clearer.

Okuno (1972) took the lead in those studies using mathematical method for the analysis of interregional automobile flows. He applied the dominant flow analysis, one of the graph theoretical methods established by Nystuen and Dacey (1961), to the O-D table (a 264× 264 matrix) for automobile flows in the Chukyo district which is composed of Aichi, Gifu and Mie prefectures. According to the mathematical procedure, he set up a hierarchy of traffic regions comprising five orders. It becomes clear that the Chukyo district is composed of five areal linkage systems, i.e., five fifth-order traffic regions, that the terminal nodes of these systems, i.e., the foci (centers) of the fifth-order traffic regions are Nagoya-shi, Takayama-shi, Ueno-shi, Ise-shi and Toyohashi-shi, and that the 264 unit areas are grouped into the 152 first-order regions, into the 63 second-order regions, into the 31 third-order regions, into the 14 fourth-order regions and finally into the five fifth-order regions.

Furthermore, Okuno (1979) applied the similar method to the O-D table (a 132× 132 matrix) for automobile flows in the Hokuriku district. He set up a hierarchy of traffic regions comprising five orders to clarify the areal linkage system and its temporal change at intervals of three years. As a result, it was found that the Hokuriku district was composed of six fifth-order traffic regions, that the foci of these fifth-order traffic regions were Niigata-shi, Muika-machi, Joetsu-shi, Toyama-shi, Wajima-shi and Kanazawa-shi, and that no significant change was recognized in the hierarchy between the two years.

As we have seen, the studies regarding the automotive traffic region at home and abroad have obtained the good results. In order to promote the further development in the field of automotive traffic region, it is necessary to establish a new point of view. Then we ought to understand the research trends and submit the unsolved problems as follows.

To delimit automotive traffic regions is a starting point for making studies in the field, so that the method of delimitation becomes a matter of great concern. In the previous studies, the method of delimitation has been dependent on the kind of basic materials. Both the bus service technique devised by Green and the method of linking traffic devides by Brush and also by Arisue in the early days are dependent on the flow maps showing the distribution of traffic volume along main roads, while the mathematical method of measuring the degree of traffic intensities between unit areas depends on the O-D table for automobile flows. Making the comparison between the two, it is obvious that the mathematical method is superior to both the bus service technique and the method of linking traffic devides, in that the characteristics of traffic regions delimited by the former method can be described more accurately through quantitative analysis.

Apart from the method of delimiting single city's automotive traffic region (Shimizu, 1952 ; Helvig, 1964 et al.), the methods of the delimitation to date have been centralization survey method which determines the foci of traffic flows. However, it would be more suitable to adopt decentralization survey method which delineates the external boundaries of traffic regions from their part of foci, i.e., central cities, for it is considered that most cities in advanced countries have increased their nodality more and more.

There have been at least three subjects in the field of automotive traffic region : (1) hierarchy of the traffic regions comprising several orders; (2) relationship between the size of traffic regions, i.e., their areas or their population and the centrality of the foci (central cities); (3) distance decay of traffic flows centering around a focus of the traffic region. The studies, which are concerned with each of these problems directly and indirectly, have clarified the locational pattern of automotive traffic regions in various districts. Those studies on the hierarchy of the traffic regions comprising several orders particularly have a great significance in that they explain the nodal regions of an area and their hierarchical structure. Nevertheless, apart from a viewpoint of hierarchy they only describe the mere facts of the horizontal arrangement of traffic regions, each of which corresponds to one distinctive part of the organization of nodal regions as a whole. In order to make the nodal regions clear, it is still necessary to detect an order of the distribution of traffic regions, or a certain regularity of their horizontal arrangement.

3. The Study Methods

In order to solve the problems as stated in section one, we must delimit the automotive traffic regions centering around each city. It is necessary for us to employ the objective method which is able to measure the magnitude of interaction between each city of the study area and its surroundings. Delimiting the automotive traffic regions is the starting point for the present study.

We will then try to find out the order in the distribution of various automotive traffic regions. As described above, the term <u>order</u> does not refer to the hierarchy of the system of traffic regions, but refers to the regularity of their horizontal arrangement. We will consider the distribution of the types of automotive traffic region to detect the order.

There are a great variety of automotive traffic regions centering around a city from the viewpoint of their regional elements. However, if we put the diversity in order by fixing our eyes upon only the essential elements and by using the pertinent measure of them, we will be able to find the types of the traffic region.[1] The significance of the types will become clear through investigating the factors which make the differences between them. In the present study, we will clarify the nodal regions in the Kanto district, from a viewpoint of the types of automotive traffic region and their distribution. The study is to be made according to the following procedures :

The starting point for the present study is to delimit the traffic regions. For the purpose of delimiting them, the decentralization survey method is used. Generally the magnitude of interaction between a city and its surrounding areas declines exponentially with distance from the center of the city and reaches its limit at last. This regularity of distance decay concerning the spatial interaction is well-known (Ullman, 1956). We will delimit the traffic region on the basis of this regularity (Figure 1).

The Pareto equation is one of the functional models describing the regularity of distance decay (Carrothers, 1956). The equation can be written as follows :

$$Tr/M = a\ (D^{-b})\ , \qquad (1)$$

where Tr is the number of automobile trips between a city and its surrounding area, M is a mass of the surrounding area's, D is the distance between them, and a and b are parameters, respectively. These parameters are estimated empirically. The Pareto equation has been an useful model for describing traffic flows in general, since before the quantitative revolution in geography (Arisue, 1953b, 1956 ; Ishimizu, 1957). Applying the equation (1) to the automobile traffic flows between a city and its surroundings, we can specify the regularity of distance decay for each of the cities. According to the Pareto equation (1), the rate of distance decay becomes invariable around a city, so that the outline of the traffic region centering around the city presents a circle. Thus we can delimit the city's traffic region by the two elements, a radius r of the circular region and a rate of distance decay b (considered as an interval of isopleth), as illustrated in Figure 1.

Subsequently, we will classify the traffic regions based on the common measure of their elements and obtain the types. The diversity of various traffic regions is to be arranged by the

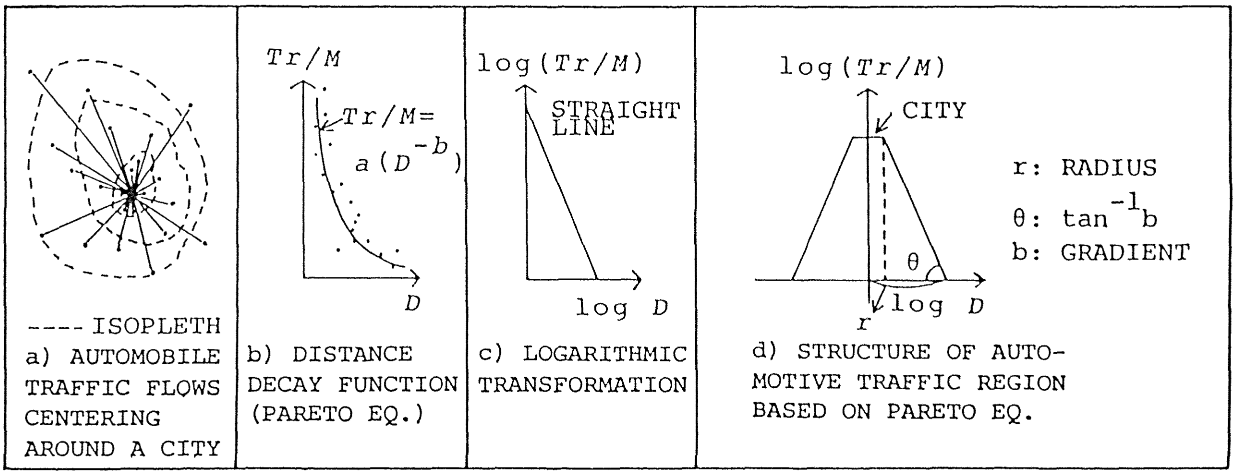


Figure 1. Procedure for the delimitation of automotive traffic region.

classification. We take up the two elements of the traffic region as the criteria of classification, that is, a radius of the circular region and a rate of distance decay. These two are the most essential among elements of the traffic region. We may call the former size element. And we may call the latter gradient element, because it is equivalent to the elasticity of the traffic volume with the traveling distance from a city, and equivalent to the angle between the regression line and the horizontal axis as shown in Figure 1. In this way, we are able to grasp the characteristics of a traffic region in terms of not only the distance between the center of the city and the limit of the traffic region, but also the gradient of distance decay. In other words, the traffic regions, here in the present study, are to be classified by putting stress on both their areal extents and their three-dimensional shapes of the so-called demand cone.

Next, we will investigate some factors affecting the difference between the types of traffic region to interprete the significance of the diversity in them. For this purpose, we examine how the types of traffic region correspond with the various nature of the central cities. First, we postulate some factors affecting the size and the gradient of traffic region respectively, and then examine those factors respectively by correlation analysis. Furthermore, by pooling only the main factors whose validity was confirmed in the preceding analysis, we statistically examine the relationship between those factors and the types of traffic region. The statistical discriminant function is suitable for a method of the correlation analysis, because the criterion variable (the types of traffic region) is categorical. In order to examine the significance of the correlation, the testing statistical hypothesis is performed.

At the final stage we will concern ourselves with the distribution of the types of automotive traffic region, in relation to the characteristics of central cities. The discriminant functions obtained in the preceding part are the linear combinations of the explanatory variables showing urban characteristics. Based on the measured values of the explanatory variables in these discriminant functions, we can estimate the degree of possibility for each city to fall under each of the types of traffic region in terms of urban characteristics. The possibility called Bayesian posterior probability is a valid criterion to distinguish the types of traffic region in relation to the nature of central city. Therefore, by extracting only a central city from three components of the traffic region, that is, the focus (the central city), its surrounding areas and traffic flows between them, and by depicting the distribution of the posterior probability assigned to each city on maps by each of the types, we attempt to analyze the distribution pattern of the posterior probabilities and to detect some order in the distribution of the types of traffic region, by means of diagrams, graphs and tables in addition to the text. The main analytical methods used in the final part are centrographic measures and variance analysis.

The basic material for the present study originates from the Ministry of Construction's Automobile O-D Survey conducted during the Autumn of 1980. Through re-collecting the daily number of two-way automobile trips between cities (shi), towns (machi) and villages (mura) in the Kanto district from the material, we prepare the O-D table (a 453× 453 matrix). In this table, the Tokyo 23 special wards (ku) are united into a city, and they are generically called the city of Tokyo.

4. General Survey of the Study Area

The Kanto district, East-central Japan, consists of Tokyo metropolitan prefecture and six other prefectures, that is, Ibaraki, Tochigi, Gunma, Saitama, Chiba and Kanagawa. In the district, the Kanto plains, the largest one in this country stretches for more than one hundred kilometers and the network of principal roads connects the cities (Figure 2). There are 151 cities and the city of Tokyo in October 1st, 1980. The density of city distribution in the Kanto district is the highest of all the districts in Japan.

The cities of various sizes and of various functions exist in the district. The system of cities consists of several orders of urban hierarchy in which there are the city of Tokyo, the large cities such as Yokohama and Kawasaki, the regional capitals such as Chiba, Urawa, Utsunomiya, Maebashi and Mito, the local cities, the satellite cities and so forth.

The dual orders in the locational pattern of cities of the Kanto district has become clear (Ishimizu, 1961,1964 ; Yamaga, 1967 ; Masai and Matsumoto, 1971 ; Sawada, 1978 ; Watanabe, 1982 ; Todokoro, 1986 and so on).

First, the concentric pattern centering around the city of Tokyo is observed. Due to the concentration of urban functions into the metropolis during the period of high economic growth and

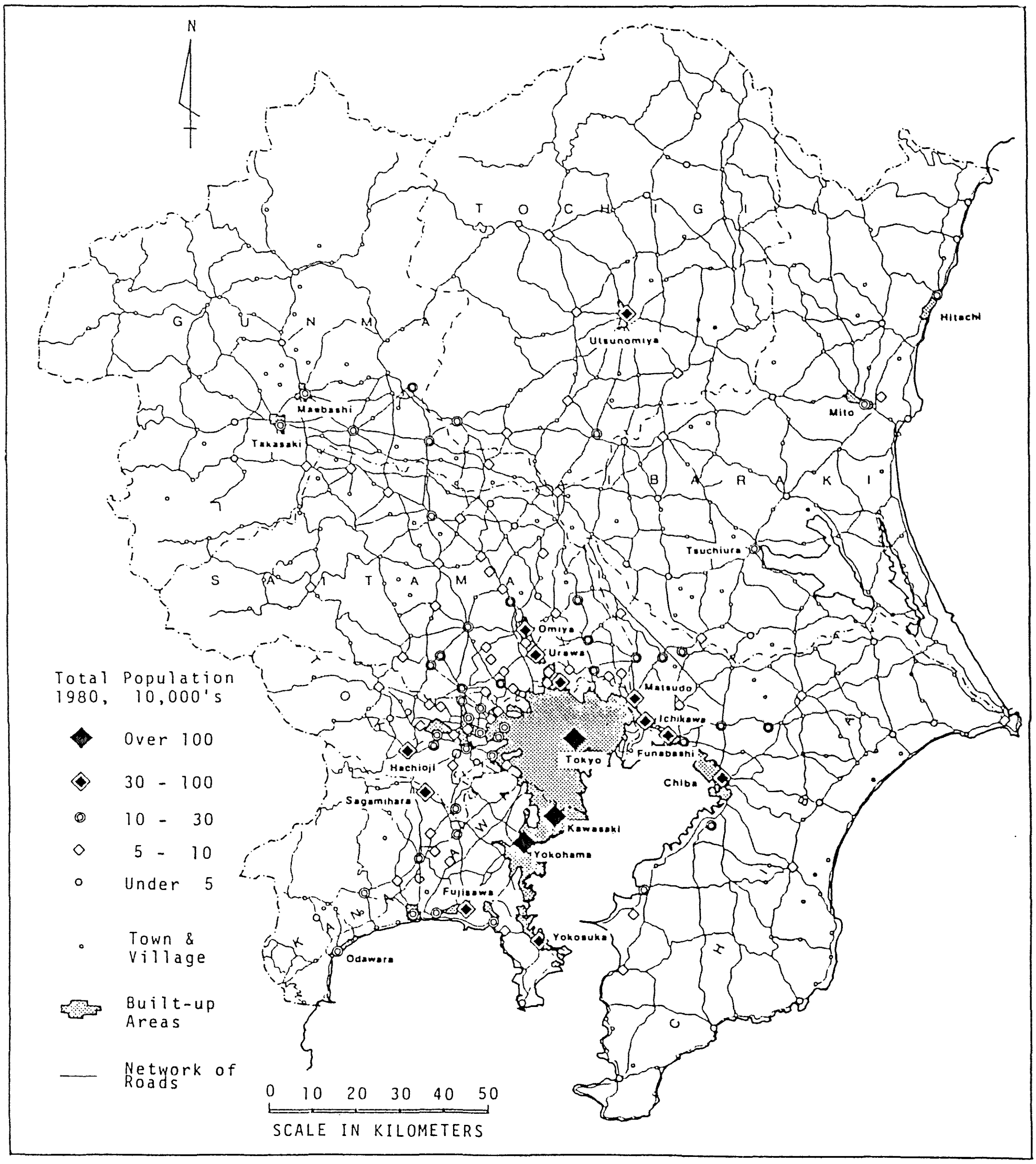


Figure 2. Locational features of the study area. Source: Geographical Survey Institute (1977): National Atlas of Japan, and Statistics Bureau, Prime Minister's Office (1981,1982): Population Census of Japan, 1980.

the process of metropolitanization, many satellite cities have been gradually grown up by the centrifugal forces. Satellite cities are thickly distributed in the zone of distances under 30 kilometers from the heart of Tokyo, where the conurbation becomes remarkable with regard to the cityscape. Outside this zone, the density of city distribution becomes less with the increase of distance. The ring of distances between 30 to 60 kilometers from Tokyo corresponds to either the commuters' residential areas pointing to Tokyo, or the traditional rural areas under the influence of industrialization. Moreover, the ring of distances between 60 to 100 kilometers is beyond the limit of sphere of living centering on Tokyo, where the regional capitals and the local cities are distributed. The outermost ring of distances of 100 kilometers and more corresponds to the mountainous area of the northern Kanto, where the daily interaction with Tokyo is very weak.

On the other hand, the radiated pattern of the city distribution from Tokyo is also observed. Along the radiated highways from Tokyo and the navigable waterways of Tone River both of which were fixed in the Edo era, and along the railways laid after the Meiji era, for example, along the Tokaido, the Chuodo, the Kan'etsudo, the Tohokudo, the Jobando and the Keiyodo, the cities are distributed radially. And these sectorial zones differ significantly in urbanization and population density.

According to the nation-wide maps of automotive traffic regions depicted by Arisue(1964b) and Okuno(1969), the Kanto district as a whole is so completely covered with Tokyo's traffic region of the third order that we can imagine the great importance of Tokyo's influence upon the district. Tokyo's traffic region of the third order extending over neighbouring districts is the largest one of the country. Because the basic materials for both studies differ in the date of traffic survey conducted, the central cities of the second order are somewhat different between both of the studies. Despite the discrepancy, roughly speaking, those traffic regions of the second order centering around the local cities such as Maebashi, Utsunomiya, Ashikaga (Kiryu), Hitachi (Mito), Tsuchiura and Sawara in the northern Kanto, and Katsuura (Kamogawa) and Tateyama in the Boso peninsula each of which occupies a prefecture or half a prefecture, stand in a row. The traffic region of the first order corresponding to the sphere of living is formed around a major city of the district. Tokyo's traffic region of the first order that resembles a starfish in shape stretches along the principal roads radiated from Tokyo, and reaches 50 to 60 kilometers in the Kanto plains.

CHAPTER II

DELIMITATION AND CLASSIFICATION OF THE AUTOMOTIVE TRAFFIC REGIONS

In the first place, we will delimit automotive traffic regions on the basis of the data concerning the automobile trips between each of 152 cities and its surrounding areas, and then will classify their regions.

1. Method of Delimiting the Automotive Traffic Regions

The number of automobile trips between a city and its surrounding areas diminish with distance from the city. The functional model describing this regularity of distance decay is genarally written as follows :

$$T_i = f(D_i) \quad , \qquad (2)$$

where T_i is the number of automobile trips between a city and its surrounding area *i*, *f* is a function of D_i and D_i is the distance between them. The most basic formula of these functions is the social gravity model written as follows :

$$T = k\ e^{-bf(D)} \quad , \qquad (3)$$

where *T* is the number of automobile trips between a city and its surrounding area, *D* is the distance between them, *k* and *b* are parameters obtained empirically. According to the distance function f(D), a family of the gravity models are classified into five kinds of groups, that is, the exponential model, the normal model, the square root exponential model, the Pareto model, and the log-normal model. We will use, here in this study, the Pareto model, because of its better fittness (Taylor,1975). The Pareto model may be written in the form as follows :

$$\log T = k - b \log D \tag{4}$$

This is rewritten involving a mass term of the surrounding area as follows :

$$\log (Tr/M) = k - b \log (D) \ , \tag{5}$$

where Tr is the daily number of two-way automobile trips generated between a city and its surrounding area, and M is the mass term, generally shown as day-time population of the surrounding area (unit by thousand). So, we can say, Tr/M of the left hand is equivalent to the weighted number of automibile trips between a city and its surrounding area, measured by 1,000 population.[2] And D is the distance between a city and its surrounding area, which is measured as the linear distance between the central point of the city and that of its surrounding. The central point is defined as the location of city office or town (village) office. As for a case of the city of Tokyo which is composed of the 23 special wards, the location of the Metropolitan Government Office is represented as the central point. The day-time population by city, town and village are extracted from the Population Census of Japan in the year of 1980. The letters k and b indicate parameters. If we obtain the converse logarithm of both sides in the equation (5), it becomes the following equation :

$$Tr/M = a\ (D^{-b})$$

This is the same as the above mentioned equation (1).

Figure 3 shows the distribution pattern of the weighted number of automobile trips generated between the city of Tokyo and its surrounding area in the Kanto district. According to the map, the number of surrounding areas with trips amounts to 351, nearly three quarters of the total number of unit areas. A circular or belt-like pattern emerges. This regularity of distance decay is also obvious in the scatter diagram, Figure 4, in which the horizontal axis corresponds to the distance from the city of Tokyo, and the vertical axis the weighted number of automobile trips.

The parameters k and b in the equation (5) ought to be estimated using the suitable calibration method for 152 cities. According to Baxter(1982), the parameter estimation of spatial interaction models can be carried out, based on the statistical assumption that the criterion variable, or the magnitude of interaction is a discrete variate. That is to say, assuming the Poisson or multinominal distributions as the probability distribution, the recent studies have calibrated the spatial interaction models using different methods. Such calibration methods are, (1) maximum likelihood estimation based on the Poisson or

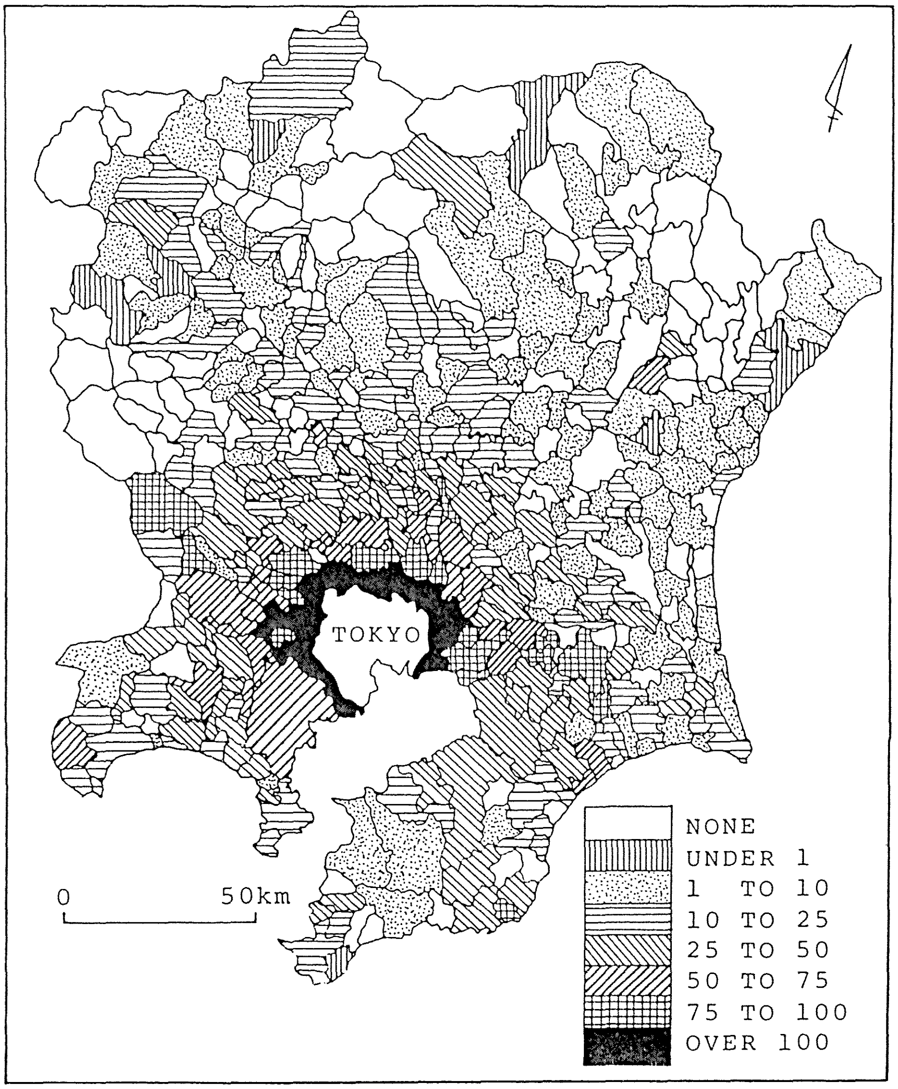


Figure 3. Daily number of automobile trips centering around the city of Tokyo by cities, towns and villages per 1,000 population, 1980.

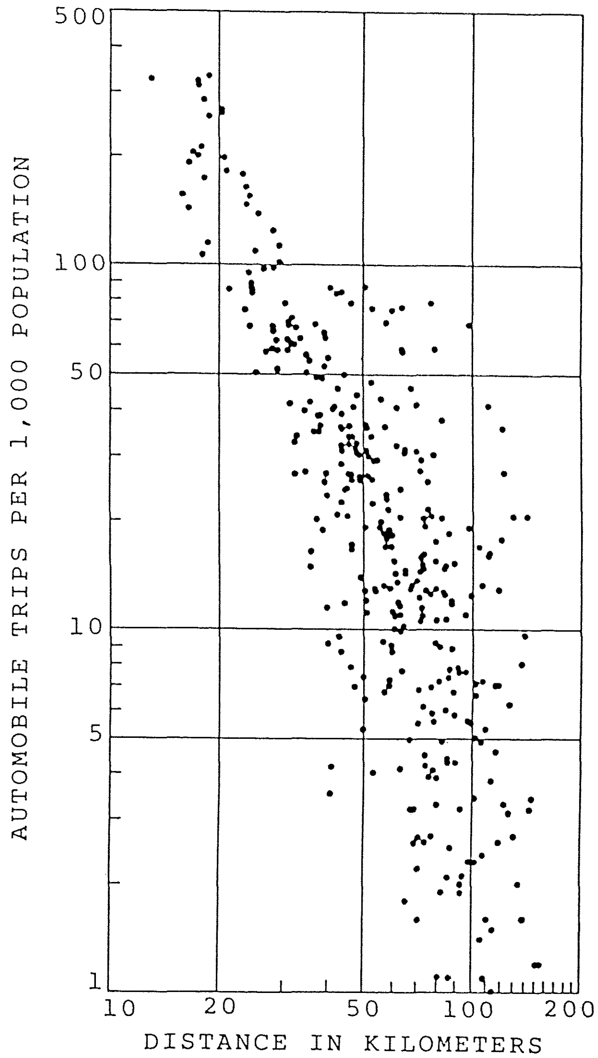


Figure 4. Association between weighted number of automobile trips centering around the city of Tokyo and linear distance.

multinominal assumptions, (2) entropy maximizing estimation, (3) weighted least squares estimation, and (4) logit regression analysis. However, the assumption would not be applicable to the equation (5), for the criterion variable is not a discrete variate, but a continuous variate. So, we can not use those parameter estimations (1) to (4) which assume the Poisson distribution.

We should expect that the statistical data on automobile trips Tr would contain by chance outliers because the statistical data were obtained from the sample survey. Outliers are so great that we can not ignore them as random errors. If the data have such great outliers, the accuracy of parameter estimation in the regression model by using ordinary least squares method would become lower. Moreover, when a linear equation has the serial correlation in the error terms, the reliability of parameters estimated by the ordinary least squares method would also become lower, because of the existence of spatial autocorrelation in the distribution of day-time population (Curry,1972).

We must use a calibration method which provides the same parameter estimates with those obtained from the ordinary least squares method for the data with good qualities satisfying several preconditions of the ordinary least squares method, and moreover which provides the better parameter estimates than those obtained from the ordinary least squares method for the data with bad qualities without satisfying them. These preconditions are described as follows (Norcliffe, 1977) :

1. The values of e (the residuals from the regression) are pairwise uncorrelated.

2.Each conditional distribution of e has a mean of zero.

3.The error term is homoscedastic.

4.Each conditional distribution of e is normally distributed.

One of the best calibrations to satisfy the above mentioned preconditions may be on the basis of the maximum likelihood method. As for the simple regression model, the procedures are carried out through the following steps :

First, the estimates obtained by the ordinary least squares method will be used as the initial estimates. Then, we will apply Tukey's dynamic biweight method, one of the algorism of robust estimation, to the initial estimates. That is to say, the iteratively weighted least squares procedure will be repeated until the parameter estimates converge. This procedure is six-fold as mentioned below (Nakagawa and Oyanagi,1982).

1.The estimates obtained by the ordinary least squares method are set up as the initial estimates of parameters $x^{(o)}$.

2.The residual from the regression V_i is calculated and then standardized through dividing it by the measurement precision σ . The quotient Z_i is called standardized residual.

$$Z_i = V_i / \sigma$$

3.The average size of the standardized residual $|Z_i|$ is expressed by means of its median.

$$s = \text{median}\ \{|Z_i|\}$$

4.The effective weight W_i for the standardized residual is calculated as follows :

$$W_i = \Psi(Z_i)/Z_i \ ,$$

where $\Psi(Z_i)$ is the data fitting function. The median as stated above is properly used, that is,

$$\Psi(Z_i) = [\ 1 - (\ Z_i \ / \ cs\ )^2\ ]^2 \qquad \text{for } |Z_i| < cs$$
$$= \quad 0 \qquad \text{for } |Z_i| \geqq cs$$

Tukey's dynamic biweight method adjusts the value of c according to the value of s, that is,

$$c = 6 \qquad \text{for} \qquad s \leqq 5$$
$$c = 10 \qquad \text{for} \quad 5 < s \leqq 100$$
$$c = 20 \qquad \text{for} \quad 100 < s$$

5. The supplementary value of parameters Δx is estimated by the least squares using the effective weight W_i.

6. The adjusted parameter estimates $x^{(k+1)}$ are rewritten as follows :

$$x^{(k+1)} = x^{(k)} + \Delta x$$

The procedures from (2) to (5) are repeated until the parameter estimates converge.

The parameter estimates obtained from this calibration method are hard to be biased against a systematic error, and are robust against a non-normal distribution as the probability distribution of the data. Then, calculating the weighted number of automobile trips and measuring the linear distance in the equation (5) for each of 152 cities, we carry out the calculation of iteratively weighted least squares procedure.

The results of the computer run are shown in Table 1. The significance of the maximum likelihood estimator in a regression equation is tested on the assumptions that it has Normality and independence asymptotically. That is, we compare the test

TABLE 1

MAXIMUM LIKELIHOOD ESTIMATES OF PARAMETERS CONTAINED IN PARETO EQUATION FOR EACH CITY OF THE KANTO DISTRICT AND THEIR TEST STATISTICS

Name of city	Initial estimates		Final estimates		Test statistics	
	k	b	k	b	k	b
Ibaraki Pref.						
Mito	5.277	2.611	5.235	2.577	11.46**	9.20**
Hitachi	4.543	2.204	4.492	2.160	8.91**	6.97**
Tsuchiura	4.807	2.601	4.814	2.606	10.22**	8.19**
Koga	2.807	1.487	2.796	1.480	9.11**	6.79**
Ishioka	4.158	2.334	4.160	2.336	8.51**	6.93**
Shimodate	3.826	2.120	3.835	2.125	8.86**	7.20**
Yuki	2.705	1.411	2.700	1.407	7.28**	5.45**
Ryugasaki	3.459	1.843	3.385	1.778	6.92**	5.08**
Nakaminato	3.102	1.732	3.104	1.733	6.81**	5.27**
Shimotsuma	3.855	2.234	3.887	2.257	7.71**	5.94**
Mitsukaido	3.727	2.159	3.731	2.162	7.85**	6.16**
Hitachiota	3.881	2.265	3.871	2.261	5.35**	4.14**
Katsuta	3.642	1.789	3.584	1.727	8.28**	5.78**
Takahagi	3.118	1.512	3.130	1.521	4.91**	3.84**
Kitaibaraki	2.139	0.882	2.146	0.894	2.75**	1.98*
Kasama	3.116	1.678	3.123	1.686	7.30**	5.68**
Toride	2.853	1.472	2.746	1.388	6.97**	5.03**
Iwai	2.483	1.255	2.464	1.241	5.73**	3.98**
Tochigi Pref.						
Utsunomiya	5.708	2.890	5.713	2.889	10.66**	8.68**
Ashikaga	3.431	1.785	3.455	1.800	7.92**	6.04**
Tochigi	3.587	1.982	3.623	1.954	8.05**	6.36**
Sano	3.385	1.854	3.020	1.615	6.97**	5.35**
Kanuma	3.997	2.076	4.012	2.082	8.01**	6.23**
Nikko	2.757	1.291	2.914	1.390	4.47**	3.45**
Imaichi	4.739	2.453	4.728	2.447	5.97**	4.74**
Oyama	3.675	1.914	3.701	1.932	9.66**	7.64**
Moka	3.308	1.633	3.304	1.632	6.99**	4.99**
Otawara	4.766	2.511	4.723	2.486	5.63**	4.21**
Yaita	3.618	1.836	3.621	1.841	5.76**	4.24**
Kuroiso	4.085	2.101	4.081	2.098	5.46**	4.17**
Gunma Pref.						
Maebashi	4.537	2.185	4.557	2.198	12.22**	9.12**
Takasaki	4.666	2.332	4.682	2.342	11.31**	8.39**
Kiryu	4.197	2.293	4.209	2.304	9.54**	7.53**
Isesaki	3.913	2.115	3.915	2.117	10.38**	7.87**
Ota	4.021	2.159	4.012	2.154	9.46**	7.33**
Numata	4.330	2.373	4.327	2.372	7.38**	5.74**
Tatebayashi	3.240	1.741	3.241	1.746	8.00**	6.24**
Shibukawa	4.338	2.432	4.372	2.461	8.33**	6.28**
Fujioka	3.262	1.655	3.271	1.663	7.64**	5.28**

TABLE 1 --Continued

Name of city	Initial estimates		Final estimates		Test statistics	
	k	b	k	b	k	b
Tomioka	3.996	2.247	3.970	2.232	6.25**	4.84**
Annaka	2.885	1.443	2.841	1.415	5.69**	3.63**
Saitama Pref.						
Kawagoe	3.233	1.662	3.282	1.702	9.98**	7.37**
Kumagaya	3.773	1.985	3.810	2.009	10.52**	8.10**
Kawaguchi	2.341	1.085	2.350	1.094	9.67**	6.88**
Urawa	2.609	1.293	2.622	1.300	9.93**	7.07**
Omiya	2.729	1.269	2.731	1.270	11.01**	7.61**
Gyoda	3.363	1.887	3.369	1.893	8.77**	6.62**
Chichibu	4.288	2.368	4.265	2.334	7.78**	6.22**
Tokorozawa	2.039	0.907	2.099	0.947	8.97**	5.51**
Hanno	2.235	1.119	2.179	1.086	5.28**	3.62**
Kazo	2.724	1.545	2.782	1.589	7.23**	5.33**
Honjo	3.572	2.027	3.590	2.048	8.33**	6.30**
Higashimatsuyama	3.985	2.331	4.013	2.357	8.74**	6.79**
Iwatsuki	1.888	0.892	1.927	0.919	8.17**	5.31**
Kasukabe	2.550	1.275	2.655	1.367	8.94**	6.19**
Sayama	2.208	1.070	2.239	1.096	7.41**	4.96**
Hanyu	2.744	1.467	2.707	1.428	8.06**	5.64**
Konosu	2.799	1.527	2.813	1.539	7.77**	5.64**
Fukaya	3.216	1.767	3.258	1.798	8.60**	6.47**
Ageo	2.642	1.389	2.600	1.362	9.89**	7.24**
Yono	1.559	0.670	1.553	0.657	7.03**	4.01**
Soka	2.013	1.016	1.972	0.997	6.64**	4.82**
Koshigaya	2.326	1.152	2.304	1.137	8.11**	5.83**
Warabi	1.830	1.051	1.842	1.063	5.92**	4.36**
Toda	1.726	0.812	1.742	0.827	7.88**	5.10**
Iruma	2.412	1.210	2.448	1.242	7.70**	5.20**
Hatogaya	1.509	0.782	1.507	0.783	4.55**	2.95**
Asaka	1.831	0.962	1.811	0.947	6.20**	4.03**
Shiki	1.748	0.884	1.768	0.909	6.20**	3.88**
Wako	1.510	0.690	1.545	0.720	5.15**	3.06**
Niiza	1.909	0.978	1.882	0.971	7.97**	5.31**
Okegawa	2.488	1.406	2.514	1.432	7.48**	5.59**
Kuki	2.447	1.325	2.605	1.441	9.40**	6.80**
Kitamoto	2.692	1.493	2.721	1.517	8.32**	5.88**
Yashio	1.412	0.616	1.379	0.603	5.20**	3.12**
Fujimi	2.186	1.244	2.200	1.259	7.24**	4.92**
Kamifukuoka	2.048	1.170	2.056	1.180	5.70**	3.82**
Misato	1.580	0.768	1.541	0.743	5.93**	4.08**
Hasuda	1.836	0.955	1.846	0.966	7.35**	4.90**
Sakado	3.498	2.058	3.511	2.071	8.18**	6.26**
Chiba Pref.						
Chiba	4.278	1.950	4.306	1.964	11.45**	8.54**
Choshi	3.633	1.679	3.655	1.691	6.83**	5.12**
Ichikawa	2.141	0.995	2.094	0.963	8.08**	5.84**
Funabashi	2.809	1.312	2.825	1.321	9.61**	7.26**

TABLE 1 --Continued

Name of city	Initial estimates		Final estimates		Test statistics	
	k	b	k	b	k	b
Tateyama	4.653	2.341	4.655	2.343	6.59**	4.97**
Kisarazu	3.494	1.712	3.518	1.726	5.91**	4.64**
Matsudo	2.484	1.143	2.475	1.137	8.62**	6.15**
Noda	1.660	0.697	1.604	0.671	4.61**	2.68**
Sawara	3.735	1.929	3.861	2.014	8.60**	6.43**
Mobara	4.204	2.172	4.238	2.198	7.50**	5.71**
Narita	3.904	2.002	3.917	2.010	10.62**	8.01**
Sakura	2.971	1.476	2.980	1.483	7.95**	5.79**
Togane	3.416	1.704	3.432	1.714	8.27**	5.99**
Yokaichiba	3.203	1.649	3.257	1.685	7.22**	5.01**
Asahi	3.496	1.712	3.521	1.728	7.49**	5.14**
Narashino	1.974	0.893	1.959	0.885	6.95**	4.76**
Kashiwa	2.581	1.267	2.595	1.281	8.74**	6.31**
Katsuura	3.982	2.001	3.979	2.000	5.13**	4.03**
Ichihara	2.830	1.213	2.838	1.222	7.08**	4.99**
Nagareyama	1.357	0.537	1.345	0.533	3.94**	2.19**
Yachiyo	2.883	1.531	2.884	1.533	7.34**	5.57**
Abiko	1.742	0.689	1.750	0.695	6.94**	3.82**
Kamogawa	4.919	2.720	4.918	2.718	4.73**	3.74**
Kamagaya	1.669	0.730	1.620	0.696	4.97**	2.99**
Kimitsu	3.202	1.550	3.209	1.555	6.17**	4.76**
Futtsu	3.023	4.462	3.019	1.461	3.65**	2.79**
<u>Tokyo Metro.</u>						
Tokyo	4.651	1.941	4.676	1.955	21.75**	15.89**
Hachioji	3.166	1.613	3.235	1.668	9.54**	6.81**
Tachikawa	2.301	1.055	2.318	1.071	7.80**	4.50**
Musashino	1.782	0.791	1.831	0.832	8.32**	4.95**
Mitaka	1.883	0.889	1.978	0.972	7.58**	4.98**
Ome	3.795	2.209	3.784	2.203	7.85**	5.94**
Fuchu	2.666	1.465	2.712	1.508	10.01**	7.05**
Akishima	2.601	1.375	2.596	1.385	7.57**	5.07**
Chofu	2.193	1.176	2.209	1.187	7.57**	5.30**
Machida	2.149	1.047	2.153	1.055	7.50**	5.07**
Koganei	1.858	0.922	1.868	0.930	7.33**	4.39**
Kodaira	2.110	1.053	2.126	1.067	9.12**	5.77**
Hino	1.983	1.037	1.982	1.042	7.80**	4.82**
Higashimurayama	2.043	1.059	2.038	1.055	10.19**	6.51**
Kokubunji	1.555	0.664	1.548	0.658	7.20**	3.48**
Kunitachi	1.753	0.923	1.755	0.922	7.41**	4.33**
Tanashi	1.388	0.643	1.404	0.662	6.32**	3.76**
Hoya	1.715	0.924	1.714	0.926	7.72**	4.77**
Fussa	2.930	1.846	2.971	1.896	6.89**	4.96**
Komae	1.812	1.214	1.821	1.221	3.81**	2.95**
Higashiyamato	1.877	0.992	1.876	0.990	7.47**	4.58**
Kiyose	1.645	0.854	1.681	0.884	7.09**	3.91**
Higashikurume	1.567	0.690	1.586	0.716	6.50**	3.67**
Musashimurayama	2.138	1.164	2.147	1.173	7.16**	4.65**

TABLE 1 ——Continued

Name of city	Initial estimates		Final estimates		Test statistics	
	k	b	k	b	k	b
Tama	1.723	0.911	1.705	0.892	5.46**	3.30**
Inagi	1.036	0.378	0.997	0.349	3.86**	1.53
Akikawa	2.046	1.326	2.718	1.296	5.10**	3.05**
Kanagawa Pref.						
Yokohama	3.024	1.313	3.065	1.340	10.72**	8.17**
Kawasaki	2.044	0.838	2.026	0.833	7.08**	4.90**
Yokosuka	2.775	1.326	2.718	1.296	5.36**	4.00**
Hiratsuka	3.341	1.572	3.372	1.595	12.04**	8.62**
Kamakura	2.593	1.309	2.600	1.314	7.08**	5.05**
Fujisawa	3.168	1.469	3.167	1.467	9.26**	6.52**
Odawara	4.438	2.230	4.475	2.259	12.36**	9.37**
Chigasaki	2.740	1.261	2.733	1.252	8.62**	5.37**
Zushi	2.176	1.026	2.166	1.030	4.64**	2.89**
Sagamihara	2.635	1.169	2.630	1.168	8.30**	5.46**
Miura	0.965	0.246	0.538	−0.010	1.40	−0.04
Hadano	3.949	2.238	3.959	2.247	7.90**	5.67**
Atsugi	3.041	1.423	3.019	1.408	10.10**	6.77**
Yamato	2.714	1.448	2.726	1.455	6.63**	4.69**
Isehara	2.720	1.357	2.717	1.354	7.63**	4.85**
Ebina	2.532	1.361	2.541	1.366	6.37**	4.22**
Zama	2.263	1.161	2.283	1.176	6.66**	4.61**
Minamiashigara	3.029	1.694	3.025	1.686	6.94**	4.62**
Ayase	2.332	1.217	2.345	1.231	5.75**	3.87**

Note : The initial estimates are obtained from the ordinary least squares regression model. The final estimates are obtained from the iterative weighted least squares procedure. The test statistics are calculated through dividing the maximum likelihood estimator by its standard error.
** : $P<0.01$, * : $P<0.05$.

statistic obtained through dividing the maximum likelihood estimator by its standard error, with the critical level on the normal probability paper (Okuno, 1988). According to the statistical test, the parameter estimates for 150 cities are significant at the 5 per cent level. The parameter estimates for two cities, the value of b for Inagi and the values of k and b for Miura are not significant at the 5 per cent level. It becomes clear that the equation (5) applies to the distance decay for the majority of cities in the Kanto district. Therefore, by using the Pareto equations, we can quantitatively establish the automotive traffic regions centering around each of the 150 cities.

We should require a further examination before employing the parameter estimates. The surrounding areas (cities, towns and villages) included in calibrating the Pareto equations, are those which are located within the Kanto district. Realistically, however, the automobile trips are daily generated beyond the boundary of the Kanto district. So, it is doubtful whether the city's parameter estimates, especially located in the fringe of the Kanto district are biased. At the beginnning of the study, it seemed to be necessary that the locations of surrounding areas in the whole country should have been included in the calibration. But the O-D table of daily numbers of automobile trips between cities, towns and villages recorded only for the Kanto district and Nagano and Yamanashi prefectures.

We will examine this problem from two different standpoints. First, an external ratio, the proportion of the daily number of automobile trips beyond the boundary of the Kanto district to the number within the Kanto district, is calculated for each city as shown in Table 2. The external ratios for 127 cities which correspond to 84 per cent of the total number of cities, are under 1.0%, so that the internal completeness of automobile traffic is fairly high in the district. This ratio is higher in the fringe than in the central part of the study area. Examples with the highest ratio are Kitaibaraki (20.01%), Takahagi (6.43%) and Hitachi (3.50%) of Ibaraki prefecture, Kuroiso (5.48%) of Tochigi prefecture, Hachioji (2.14%) of Tokyo metropolitan prefecture, Odawara (7.91%) and Minamiashigara (2.58%) of Kanagawa prefecture. It is clear that Kitaibaraki's ratio is outstanding among those. So, we will not employ that city's parameter estimates because the number of automobile trips between the city and the areas outside the Kanto district is exceptionally large.

Subsequently, as for Hachioji-shi with a certain number of automobile trips to the areas of Yamanashi prefecture, the two regression lines, one drawn for the surrounding areas within the Kanto district and the other drawn for the areas of Yamanashi prefecture in addition to the Kanto district, are superposed in a scatter diagram as shown in Figure 5. The solid line in this figure shows the former regression. Through taking the inverse logarithm of both sides of the regression equation, it can be expressed as follows :

$$Tr/M = 1.718 \times 10^{3} (D^{-1.868}) \qquad (6)$$

On the other hand, the broken line shows the latter regression, whose equation can be expressed in the form of inverse logarithm

TABLE 2

TOTAL DAILY NUMBER OF AUTOMOBILE TRIPS GENERATED AND ATTRACTED FOR EACH CITY OF THE KANTO DISTRICT AND ITS EXTERNAL RATIO, 1980

Name of city	Number of trips within the Kanto district (A)	Number of trips beyond the Kanto district (B)	External ratio (B／A) ×100
Ibaraki Pref.			
Mito	152,940	1,255	0.82
Hitachi	57,047	1,994	3.50
Tsuchiura	95,154	496	0.52
Koga	41,214	267	0.65
Ishioka	40,385	212	0.52
Shimodate	47,254	204	0.43
Yuki	33,542	126	0.38
Ryugasaki	30,594	80	0.26
Nakaminato	21,579	88	0.41
Shimotsuma	27,339	114	0.42
Mitsukaido	32,254	59	0.18
Hitachiota	26,860	101	0.38
Katsuta	70,033	286	0.41
Takahagi	17,534	1,128	6.43
Kitaibaraki	11,731	2,347	20.01
Kasama	19,141	55	0.29
Toride	35,723	108	0.30
Iwai	24,052	68	0.28
Tochigi Pref.			
Utsunomiya	159,615	2,132	1.34
Ashikaga	63,118	386	0.61
Tochigi	50,548	315	0.62
Sano	50,840	316	0.63
Kanuma	45,741	340	0.74
Nikko	19,749	339	1.72
Imaichi	31,191	127	0.41
Oyama	69,221	515	0.74
Moka	37,313	162	0.43
Otawara	37,286	329	0.88
Yaita	24,850	366	1.47
Kuroiso	27,660	1,517	5.48
Gunma Pref.			
Maebashi	189,836	1,319	0.69
Takasaki	172,315	1,849	1.07
Kiryu	80,842	422	0.52
Isesaki	88,758	325	0.37
Ota	101,300	465	0.46
Numata	29,363	270	0.92
Tatebayashi	48,372	286	0.59
Shibukawa	50,401	224	0.44
Fujioka	43,439	217	0.50
Tomioka	31,942	301	0.94

TABLE 2 -- Continued

Name of city	Number of trips within the Kanto district (A)	Number of trips beyond the Kanto district (B)	External ratio (B／A) ×100
Annaka	26,701	257	0.96
Saitama Pref.			
Kawagoe	132,880	659	0.50
Kumagaya	107,489	574	0.53
Kawaguchi	189,643	1,191	0.63
Urawa	178,289	875	0.49
Omiya	180,467	1,156	0.64
Gyoda	50,147	265	0.53
Chichibu	34,325	234	0.68
Tokorozawa	94,113	437	0.46
Hanno	36,938	103	0.28
Kazo	28,248	190	0.67
Honjo	46,279	184	0.40
Higashimatsuyama	52,429	214	0.41
Iwatsuki	49,003	599	1.22
Kasukabe	67,371	293	0.43
Sayama	73,115	478	0.65
Hanyu	25,989	110	0.42
Konosu	36,891	121	0.33
Fukaya	48,721	258	0.53
Ageo	91,227	534	0.58
Yono	66,339	163	0.25
Soka	92,135	549	0.60
Koshigaya	80,596	382	0.47
Warabi	53,314	132	0.25
Toda	82,519	731	0.89
Iruma	68,943	383	0.56
Hatogaya	33,250	99	0.30
Asaka	52,963	203	0.38
Shiki	39,390	102	0.26
Wako	35,814	97	0.27
Niiza	68,117	250	0.37
Okegawa	33,963	116	0.34
Kuki	36,809	345	0.94
Kitamoto	30,095	63	0.21
Yashio	55,663	203	0.36
Fujimi	35,857	48	0.13
Kamifukuoka	32,417	37	0.11
Misato	43,775	125	0.29
Hasuda	22,744	87	0.38
Sakado	47,055	103	0.22
Chiba Pref.			
Chiba	212,879	1,503	0.71
Chosi	33,090	505	1.53
Ichikawa	135,429	760	0.56
Funabashi	161,674	743	0.46
Tateyama	27,274	47	0.17

TABLE 2--Continued

Name of city	Number of trips within the Kanto district (A)	Number of trips beyond the Kanto district (B)	External ratio (B/A) ×100
Kisarazu	53,188	111	0.21
Matsudo	128,056	625	0.49
Noda	47,634	214	0.45
Sawara	29,035	35	0.12
Mobara	43,895	101	0.23
Narita	64,020	254	0.37
Sakura	40,886	166	0.41
Togane	33,306	26	0.08
Yokaichiba	28,247	55	0.19
Asahi	27,676	37	0.13
Narashino	68,298	291	0.43
Kashiwa	98,303	411	0.42
Katsuura	10,664	22	0.21
Ichihara	81,006	906	1.12
Nagareyama	42,657	96	0.23
Yachiyo	60,625	213	0.35
Abiko	28,939	112	0.39
Kamogawa	12,956	53	0.41
Kamagaya	36,193	58	0.16
Kimitsu	36,097	95	0.27
Futtsu	20,913	12	0.06
Tokyo Metro.			
Tokyo	1,423,181	35,087	2.47
Hachioji	166,874	3,564	2.14
Tachikawa	114,251	864	0.76
Musashino	98,204	365	0.37
Mitaka	103,714	472	0.46
Ome	60,737	405	0.67
Fuchu	111,284	971	0.87
Akishima	76,078	360	0.47
Chofu	104,220	730	0.70
Machida	104,670	975	0.93
Koganei	66,467	232	0.35
Kodaira	84,679	503	0.59
Hino	75,474	634	0.84
Higashimurayama	62,004	324	0.52
Kokubunji	46,254	242	0.52
Kunitachi	48,739	234	0.48
Tanashi	40,903	195	0.48
Hoya	52,655	132	0.25
Fussa	46,825	175	0.37
Komae	22,910	115	0.50
Higashiyamato	37,837	168	0.44
Kiyose	29,259	75	0.26
Higashikurume	64,367	234	0.36
Musashimurayama	40,131	116	0.29
Tama	41,867	300	0.72

TABLE 2 --Continued

Name of city	Number of trips within the Kanto district (A)	Number of trips beyond the Kanto district (B)	External ratio (B/A) ×100
Inagi	24,225	90	0.37
Akikawa	27,704	78	0.28
Kanagawa Pref.			
Yokohama	598,702	10,638	1.78
Kawasaki	360,299	4,459	1.24
Yokosuka	73,958	1,211	1.64
Hiratsuka	121,820	1,953	1.60
Kamakura	78,432	479	0.61
Fujisawa	141,603	1,496	1.06
Odawara	82,950	6,560	7.91
Chigasaki	77,060	780	1.01
Zushi	31,634	49	0.15
Sagamihara	171,608	2,651	1.54
Miura	22,988	141	0.61
Hadano	47,757	1,008	2.11
Atsugi	113,424	2,432	2.14
Yamato	88,985	658	0.74
Isehara	44,899	395	0.88
Ebina	51,592	318	0.62
Zama	54,710	625	1.14
Minamiashigara	21,267	549	2.58
Ayase	52,165	258	0.49

Source : Kanto Regional Construction Bureau, the Ministry of Construction (1981): "Origin and Destination Table in Road Traffic Census 1980"

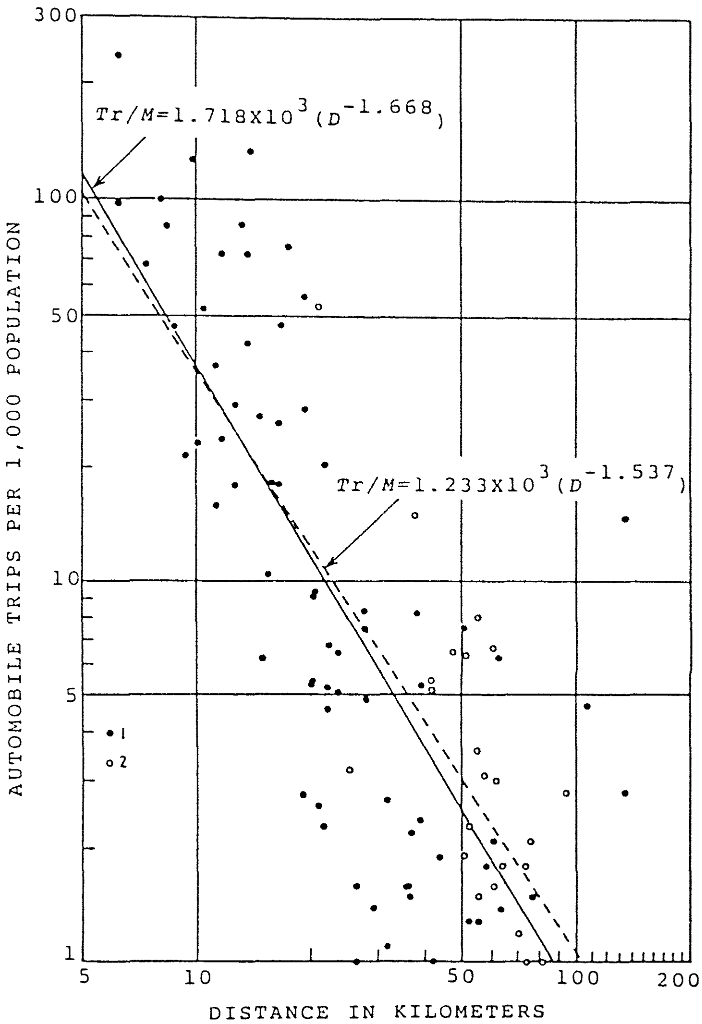


Figure 5. Association between weighted number of automobile trips centering around Hachioji-shi and linear distance.
1: Cities, towns and villages in the Kanto district, 2: Cities, towns and villages in Yamanashi prefecture.
The solid line corresponds to the regression line drawn for the sorrounding areas within the Kanto district.
The broken line corresponds to the regression line drawn for the sorrounding areas of Yamanashi prefecture in addition to the Kanto district.

as follows :

$$Tr/M = 1.233 \times 10^{3} (D^{-1.537}) \quad (7)$$

The gradient of the broken line is somewhat less steeper than that of the solid line. Although statistical test of the difference of two parameter estimates b is impracticable because of the nature of calibration method, it can be said that there is no difference between them. In other words, the parameter estimates involved in the equation (6) are not biased. As the above examination results show, the parameter estimates for those cities located in the fringe of the Kanto district are not biased except for Kitaibaraki-shi.

2. Delimitation of Automotive Traffic Regions

We will delimit the automotive traffic regions with the parameter estimates involved in the Pareto equations, for 149 cities. The excluded cities from the delimitations are Inagi and Miura both of whose Pareto equations are not formed, and Kitaibaraki whose relative number of automobile trips with the areas outside the Kanto district is not small. For the purpose of delimiting the automotive traffic regions, it is necessary to specify the size element and the gradient element of distance decay for each city. The latter is equal to the exponent b of the distance term in the equation (5) (Figure 1-4, Chapter I). The exponents have been already tabulated (Table 1). On the other hand, given that a traffic region takes a circle in shape, we can regard its radius as the size of a traffic region. In order to specify the radius, we ought to make use of the conception of reverse estimation in the regression model. By esimating distance D in the right side of the equation (5) which corresponds to weighted number of trips Tr/M in the left side, we will employ the estimates (D) as the radius of a circle. A reasonable value of the weighted number of trips is determined as stated below.

To begin with, we estimate the distance corresponding to each value of the weighted number of trips, that is, Tr/M = 100.0, 50.0, 30.0 and 20.0 from the equation (5), for each of 149 cities. Furthermore, we draw a circle centering around each of 149 cities with a radius just above estimated, at every four values of the weighted number of trips. The results which are obtained in this manner are shown in Figure 6.

At the value Tr/M = 100.0, a wide area which does not belong to any traffic region remains in the Kanto district because radii of such major cities as the city of Tokyo (the radius of 23.4 kilometers), Utsunomiya (19.3), Mito (18.0), Chiba (14.9), Maebashi (14.6), Hitachi (14.2), Takasaki (14.0),Tateyama (13.6), Imaichi (13.0), Odawara (12.5), Otawara (12.5), Tsuchiura (12.0), Kamogawa (11.8) and Mobara (10.4) are fairly small. As mentioned in the previous Chapter, most cities in today's Japan function as the nodal points of interregional automobile flows. Therefore, the majority of the Kanto district ought to be covered with the automotive traffic regions centering around each of 149 cities. It is evident that the circles are too small.

Next, at the value Tr/M = 50.0, although an area that

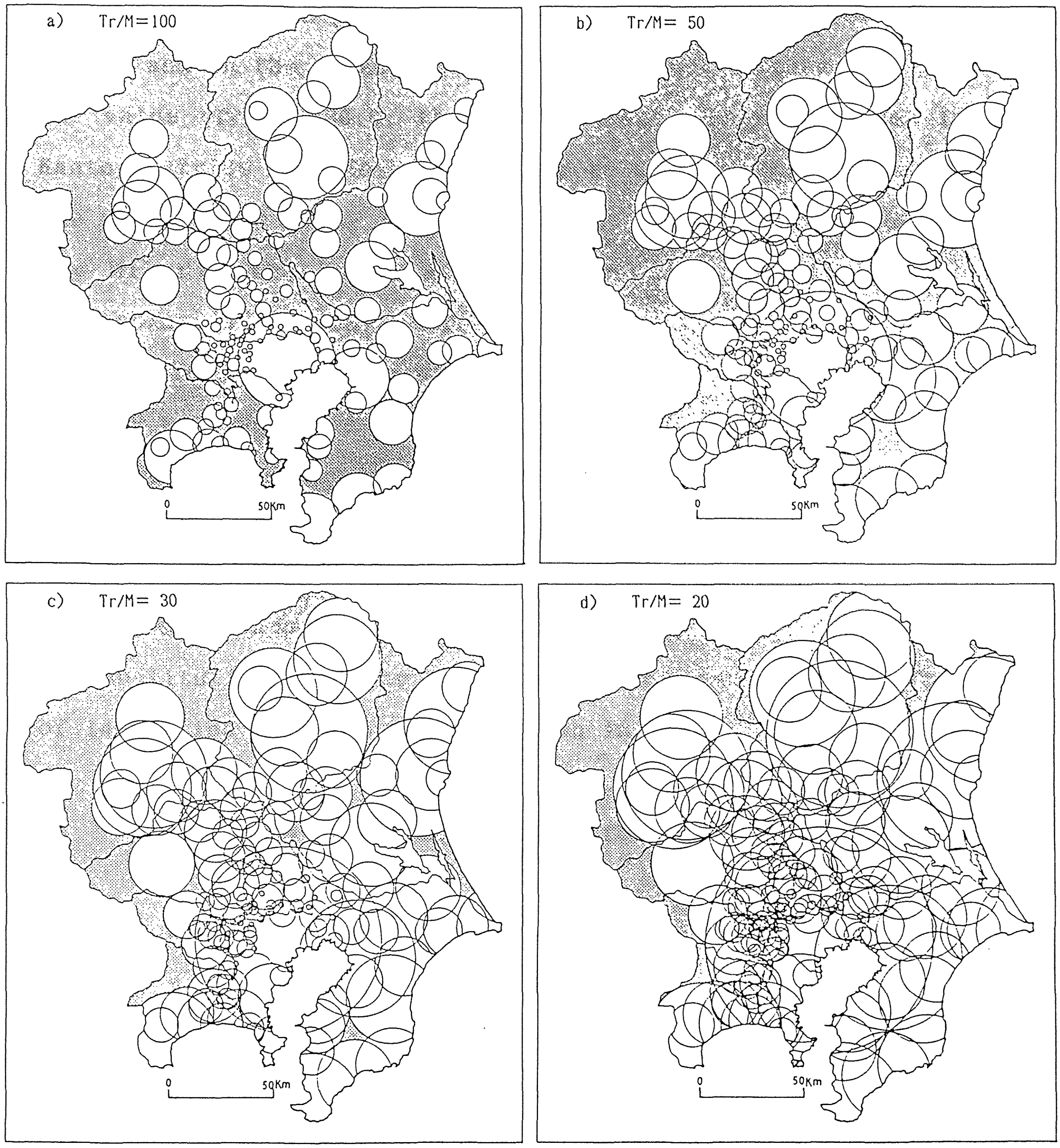


Figure 6. Isopleth maps of the weighted number of automobile trips centering around each city on the basis of the Pareto equation.

does not belong to any traffic region becomes narrower, it still remains to some degree we can not ignore. At the value Tr/M = 30.0, such an area yet remains in the central part of the Kanto plains and in the Rokko region of Ibaraki prefecture. Finally, at the value (Tr/M)= 20.0, there are almost no such an area in the Kanto district that does not belong to any traffic region, except the mountainous areas like the Yamizo, the Taishaku, the Ashio, the Mikuni, the Kanto and the Tanzawa mountains where the automobile is scarcely passable. In addition, the radius of the city of Tokyo is calculated as 53.3 kilometers. This value is roughly equivalent to the city's sphere of living (50 kilometers) (Sawada, 1975). We may conclude from these examinations that it is satisfactory to employ 20.0 as a reasonable value of the weighted number of trips.

Subsequently, we calculate the radius (or the distance) by substituting 20.0 for the left hand of equation (5), for each of 149 cities. The results are shown in Table 3.

3. The Types of Automotive Traffic Region

Both two elements of automotive traffic region, that is to say, a size element which is measured as a radius $\underline{r}$ of the circular region and a gradient element $\underline{b}$ of distance decay which is measured as an exponent of the distance term in the equation (5), have been determined for each of 149 cities. By using these numerical values $\underline{r}$ and $\underline{b}$, we can delimit the automotive traffic regions for all the cities.

The next procedure is to classify the various automotive

TABLE 3

RADIUS OF AUTOMOTIVE TRAFFIC REGION ESTIMATED
BY THE PARETO EQUATION FOR EACH CITY
OF THE KANTO DISTRICT

Name of city	Radius	Name of city	Radius	Name of city	Radius
Ibaraki Pref.		Hanno	6.4	Abiko	4.4
Mito	33.6	Kazo	8.6	Kamogawa	21.4
Hitachi	30.0	Honjo	13.1	Kamagaya	2.9
Tsuchiura	22.3	Higashimatsuyama	14.1	Kimitsu	16.9
Koga	10.2	Iwatsuki	4.8	Futtsu	15.0
Ishioka	16.7	Kasukabe	9.8	Tokyo Metro.	
Shimodate	15.6	Sayama	7.2	Tokyo	53.3
Yuki	9.9	Hanyu	9.7	Hachioji	14.4
Ryugasaki	14.9	Konosu	9.6	Tachikawa	8.9
Nakaminato	11.0	Fukaya	12.3	Musashino	4.3
Shimotsuma	14.0	Ageo	9.0	Mitaka	5.0
Mitsukaido	13.3	Yono	2.4	Ome	13.4
Hitachiota	13.7	Soka	4.7	Fuchu	8.6
Katsuta	21.0	Koshigaya	7.6	Akishima	8.6
Takahagi	15.9	Warabi	3.2	Chofu	5.8
Kitaibaraki	x	Toda	3.4	Machida	6.4
Kasama	12.0	Iruma	8.4	Koganei	4.1
Toride	11.0	Hatogaya	1.8	Kodaira	5.9
Iwai	8.7	Asaka	3.5	Hino	4.5
Tochigi Pref.		Shiki	3.3	Higashimurayama	5.0
Utsunomiya	33.7	Wako	2.2	Kokubunji	2.4
Ashikaga	15.7	Niiza	4.0	Kunitachi	3.1
Tochigi	15.4	Okegawa	7.0	Tanashi	1.4
Sano	11.6	Kuki	8.0	Hoya	2.8
Kanuma	20.0	Kitamoto	8.6	Fussa	7.6
Nikko	14.5	Yashio	1.3	Komae	2.7
Imaichi	25.1	Fujimi	5.2	Higashiyamato	3.8
Oyama	17.5	Kamifukuoka	4.4	Kiyose	2.7
Moka	16.9	Misato	2.1	Higashikurume	2.5
Otawara	23.8	Hasuda	3.7	Musashimurayama	5.3
Yaita	18.2	Sakado	11.7	Tama	2.8
Kuroiso	21.1	Chiba Pref.		Inagi	x
Gunma Pref.		Chiba	33.9	Akikawa	5.7
Maebashi	30.3	Choshi	24.7	Kanagawa Pref.	
Takasaki	27.8	Ichikawa	6.7	Yokohama	20.7
Kiryu	18.3	Funabashi	14.2	Kawasaki	7.4
Isesaki	17.2	Tateyama	27.0	Yokosuka	12.4
Ota	18.1	Kisarazu	19.3	Hiratsuka	19.9
Numata	18.9	Matsudo	10.8	Kamakura	9.7
Tatebayashi	12.9	Noda	2.8	Fujisawa	18.7
Shibukawa	17.7	Sawara	18.7	Odawara	25.4
Fujioka	15.3	Mobara	21.7	Chigasaki	13.9
Tomioka	15.7	Narita	20.0	Zushi	6.9
Annaka	12.2	Sakura	13.6	Sagamihara	13.7
Saitama Pref.		Togane	17.5	Miura	x
Kawagoe	14.6	Yokaichiba	14.5	Hadano	15.2
Kumagaya	17.7	Asahi	19.3	Atsugi	16.6
Kawaguchi	9.1	Narashino	5.5	Yamato	9.5
Urawa	10.4	Kashiwa	10.2	Isehara	11.1
Omiya	13.4	Katsuura	21.8	Ebina	8.1
Gyoda	12.4	Ichihara	18.1	Zama	6.8
Chichibu	18.6	Nagareyama	1.2	Minamiashigara	10.5
Tokorozawa	7.0	Yachiyo	10.8	Ayase	7.0

Note: Units of radius are given in kilometers.

traffic regions into the types according to the two elements of size and gradient as the criteria. We must examine the method that would be suitable for the classification.

Since these two elements of automotive traffic region are the continuous variates, we can apply cluster analysis, a method of the multivariate analysis, to the classification. According to the cluster analysis, the similarity or the distance between every pair of individuals (cities) is calculated, and we can classify all the individuals into a fewer groups (types). However, as there is a closely positive correlation between two variables of the size r and the gradient b, the application of cluster analysis to this classification may bring about many single-member groups. The interpretation of the nature of all the single-member groups will be very difficult.

It is also possible to calculate a set of mean value and standard deviation for each variable and by combining these two indices of the statistic the individuals can be grouped into several types. But the frequency distribution of the size variable presents the positively skewed one as in Figure 7. Another frequency distribution of the gradient variable also presents a quasi-bimodal one, as in Figure 7 and therefore suggests that the individuals ought to be stratified into two groups. To sum up, two of the frequency distribution present no symmetric pattern, so that the method of combining two kinds of indices will have knotty points.

In the present study we will take up a simple method as described below. First, the size classes of automotive traffic region A, B, C and D are set up at intervals of 10 kilometers as

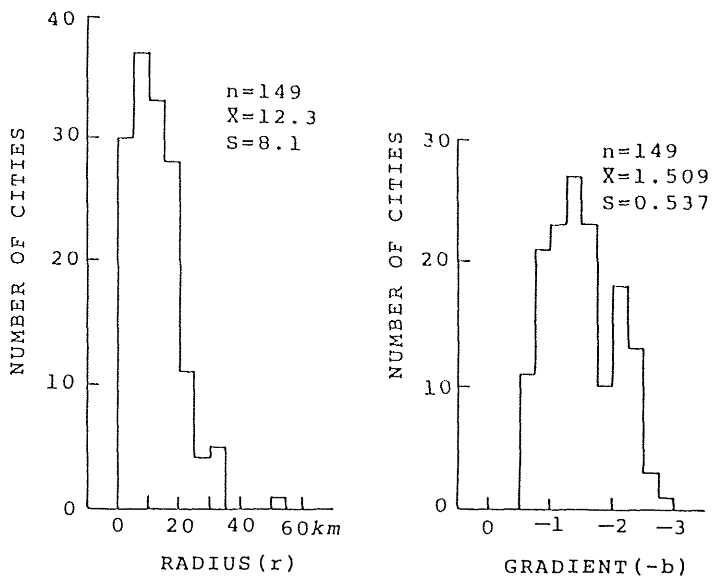


Figure 7. Frequency distribution of the radius of automotive traffic region (r) and the gradient of distance decay (b).
n: Total number of cities, X̄: Mean value, s: Standard deviation.

follows :

Radius of traffic region in kilometers (r)	Size	Class
(1) Under 10	Small	A
(2) 10 to 20	Medium	B
(3) 20 to 30	Large	C
(4) Over 30	Largest	D

The size classes set up by this mechanical method has an advantage in that the relative position of each class can be understood easily by intuition. Secondly, the gradient classes X, Y and Z whose class boundaries are put at 1.0 and 2.0, are set up as follows :

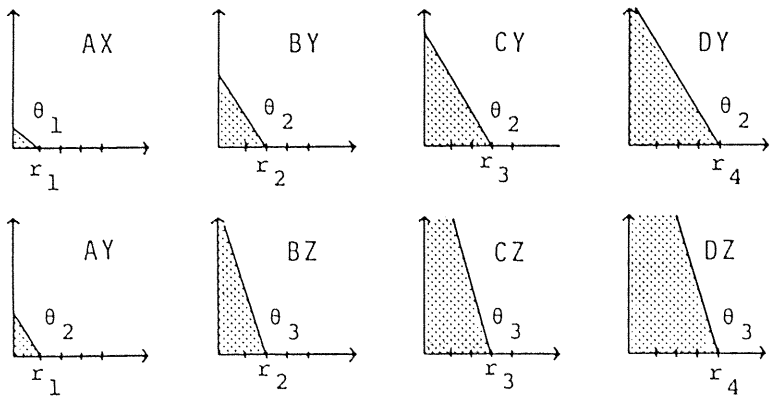
Exponent of distance term in the Pareto equation (b)	Gradient	Class
(1) Under 1.0	Lower	X
(2) 1.0 to 2.0	Medium	Y
(3) Over 2.0	Steeper	Z

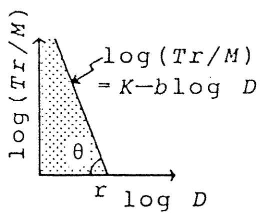
The class boundaries are both round numbers. When the value is equal to 1.0, the weighted number of trips is in inverse proportion to the distance, and when the value is equal to 2.0, the number is in proportion to the square of distance.

Combining these two-dimensional classes, we can set up the types of automotive traffic region. The number of the obtained types amounts to eight. The eight types are named after both of the size and the gradient classes as follows :

Type of automotive traffic region		Size	Gradient
(1)	AX	Small	Lower
(2)	AY	Small	Medium
(3)	BY	Medium	Medium
(4)	BZ	Medium	Steeper
(5)	CY	Large	Medium
(6)	CZ	Large	Steeper
(7)	DY	Largest	Medium
(8)	DZ	Largest	Steeper

Figure 8 shows the shapes of eight regression lines for eight types. Table 4 shows the name of cities falling under each type of traffic region. According to Table 4, the number of cities falling under type BY account for 28 per cent, the largest majority, and type AX and type AY account for 21 per cent and 24 per cent respectively. These three types together account for 73 per cent. On the other hand, the cities falling under each of the types CY, DY and DZ are a few.





r_1	UNDER 10km
r_2	10 TO 20
r_3	20 TO 30
r_4	OVER 30

$\tan\theta_1$	UNDER 1
$\tan\theta_2$	1 TO 2
$\tan\theta_3$	OVER 2

Figure 8. Genelarized regression lines for the types of automotive traffic region.

TABLE 4

NAME OF CITIES FALLING UNDER EACH TYPE
OF AUTOMOTIVE TRAFFIC REGION

Type	Description	Name of city		
A X (31)	small size lower gradient	Iwatsuki	Tokorozawa	Yono
		Soka	Toda	Hatogaya
		Asaka	Shiki	Wako
		Niiza	Yashio	Misato
		Hasuda	Ichikawa	Noda
		Narashino	Nagareyama	Abiko
		Kamagaya	Musashino	Mitaka
		Koganei	Kokubunji	Kunitachi
		Tanashi	Hoya	Higashiyamato
		Kiyose	Higashikurume	Tama
		Kawasaki		
A Y (36)	small size medium gradient	Yuki	Iwai	Kawaguchi
		Hanno	Kazo	Kasukabe
		Sayama	Hanyu	Konosu
		Ageo	Koshigaya	Warabi
		Iruma	Okegawa	Kuki
		Kitamoto	Fujimi	Kamifukuoka
		Tachikawa	Fuchu	Akishima
		Chofu	Machida	Kodaira
		Hino	Higashimurayama	Fussa
		Komae	Musashimurayama	Akikawa
		Kamakura	Zushi	Yamato
		Ebina	Zama	Ayase
B Y (42)	medium size medium gradient	Koga	Ryugasaki	Nakaminato
		Takahagi	Kasama	Toride
		Ashikaga	Tochigi	Sano
		Nikko	Oyama	Moka
		Yaita	Tatebayashi	Fujioka
		Annaka	Kawagoe	Urawa
		Omiya	Gyoda	Fukaya
		Funabashi	Kisarazu	Matsudo
		Sakura	Togane	Yokaichiba
		Asahi	Kashiwa	Ichihara
		Yachiyo	Kimitsu	Futtsu
		Hachioji	Yokosuka	Hiratsuka
		Fujisawa	Chigasaki	Sagamihara
		Atsugi	Isehara	Minamiashigara
B Z (19)	medium size steeper gradient	Ishioka	Shimodate	Shimotsuma
		Mitsukaido	Hitachiota	Kiryu
		Isesaki	Ota	Numata
		Shibukawa	Tomioka	Kumagaya
		Chichibu	Honjo	Higashimatsuyama
		Sakado	Sawara	Ome
		Hadano		
C Y (3)	large size medium gradient	Katsuta	Choshi	Yokohama
C Z (12)	large size steeper gradient	Tsuchiura	Kanuma	Imaichi
		Otawara	Kuroiso	Takasaki
		Tateyama	Mobara	Narita
		Katsuura	Kamogawa	Odawara
D Y (2)	largest size medium gradient	Chiba	Tokyo	
D Z (4)	largest size steeper gradient	Mito	Hitachi	Utsunomiya
		Maebashi		

Note : Numerical value in the parentheses refers to the number of cities falling under each of the types. As the explanation in the letterpress, the three cities, Kitaibaraki, Inagi and Miura are excluded from the Table.

CHAPTER III

THE RELATIONSHIP BETWEEN THE TYPES OF AUTOMOTIVE TRAFFIC REGION AND THE CHARACTERISTICS OF CENTRAL CITIES

In this chapter in order to examine the differences among the types of automotive traffic region, we will test the correlations between the types of automotive traffic region and the functional and locational characteristics of the central city statistically.

1. Selected Variables Concerning the Characteristics of Central Cities

The procedure of the selection of variables for the correlation analysis as stated above is two-fold. First, factors which may be related to the differences in the size classes and in the gradient classes of automotive traffic region are postulated, and then examined individually. Secondly, the significant main factors in the first analysis are pooled, and the relationship between those factors and the types of automotive traffic region is statistically examined. In this section, some variables of the urban characteristics that are expected to have the close relations with the size and with the gradient of distance decay of automotive traffic region respectively, will be defined.

1.1 Factors Affecting the Size Element of Automotive

Traffic Region

The factors affecting the size element of automotive traffic region could be divided into three main categories. First of all, the factor of city size is postulated. It is genarally observed that the larger the city is, the larger becomes its tributary area.[3] Such an interdependency can apply to the relationship of size between a city and its automotive traffic region. Secondly, the factor of friction between the city and its neighbouring one (the friction factor) is postulated. An automotive traffic region of one city competes with the other, so that the locations of other cities will limit the extent of its region.[4] Thirdly, the factor of central functions is postulated. The degree of the city's central functions, or the centrality is one of determinants affecting the size of tributary area. The city size is proportional to the centrality, both the centrality and the city size are not always identical.[5] Therefore, we should examine the degree of central functions as the third factor.

The following explanatory variables each of which corresponds to these three factors affecting the size element of automotive traffic region may be defined as follows (Table 5).

V_1 : Day-time population This variable is representative of the city size. It is natural to expect that the larger the city's day-time population is, the larger becomes the automotive traffic region. Since the spatial separation of commuter's working place and residence beyond the boundary of a city is highly taking place in the greater metropolitan region of the southern Kanto nowadays, the day-time population is suitable for the analysis as

TABLE 5

DEFINITION OF EXPLANATORY VARIABLES USED IN THE ANALYSIS, THEIR COEFFICIENTS OF VARIATION, VARIATE TRANSFORMATION AND DATA SOURCE

Variable		Operational definition	Coeff. of variation	Variate transformation	Source
V_1	Day-time population	Population by place of work or schooling	4.351	log X	Census of Population, 1980
V_2	Distance to the nearest city	Linear distance between the city offices (kilometers)	0.629		
V_3	Retail sales per 1,000 population	Dividing annual retail sales(million yen) by night-time population	0.306		Census of Commerce, 1980
V_4	Wholesale sales per 1,000 population	Dividing annual wholesale sales(million yen) by night-time population	1.435	log X	Census of Commerce, 1980
V_5	Ratio of loans to deposits of all banks	Dividing bank loans by bank deposits	0.263		Municipal Year Book of Japan, 1980
V_6	Score of administrative function	According to Okui(1988)	1.094	log(X+1)	Yearbook of Government and Public Offices
V_7	Number of sickbeds per 1,000 population	Dividing number of hospital sickbeds by night-time population	0.665		Municipal Year Book of Japan, 1980
V_8	Number of books in public libraries per 1,000 population	Dividing number of books in public libraries by night-time population	0.831		Statistics on Libraries in Japan, 1980
V_9	Value of manufacturing products per 1,000 population	Dividing value of manufacturing products (million yen) by night-time population	1.381	log X	Census of Manufactures, 1980
V_{10}	Ratio of day-time population to the night time	Dividing day-time population by night-time population	0.115		Census of Population, 1980
V_{11}	Share of automobile	Dividing number of commuting employed persons by private car or bus by total number of commuting employed persons to and from a city	0.436		Census of population, 1980

compared with the night-time population.

V_2 : Distance to the nearest neighbour city This variable is the straight distance to the nearest neighbour city. It is hypothesized that the more distantly the nearest neighbour city locates, the larger becomes the automotive traffic region of the city concerned.

Seven variables V_3 to V_9 in the following are the indices of the degree of central functions. W.Christaller who developed his central place theory, showed such central functions as administration, culture, health, social service, organization of economic and social life, finance, trade, service industries, labor market, and traffic (Christaller,1933). Among these functions, we adopt those which seem to have the close relations with the generation of automobile traffic. It is considered that the respective correlation between each of the variables V_3 to V_9 and the size of automotive traffic region is positive.

V_3 : Retail sales per 1,000 population This variable, an index of the retail trade, suggests the expected level of one central place. The degree to which such a central place exceeds this figure indicates its level of regional centrality (Dickinson,1964). It is hypothesized that the larger this variable value is, the larger becomes the retail trade area.

V_4 : Wholesale sales per 1,000 population This variable is an index of the wholesale trade. The wholesale trade is a basic urban function. It is hypothesized that the larger this variable value is, the larger become the purchasing area and the saling area.

V_5 : Ratio of loans to deposits of all the banks Although the interregional flows of money do not make a direct contribution to the formation of automotive traffic region, the financial organizations located in a city do control the central functions that generate automobile traffic. This variable is an index of the financial function. Generally speaking, the ratio of loans to deposits of banks is higher in a metropolis or in a large city where banks accumulate (Takahashi,1983). It is hypothesized that the higher this ratio is, the larger becomes the financial territory.

V_6 : Score of administrative function This is an index of the regional administrative function of each city. The main branches of national government and of the prefectural offices are considered in determining each city's administrative function. With data from "Yearbook of Government and Public Offices, 1980", we calculated the each city's score of administrative function in an established form (Okui,1988). It is hypothesized that the higher the score is, the larger becomes the public service area.

V_7 : Number of sickbeds per 1,000 population This variable is an index of the health and medical facilities. It is hypothesized that the larger the variable value is, then the more the outpatients come to the city from the surrounding areas, and the larger becomes the medical service area.

V_8 : Number of books in public libraries per 1,000 population This variable is an index of the cultural function. It is hypothesized that the larger the variable value is, the larger becomes the public library's service area.

V_9 : Value of manufacturing products per 1,000 population

The manufacturing industries that are locally oriented[8] organize a commodity distribution area around a city. This variable is an index of manufacturing function. It is hypothesized that the larger the variable value is, the larger becomes the commodity distribution area.

As Table 5 shows, the coefficients of variation of the four variables V_1, V_4, V_6, and V_9 are so high that the logarithmic transformation of the measurements should be applied to them. The reason why we obtain the variate transformation is that the practice of statistical analysis in this chapter is based on Normality of a variable. Through the variate transformation the distribution of a variate approximates to the normal distribution.

1.2 Factors Affecting the Gradient Element of Automotive Traffic Region

A few studies have been done on the magnitude of a gradient which is equivalent to the elasticity of the traffic volume against the traveling distance from a city. Although the meaning of distance parameter contained in Wilson's entropy maximizing model (Wilson,1967) has gradually become clear through recent empirical researches (Ishikawa, 1986 ; Itoh, 1986 et al.), the model differs from the Pareto equation model in that a criterion variable of the former is the discrete variate. This indicates that the distance parameter of the entropy maximizing model has the fundamental difference from the gradient element of the present study.

When we examine scatter diagrams showing the relationship between the weighted number of trips and the distance for each of 149 cities, two factors come to be postulated.

First, the factor of the city's local centrality is postulated. A city with a steeper gradient has many surrounding areas with high weighted number of trips in the short distances of 5 to 20 kilometers. An example of Mito-shi with a steeper gradient (b =2.577) is shown in Figure 9. It is clear from this figure that there are many plots in the upper left part of the diagram. These plots (surrounding areas) coincide with such areas as Katsuta, Nakaminato, Hitachiota and Kasama cities, each of which is located in the vicinity of Mito-shi, and towns or villages of Higashiibaraki and Naka-gun in the central-northern part of Ibaraki prefecture. The automobile traffic between Mito-shi and its neighbouring areas makes the city's gradient steeper (class Z). In general, such a city as Mito which has many dependent surrounding areas is regarded as a central place in its sphere of living.

Another factor, the dependency upon automobiles is postulated. As for the scatter diagram of Musashino-shi with a less steep gradient (b =0.832), the whole positions of plots are located in the lower part of the diagram (Figure 10). Since the retail trade functions, including the department stores, are concentrated in the Kichijoji district of Musashino-shi, the city's local centrality must be high. Nevertheless, the gradient of distance-decay of Musashino-shi is lower (class X). This is perhaps because most of the customers from the surrounding areas come by suburban railways, that is, the Chuo line or the Inokashira line. Given two cities A and B of equal centrality,

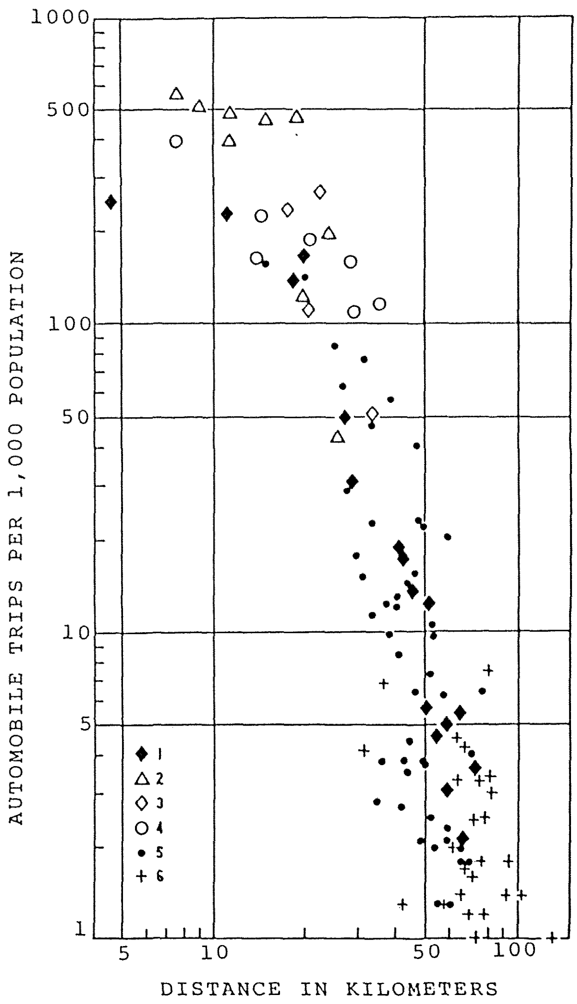


Figure 9. Association between weighted number of automobile trips centering around Mito-shi and linear distance.

1: City of Ibaraki prefecture, 2: Town or village of Higashiibaraki-gun, 3: Town or village of Nishi-ibaraki-gun, 4: Town or village of Naka-gun, 5: Other town or village of Ibaraki prefecture, 6: Town or village outside Ibaraki prefecture.

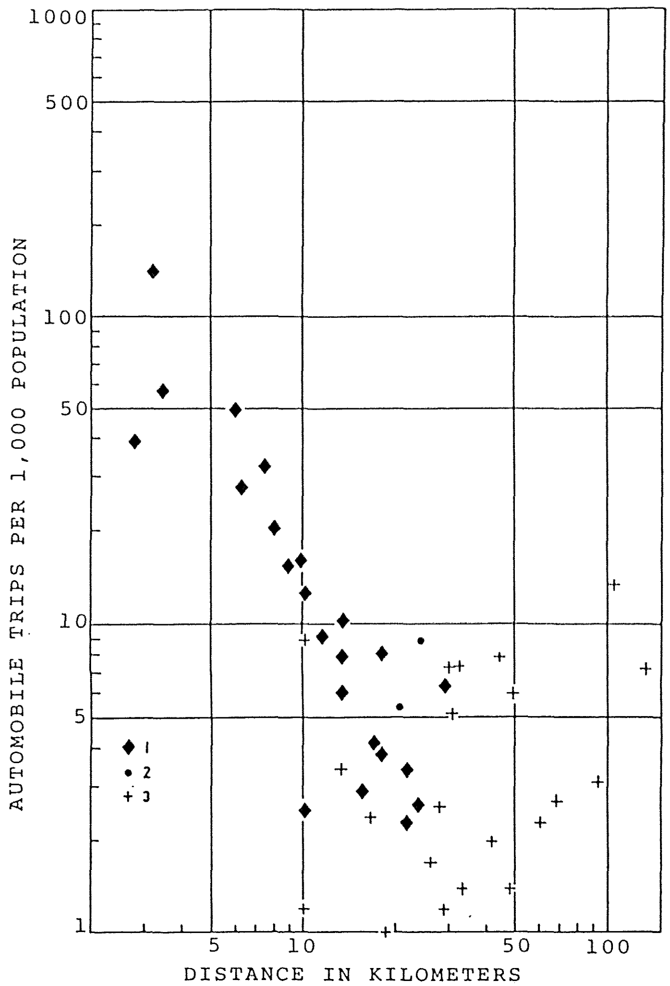


Figure 10. Association between weighted number of automobile trips centering around Musashino-shi and linear distance.
1: City of Tokyo metropolitan prefecture, 2: Town or village of Nishitama-gun, 3: City, town or village outside Tokyo metropolitan prefecture.

the gross magnitude of interaction generated between each city and its surrounding areas ought to be theoretically equal. Given that city A has a railway station and that city B does not have it, the dependency upon automobile traffic in city A's external interaction may be smaller than that in city B's. As a result, the weighted number of automobile trips between city A and its surrounding areas is estimated to be lower on the whole.

Two explanatory variables each of which corresponds to respective factors affecting the gradient element of automotive traffic region may be defined as follows (Table 5):

V_{10} : Ratio of day-time population to night-time population
This variable is an index of local centrality. It is hypothesized that the higher the variable value is, the steeper becomes the gradient.

V_{11} : Share of automobile This variable measures the proportion of automobile traffic volume to the gross volume of traffic flows generated between a city and its surrounding areas. Except the commuter traffic,[7] no other data exists in terms of the share of traffic modes. Figure 11 shows the distribution of values of this variable. It is interesting to note that the share of automobile is low around the city of Tokyo where the railways have dense networks, while it is higher in the northern Kanto district.

2. The Statistical Discriminant Function

In order to investigate the correlation between the types of automotive traffic region and the characteristics of the

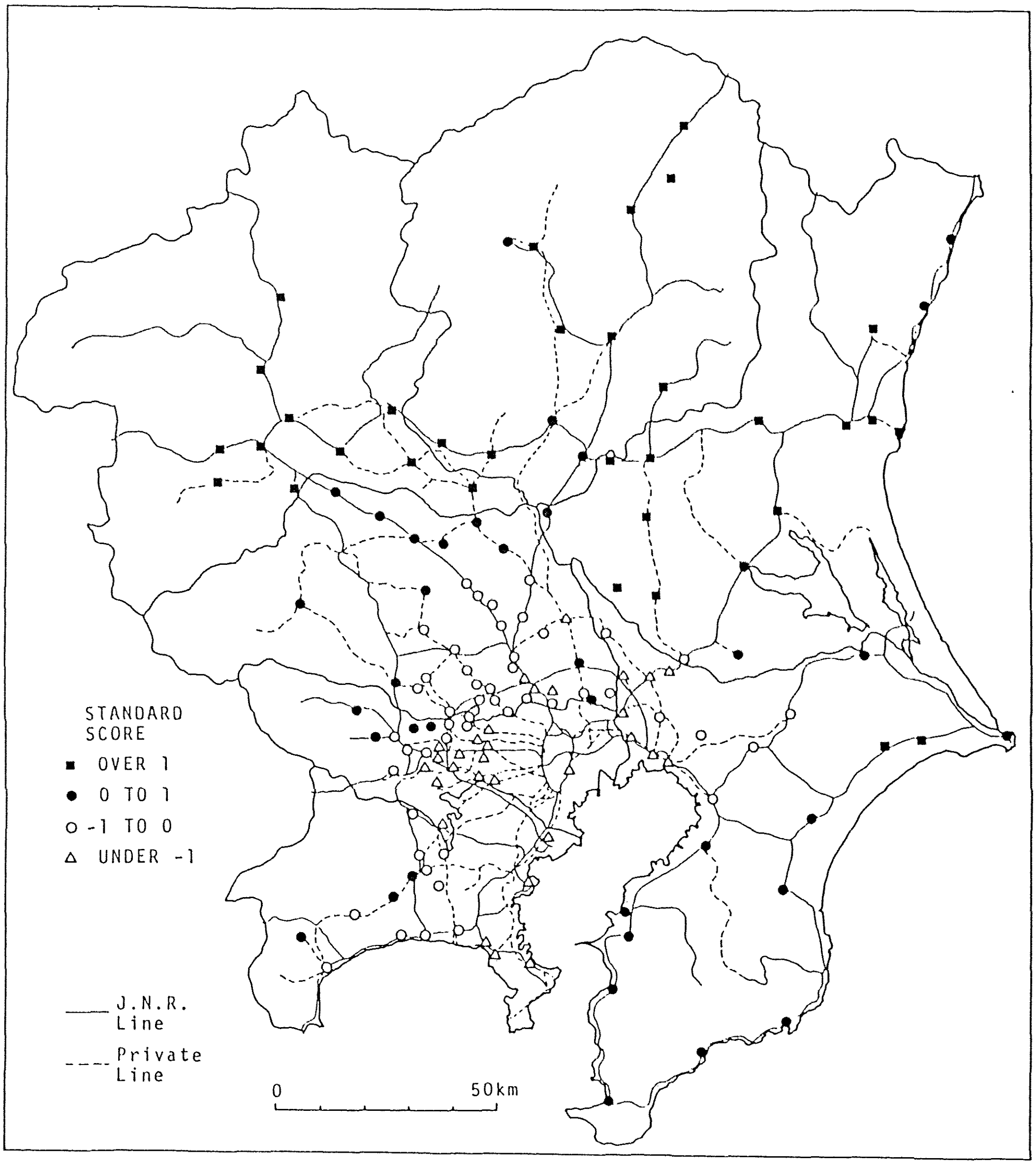


Figure 11. Distribution of measured values of the explanatory variable V_{11} (share of automobile), 1980.

central city, the statistical discriminant function can be employed. The purpose of this statistical analysis model is not only to aid in the classification of an individual observation into one of more than two groups so as to reduce the possibility of misclassification, but also to describe the differences between groups like a factorial experiment such as multivariate analysis of variance (Lachenbruch,1975). In geographical researches to date, the discriminant function has often been used to check up on the errors in the sample by reassigning the set of observations (areas) to the obtained function, or to explain and test the differences between groups (King,1967 ;Ito et al.,1976 ;Sugiura,1978).

A linear discriminant function is defined as follows:

$$S_1=c_1^{(1)}X_1+c_2^{(1)}X_2+\cdots+c_r^{(1)}X_r \ , \qquad (8)$$

where S_1 is a discriminant function for group G_1, $c_r^{(1)}$ is a weighting coefficient (discriminant coefficient) for variable X_r. These weighting coefficients are estimated in order that the within-group variance is minimized, while the between-group variance is maximized. The value for observation *k* in the group G_1 on the *m*th discriminant function is defined as follows:

$$S_{1mk}=\Sigma\ c_{m1}\cdot X_{1k1} \quad i=1,\cdots r \ , \qquad (9)$$

where *r* is the number of variables, X_{1k1} is the measured value on variable *i* for observation *k* in the group G_1. The significance testing for the discriminant functions is based on the likelihood ratio test.

The discrimination between the types of automotive traffic region is to be carried out following the flow chart of the analyses illustrated in Figure 12.

In the first place, the four-group discrimination between the size classes A, B, C and D is performed. A stepwise discriminatory analysis is adopted to inspect whether those explanatory variables V_1 to V_9 defined in the previous section are valid for the four-group discrimination.

Secondly, the three-group discrimination between the gradient classes X, Y and Z is performed. For the same reason with the first analysis, a stepwise discriminatory analysis is also adopted using the explanatory variables V_{10} and V_{11}.

Thirdly, those explanatory variables selected through the preceding analyses are pooled, and the eight-group *discrimination* between the types of automotive traffic region is performed across them.

3. The Discrimination between Size Classes and the Discrimination between Gradient Classes

The selection of variables was performed using a stepwise discriminatory analysis. First, the useful variables for discrimination between the four size classes were selected from the variables V_1 to V_9. As a result, the six variables V_1, V_2, V_3, V_4, V_6, and V_9 were chosen. The corresponding coefficients on the four functions for the six selected variables are given in Table 6. The significance test for these discriminant functions was

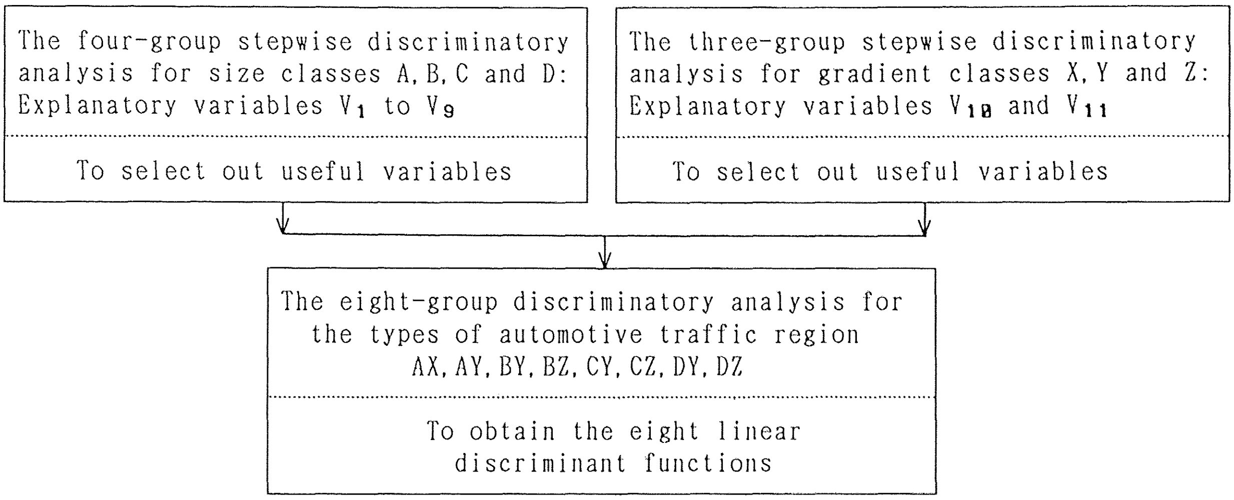


Figure 12. Analytical procedure for discrimination between the types of automotive traffic region.

TABLE 6

WEIGHTING COEFFICIENTS OF DISCRIMINANT FUNCTION FOR EACH OF THE SIZE CLASSES

Variable	Size Class			
	A	B	C	D
V_1	0.14	−0.51	0.42	2.51
V_2	−1.08	0.39	2.35	1.96
V_3	−0.20	−0.05	1.11	0.37
V_4	0.03	−0.30	−0.02	1.82
V_6	−1.22	1.48	−0.24	−0.01
V_9	−0.32	0.27	0.51	−0.40

Note : V_1 : Day-time population, V_2 : Distance to the nearest neighbour city, V_3 : Retail sales per 1,000 population, V_4 : Wholesale sales per 1,000 population, V_6 : Score of administrative function, V_9 : Value of manufacturing products per 1,000 population.

carried out by the likelihood ratio test. As a result of-calicculating a chi-square statistic across the measured values of the six variables on 149 cities, it became 200.2. With 18 degrees of freedom the chi-square is significant at the 1 per cent confidence level. The null hypothesis that a mean of the population is common to the four classes ought to be abandoned. Thus, it was found that the four functions discriminated sufficiently between the size classes A, B, C and D. With the result of analysis, two variables concerning the city size and the friction factor and four variables of the urban central functions, that is, retail, wholesale, administrative and manufacturing functions were selected. Three variables concerning the socio-cultural function, on the other hand, were not chosen.

Secondly, it was examined whether two variables V_{10} and V_{11} are valid for the discrimination between the three gradient classes. The stepwise discriminatory analysis showed that both variables were chosen. The weighting coefficients on the three functions for the two variables are listed in Table 7. The significance test for these discriminant functions was made based on likelihood ratio test. As a result of calculating a chi-square across the measured values of the two variables on 149 cities, the statistic became 80.0. With 4 degrees of freedom it proved to be significant at the 1 per cent confidence level. Therefore it is clear that the discriminant functions separate the gradient classes X, Y and Z . The weighting coefficients for two variables are differentiated similarly between the three classes. Both variables, namely, the ratio of day-time population to the night-time and the share of automobile discriminate the dif-

TABLE 7

WEIGHTING COEFFICIENTS OF DISCRIMINANT FUNCTION FOR EACH OF THE GRADIENT CLASSES

Variable	Gradient class		
	X	Y	Z
V_{10}	−0.64	−0.09	0.83
V_{11}	−0.94	−0.15	1.16

Note : V_{10} : Ratio of day-time population to the night-time,
V_{11} : Share of automobile.

ferences between the gradient classes.

4. The Discrimination between the Types of Automotive Traffic Region

Before undertaking a discriminatory analysis of the types of automotive traffic region, variance ratio tests were applied to confirm that the eight group means of each explanatory variable differ significantly (Table 8). As a result, the difference of means between the eight types of automotive traffic region was significant at the 1 per cent confidence level for each of the seven variables, that is, day-time population (V_1), distance to the nearest neighbour city (V_2), retail sales per 1,000 population (V_3), wholesale sales per 1,000 population (V_4), score of administrative function (V_6), ratio of day-time population to the night-time (V_{10}) and share of automobile (V_{11}). By contrast, for the variable V_9 or value of manufacturing products per 1,000 population, the difference of group means was not significant at the 5 per cent confidence level. Despite the result of variance ratio test, the manufacturing variable V_9 was included into the following discriminatory analysis because the variable was expected to be useful by joining with other seven variables for discrimination between the types of traffic region.

Subsequently, a discriminatory analysis of the eight types of automotive traffic region was carried out using the eight explanatory variables which were selected in the preceding stepwise discriminatory analyses. The significance of the obtained discriminant functions was tested. As a result of cal-

TABLE 8

VARIANCE RATIO TEST OF THE EXPLANATORY VARIABLES USED IN DISCRIMINATORY ANALYSIS OF THE TYPES OF AUTOMOTIVE TRAFFIC REGION

Variable	Between-group variance	Within-group variance	Variance ratio(F)
V_1	6.72	0.72	9.33^{**}
V_2	10.61	0.51	20.62^{**}
V_3	5.97	0.75	7.97^{**}
V_4	6.25	0.75	8.34^{**}
V_6	10.47	0.52	20.07^{**}
V_9	1.56	0.98	1.60
V_{10}	9.88	0.57	17.34^{**}
V_{11}	9.52	0.59	16.24^{**}

Note : V_1 : Day-time population, V_2 : Distance to the nearest neighbour city, V_3 : Retail sales per 1,000 population, V_4 : Wholesale sales per 1,000 population, V_6 : Score of administrative function, V_9 : Value of manufacturing products per 1,000 population, V_{10} : Ratio of day-time population to the night-time, V_{11} : Share of automobile. ** : $P<0.01$.

culating a chi-square value across the measurements of the eight variables on 149 cities, it became 301.3. With 56 degrees of freedom the statistic was significant at the 1 per cent confidence level. And the null hypothesis that a population mean is common to the eight groups shoud be rejected. As a result of the above statistical test, these discriminant functions distinguish between the eight types of automotive traffic region in relation to the urban functional and locational characteristics. The weighting coefficients listed in Table 9 provide the discriminant functions each of which corresponds to the eight types of automotive traffic region respectively.

This indicates that there is a significant correlation between the types of automotive traffic region and the various determinants, which are composed of not only those derived from the discrimination between the size classes such as city size, friction factor and urban central functions, but also those derived from that between the gradient classes such as urban centrality on a local level and dependency upon automobiles. In other words, it is clear that differences between the types of automotive traffic region are closely related to the variables selected here showing the urban characteristics.

Because the types of automotive traffic region have a significant relationship with the urban characteristics, it is necessary to clarify the nature of cities that fall under each type.

Figure 13 shows mean values of eight explanatory variables for every type of automotive traffic region. The origin of the vertical axis in Figure 13 is equivalent to the grand mean[8]

TABLE 9

WEIGHTING COEFFICIENTS OF DISCRIMINANT FUNCTION FOR EACH OF THE TYPES OF AUTOMOTIVE TRAFFIC REGION

Variable	Type of automotive traffic region							
	AX	AY	BY	BZ	CY	CZ	DY	DZ
V_1	−0.50	−0.58	−0.22	−0.11	4.39	0.29	7.52	4.01
V_2	−1.19	−1.01	−0.00	1.19	2.48	2.45	4.23	0.77
V_3	−0.26	−0.09	−0.33	0.66	0.63	1.14	−0.97	0.20
V_4	−0.06	0.53	−0.46	−0.37	0.27	−0.37	1.97	0.73
V_6	−1.20	−0.98	1.41	1.53	−2.44	0.14	−3.16	0.23
V_9	−0.23	0.17	0.02	0.32	0.07	0.21	−1.80	−1.33
V_{10}	0.10	−0.68	0.32	−0.28	−0.42	0.75	3.12	0.57
V_{11}	−1.55	−0.87	0.28	1.72	2.27	0.81	0.24	4.35

Note : V_1 : Day-time population, V_2 : Distance to the nearest neighbour city, V_3 : Retail sales per 1,000 population, V_4 : Wholesale sales per 1,000 population, V_6 : Score of administrative function, V_9 : Value of manufacturing products per 1,000 population, V_{10} : Ratio of day-time population to the night-time, V_{11} : Share of automobile.

Figure 13. Mean values of eight explanatory variables in each of discriminant function by eight types of automotive traffic region.
Solid line: Before discriminatory analysis (See Table 4), dotted line: According to Bayesian optimal discrimination (See Fig. 18). One unit on the vertical axis is equal to a standard deviation of each variable's standard score, and graduations on the horizontal axis indicate each variable's code number. 1: Day-time population, 2: Distance to the nearest city, 3: Retail sales per 1,000 population, 4: Wholesale sales per 1,000 population, 6: Score of administrative function, 9: Value of manufacturing products per 1,000 population, 10: Ratio of day-time population to the night-time, 11: Share of automobile.

for 149 cities. The solid line shows the actual mean values, while the dotted line shows the theoretical ones that are computed according to a result of the Bayesian optimal discrimination (See Chapter IV). The solid line and the dotted line resemble each other in shape. The nature of cities that fall under each type is explained in Figure 13.

The mean values of type AX are below the grand means for all the variables. Despite the size of population (mean value of the solid line -0.07), the levels of central functions and the ratio of day-time population to the night-time (-0.71) are low, so that the nature of this type is interpreted as one like a satellite city (Table 10). Similarly, the nature of type AY is interpreted as one like a satellite city, because a mean value is lower than the grand mean without exceptions. The deviations from the grand means for this type are smaller than those for type AX, and it is considered that type AY's independency against a mother city is somewhat higher.[9] As for a variable of share of automobile, the mean value of type AY (-0.46) is higher than that of type AX (-0.79).

The mean values of type BY lie near the grand means. Therefore, it is satisfactory to consider the cities under this type as one of standard cities, which have a number of average urban characteristics within the system of cities in the Kanto district.[10]

As for type BZ, the mean values of central functions are beyond the grand mean in general, although the population (-0.37) is less than its grand mean. In particular, the administrative function (0.74) and the retail one (0.60) do reach higher levels.

TABLE 10

THE NATURE OF CITIES FALLING UNDER EACH TYPE OF AUTOMOTIVE TRAFFIC REGION

Nature of central cities like :	Type of Automotive Traffic Region							
	AX	AY	BY	BZ	CY	CZ	DY	DZ
Satellite city	X	X						
Metropolis							X	
Standard city			X					
Local city				X		X		X
Unknown					X			

Furthermore the share of automobile (1.05) is higher and the distance to the nearest neighbour city (0.88) is longer. Judging from these features, the nature of cities falling under type BZ is interpreted as that of the local cities.

The nature of type CZ resembles that of type BZ as shown in Figure 13. But from the facts that distance to the nearest neighbour city (1.32) is the longest one among the eight types, and that the mean values of retail sales (0.92) and the ratio of day-time population to the night-time (1.05) exceed those of type BZ's, it would seem that the urban centrality of cities falling under type CZ is higher.

Although the nature of cities falling under type DZ is considered as one like a local city, they have the conspiciously higher centrality as compared with types BZ and CZ, from the viewpoint of the population, the central functions and the ratio of day-time population to night one. Therefore, the cities of type DZ appear to be as the regional capitals.

As for type DY, the mean values of population (3.91) and wholesale sales (2.61) overwhelm those of other types, and the ratio of day-time population to the night-time (1.69) and the administrative function (1.68) are fairly high, while the share of automobile (-1.38) is the lowest among all the types. Judging from these features, the nature of cities falling under type DY is interpreted as one like a metropolis. It may be difficult to understand the nature of type CY from Figure 13. Since the number of cities falling under type CY is only a few, the nature of these cities would be interpreted as an exceptional one (Table 10).

CHAPTER IV

THE DISTRIBUTIONAL ORDER OF THE TYPES OF AUTOMOTIVE TRAFFIC REGION IN RELATION TO THE CHARACTERISTICS OF CENTRAL CITIES

In this chapter we will clarify the distributional order of the types of automotive traffic region in relation to the characteristics of central cities. The linear discriminant functions, which have the effect of distinguishing the types of automotive traffic region, were derived from the analysis in the previous chapter. The degree of possibility for each city to fall under each of the eight types in terms of urban characteristics, that is Bayesian posterior probability can be estimated, based upon the discriminant functions.

Thus, by extracting only a central city from three components[11] of the traffic region, the Bayesian posterior probabilities for the city to fall under each of the eight types are estimated, and then an attempt is made to find some order in the eight types through investigating the distribution pattern of the Bayesian posterior probabilities in the Kanto district.

1. The Distribution of the Bayesian Posterior Probability

The Bayesian posterior probabilities for each city are estimated on the basis of eight discriminant functions for the types of automotive traffic region and the prior probabilities that total 149 cities possess.

As the number of cities that fall under each type of traffic region was given in Chapter II, the ratio of the number of cities that fall under each type to the total number of 149 cities was also given. Then, this ratio is calculated as follows.

$$p_i = n_i / \Sigma n_i \quad i=1,\cdots,g \ , \qquad (10)$$

where p_i is the ratio of the number of cities that fall under type $\underline{i}$, n_i is number of cities falling under type $\underline{i}$, Σn_i is total number of cities, and $\underline{g}$ is number of types. This p_i is equivalent to the prior probability. The prior probabilities of the eight types are 0.208(type AX), 0.242(type AY), 0.282(type BY), 0.128(type BZ), 0.202(type CY), 0.081(type CZ), 0.013(type DY) and 0.027(type DZ) respectively.

The discriminant functions for all the types were obtained in Chapter III. These discriminant functions are the linear combinationsof the explanatory variables showing urban characteristics. Equation (9) leads the discriminant score of each city, that is the value of the discriminant function for each type.

The probability for each city to fall under each of the eight types, namely the Bayesian posterior probability, is given by both the prior probabilities and the discriminant scores with the application of Bayes' theorem.[12] The equation to obtain the posterior probability $P(\Pi_i | \mathbf{s})$ for a certain city falling under type $\underline{i}$ is shown as follows.

$$P(\Pi_i | \mathbf{s}) = P(\mathbf{s} | \Pi_i)p_i / \{\Sigma P(\mathbf{s} | \Pi_i)p_i\} \quad i=1,\cdots,g \ , \qquad (11)$$

where **s** is discriminant score vector, p_l is prior probability, and g is number of the types. The maximum and the minimum values of the posterior probability are 1.0 and 0.0 respectively. Furthermore, the sum of the posterior probabilities for each city is 1.0, so that

$$0.0 \leqq P(\Pi_l \mid \mathbf{s}) \leqq 1.0 \ , \qquad (12)$$

$$\Sigma P(\Pi_l \mid \mathbf{s}) = 1.0 \qquad l=1,\cdots,g \qquad (13)$$

The probability values of 1192 (8 × 149) are estimated by using the equation (11).

Figure 14 indicates the distribution of the posterior probabilities by eight types of automotive traffic region. As mentioned above, the posterior probability which is based upon the measurements of explanatory variables showing urban characteristics, indicates the degree of possibility for each city to fall under each of the eight types. In terms of urban characteristics, the areas in which the cities falling under each type tend to emerge are depicted in the distribution map of the posterior probabilities which has this kind of mathematical meaning.

2. Analysis by Centrographic Measures

First of all, tendency of concentration and dispersion on the distribution map of the posterior probabilities is examined. Centrography is a method to measure the spatial distribution

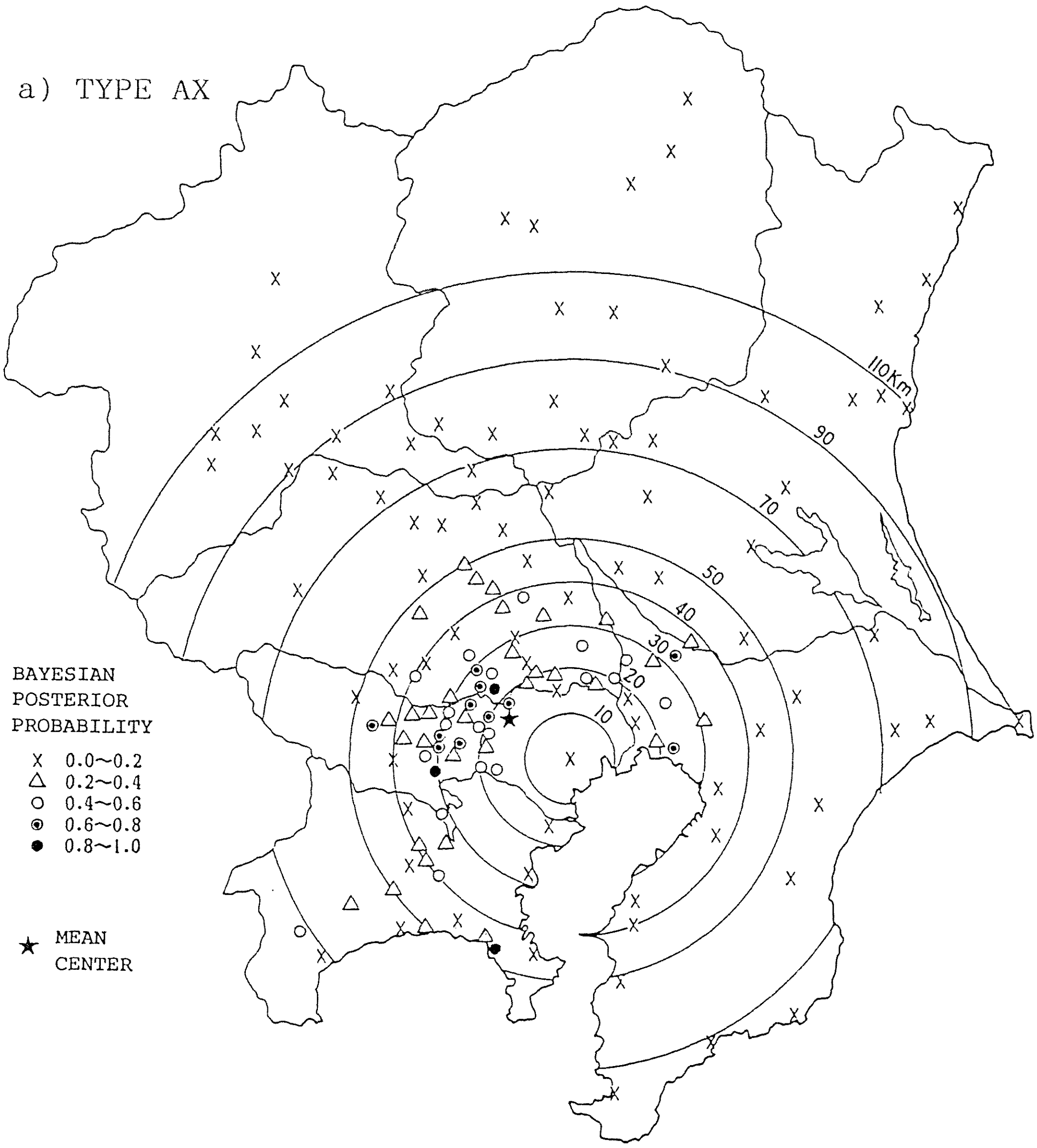
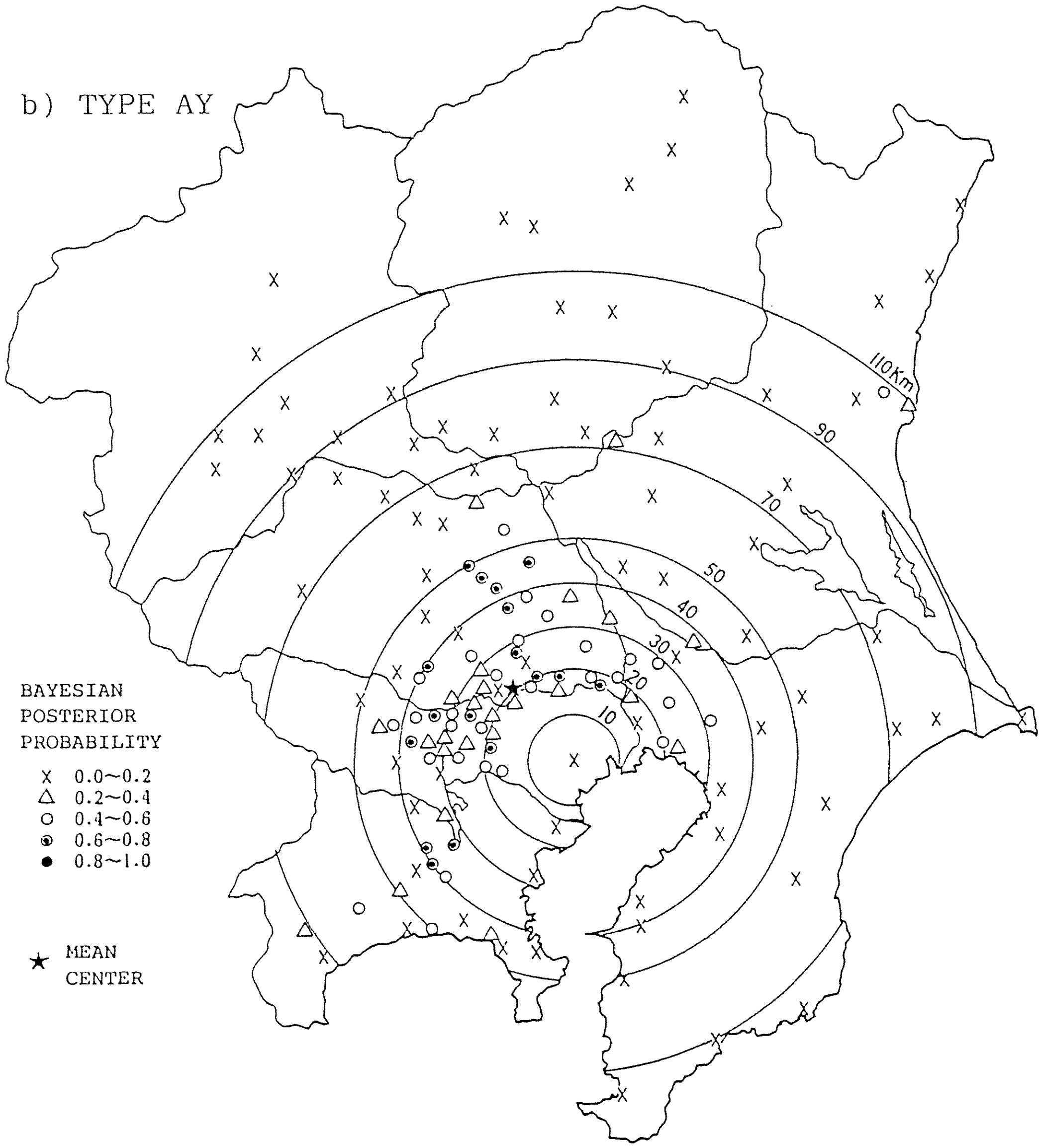
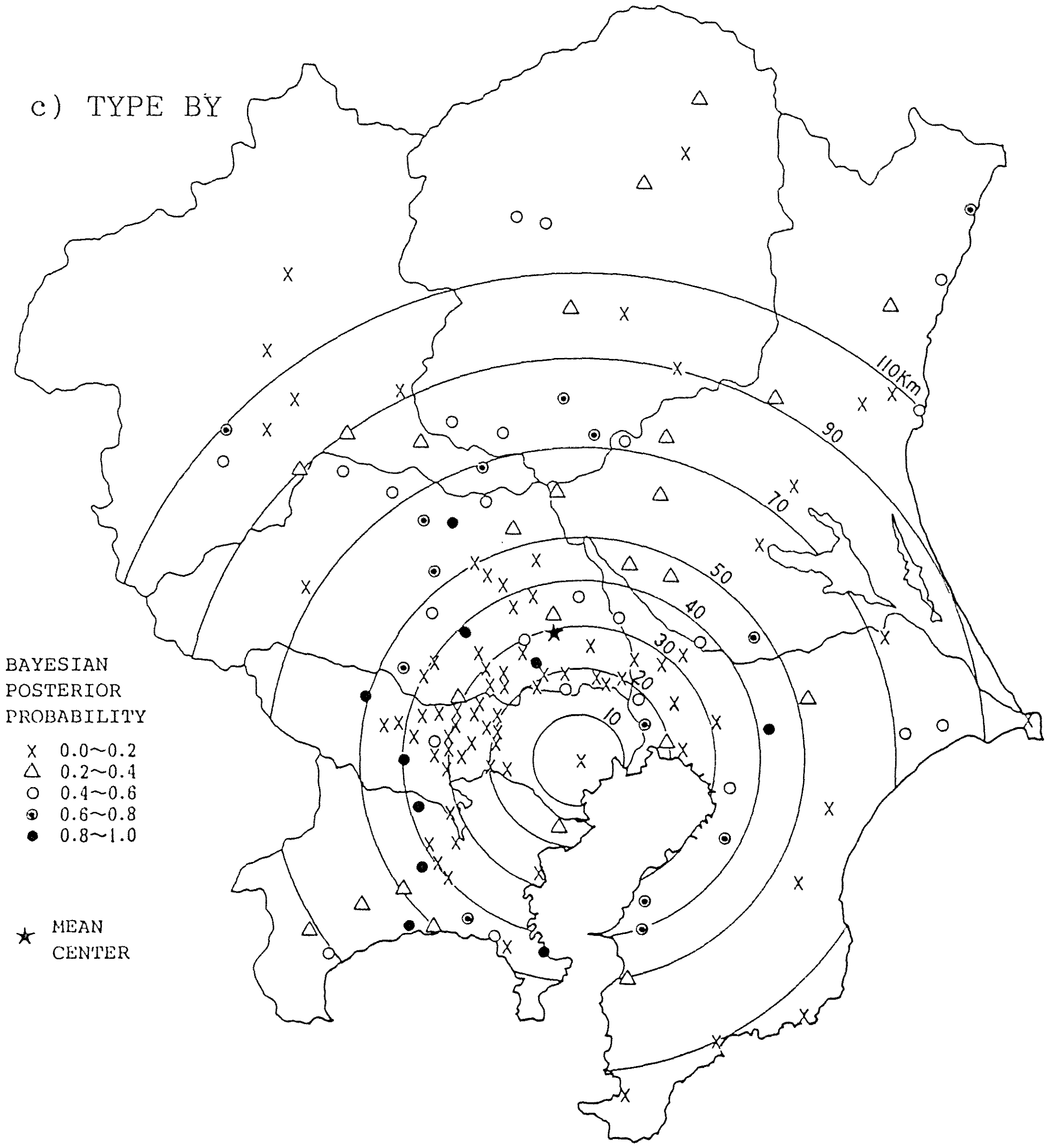
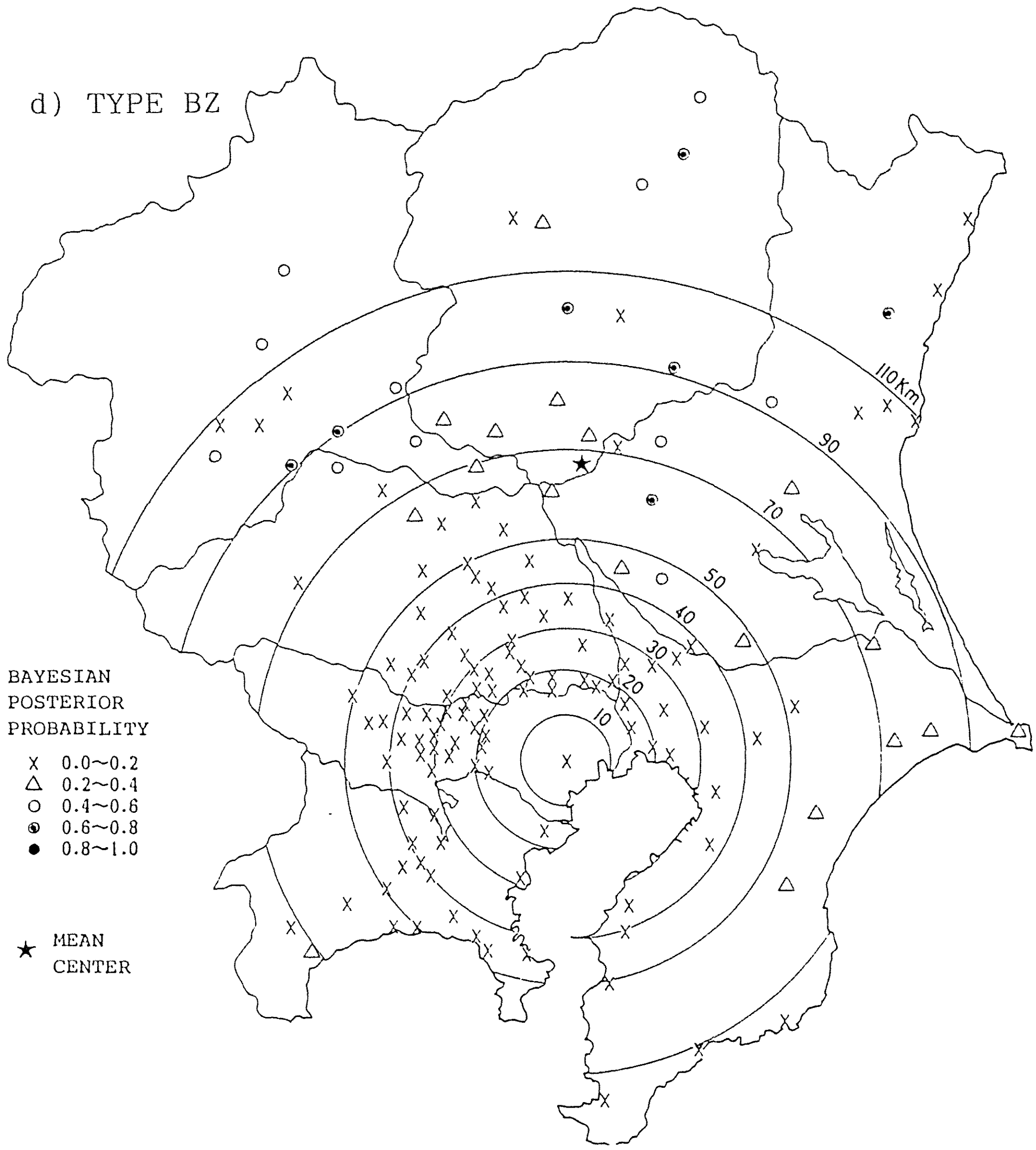


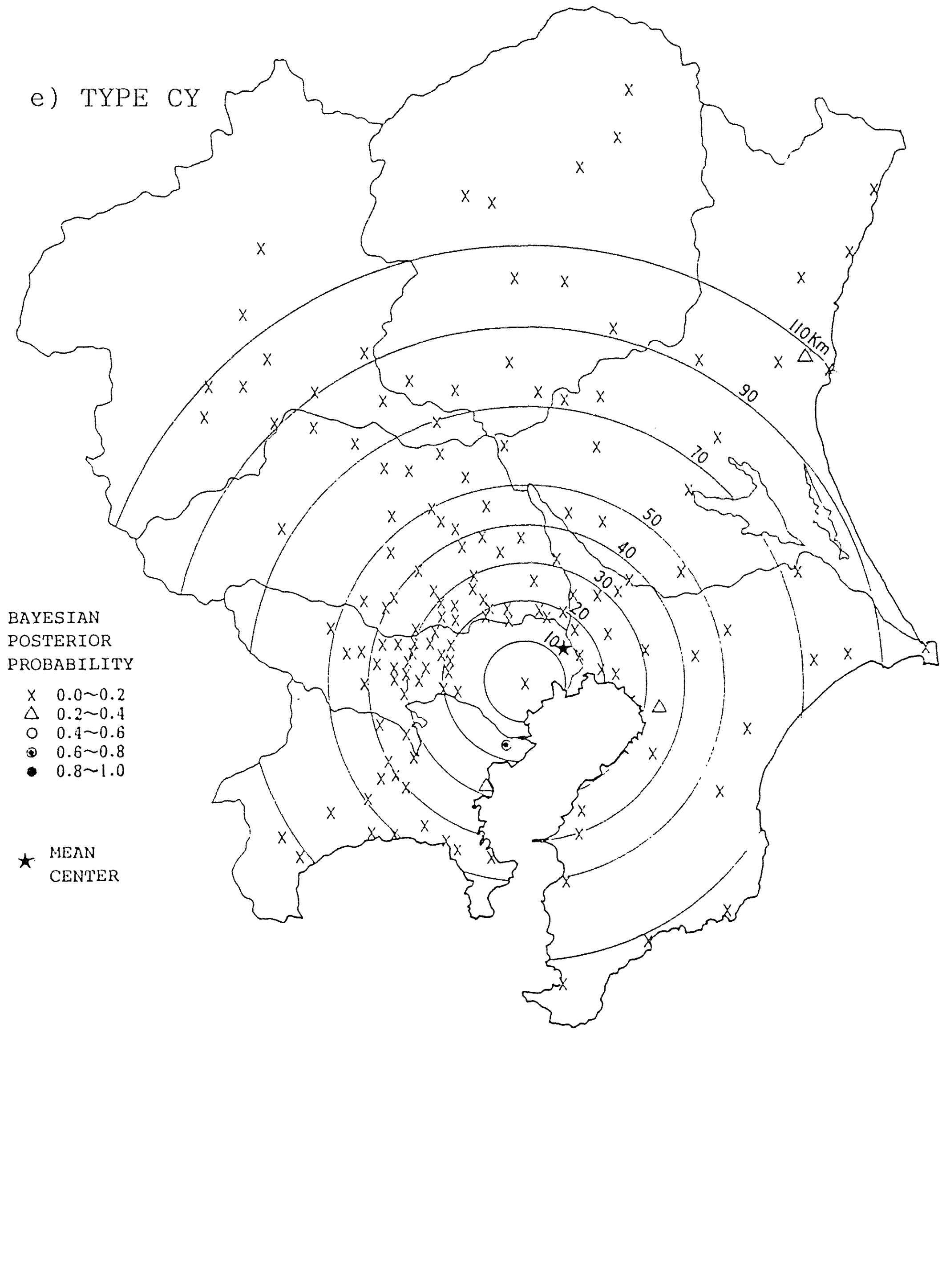
Figure 14. Distribution of the Bayesian posterior probability assigned to each of 149 cities by eight types of automotive traffic region.


b) TYPE AY
110Km
90
70
50
40
30
20
10
BAYESIAN
POSTERIOR
PROBABILITY
X 0.0~0.2
△ 0.2~0.4
○ 0.4~0.6
⊙ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER


c) TYPE BY
BAYESIAN
POSTERIOR
PROBABILITY
x 0.0~0.2
△ 0.2~0.4
○ 0.4~0.6
⊙ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER
110Km
90
70
50
40
30
20
10


d) TYPE BZ
110Km
90
70
50
40
30
20
10
BAYESIAN
POSTERIOR
PROBABILITY
X 0.0~0.2
△ 0.2~0.4
○ 0.4~0.6
⊙ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER

e) TYPE CY


110Km
90
70
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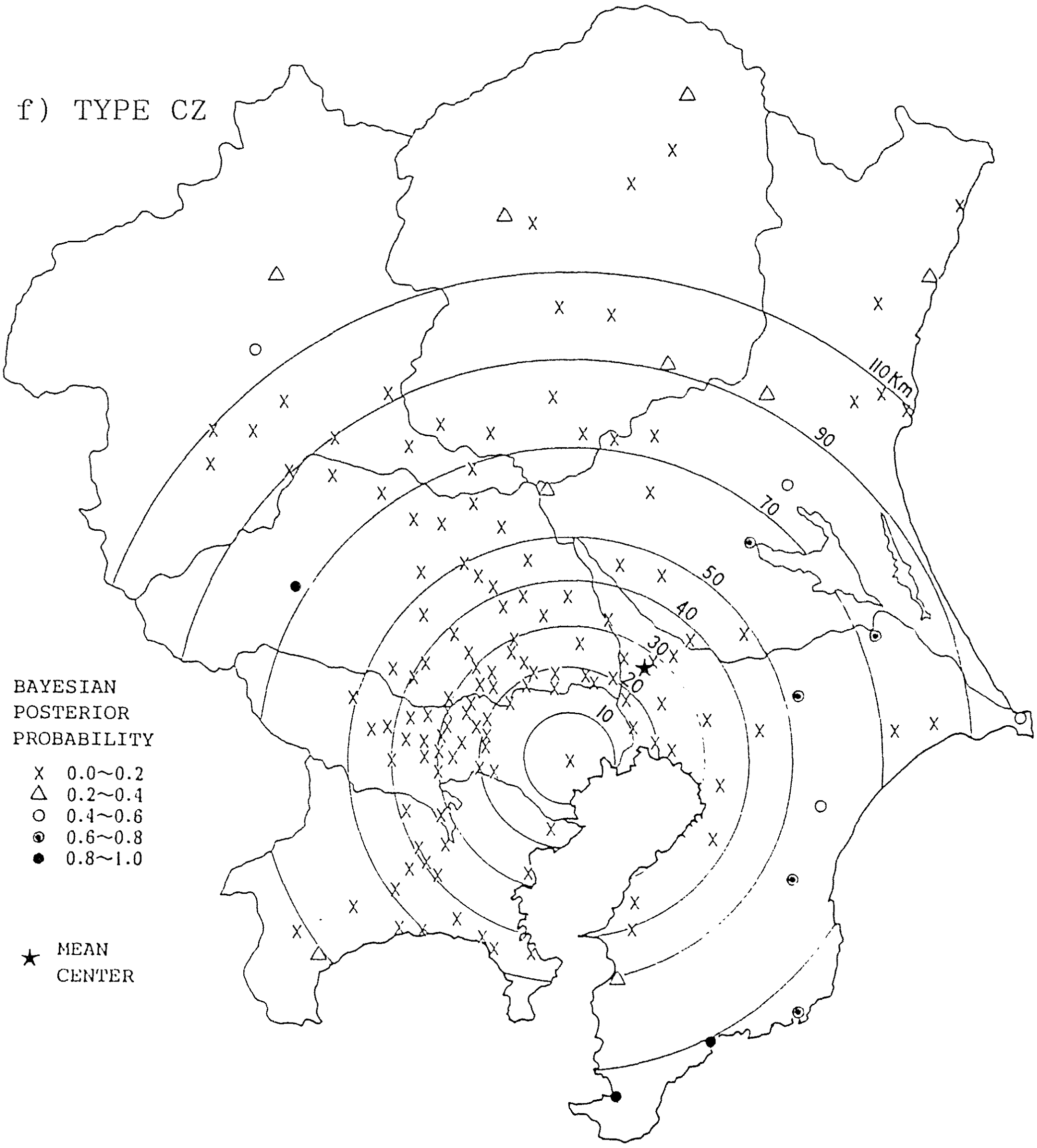
10
BAYESIAN
POSTERIOR
PROBABILITY
X 0.0~0.2
△ 0.2~0.4
○ 0.4~0.6
◉ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER


f) TYPE CZ
BAYESIAN
POSTERIOR
PROBABILITY
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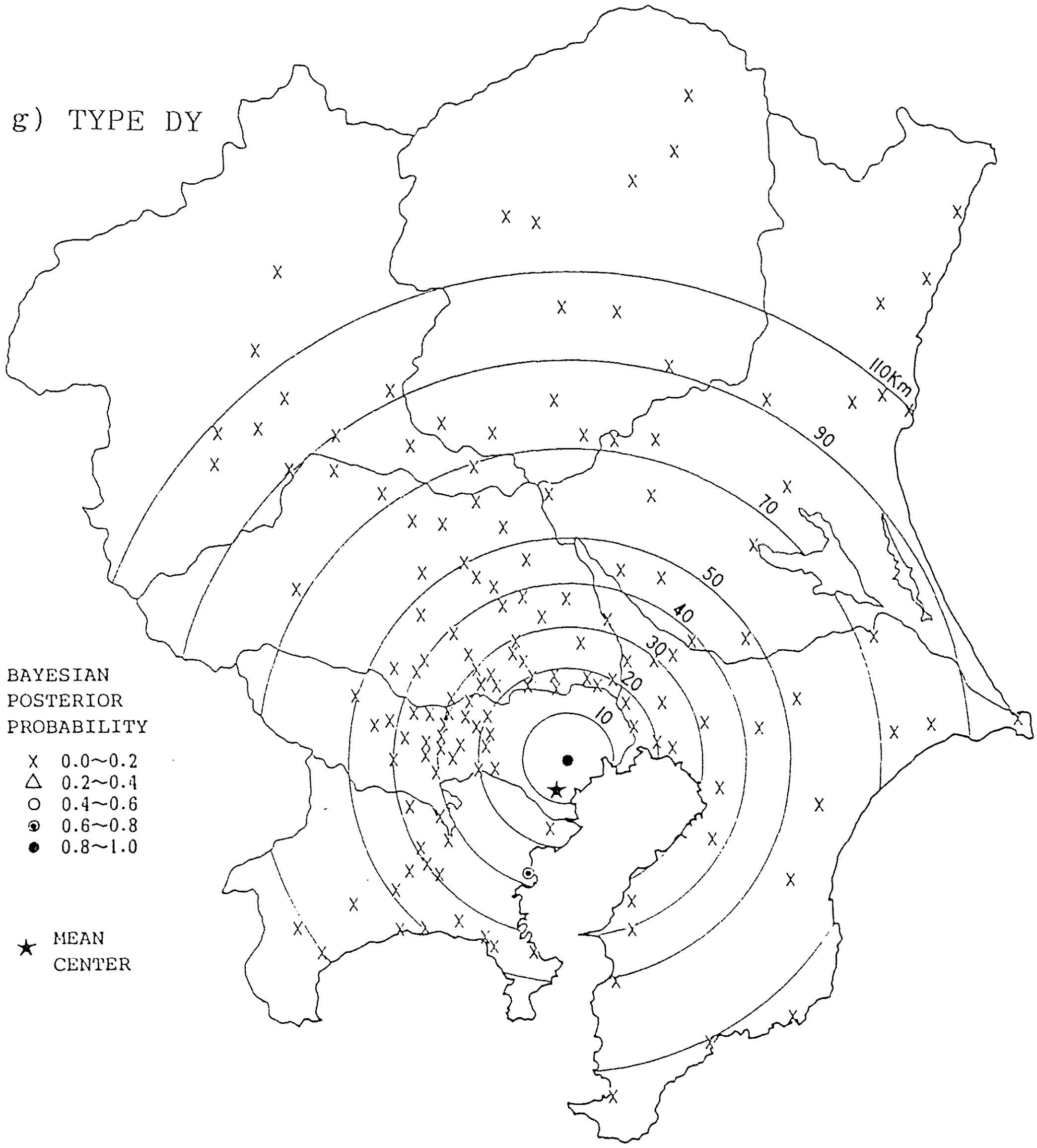
△ 0.2~0.4
○ 0.4~0.6
⊙ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER
110Km
90
70
50
40
30
20
10

g) TYPE DY


BAYESIAN
POSTERIOR
PROBABILITY
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○ 0.4~0.6
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CENTER
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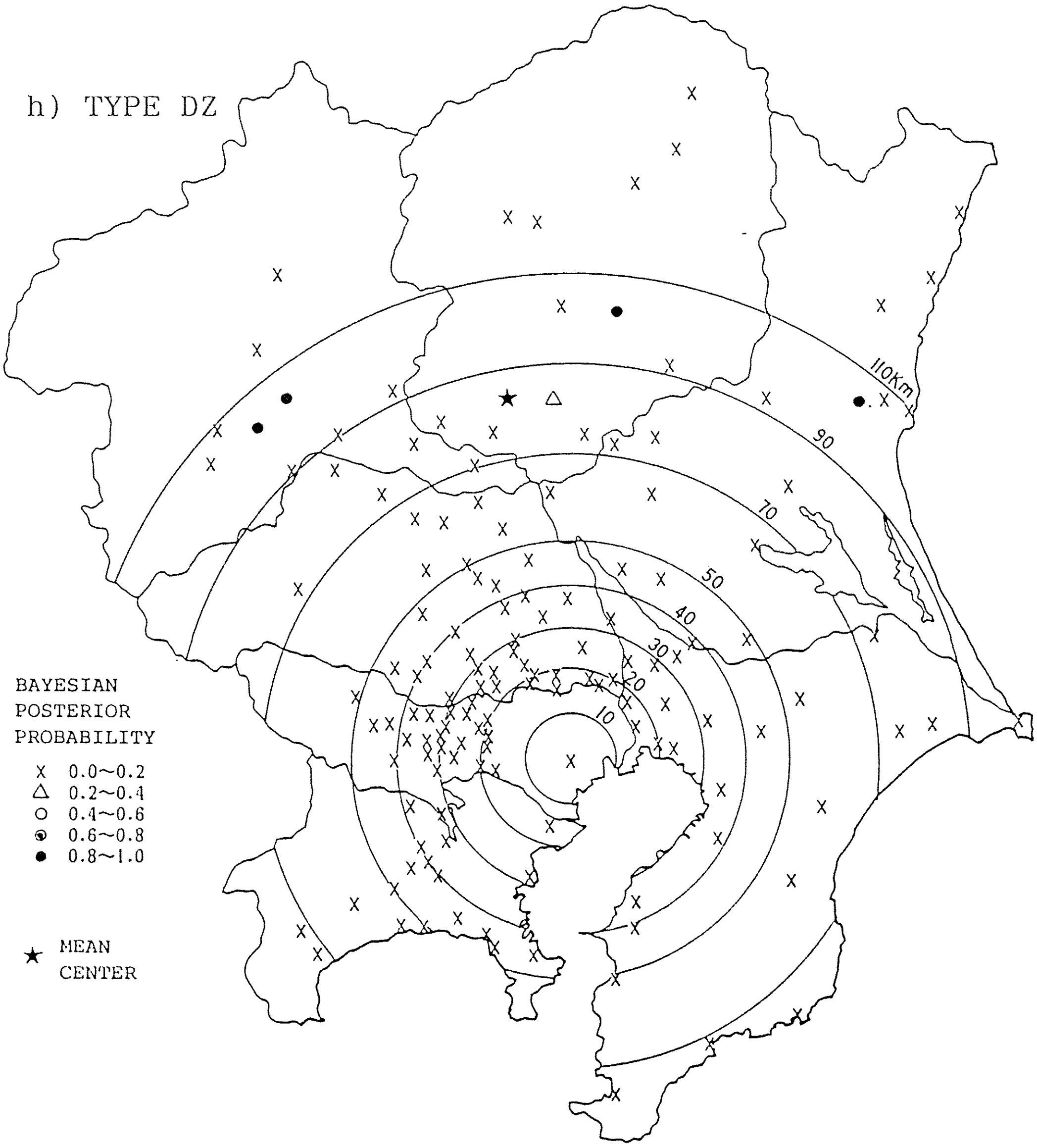
110Km


h) TYPE DZ
BAYESIAN
POSTERIOR
PROBABILITY
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△ 0.2~0.4
○ 0.4~0.6
◉ 0.6~0.8
● 0.8~1.0
★ MEAN
CENTER
110Km
90
70
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20
10

(Bachi, 1968 ; Suzuki, 1968 and so forth). Standard distance, one of the centrographic measures, is an effective index to measure the dispersion of geographical phenomena. This index which is based upon the concept of areal moment is derived from the following procedure.

Now, we set up $\underline{X}$ axis and $\underline{Y}$ axis which are perpendicular to each other on the surface of the Kanto district. And then we define the posterior probability for city $\underline{i}$ to fall under type $\underline{l}$ as Z_{li}, the coordinate of city $\underline{i}$ as (X_i, Y_i), the coordinate of the mean center of distribution of type $\underline{l}$ as $(\overline{X}_l, \overline{Y}_l)$ and the standard distance of type $\underline{l}$ as SD_l.

1) First, the mean center of distribution for each type is determined. The coordinate of each city is fixed at the location of municipal office. The coordinate of the city of Tokyo is set at the location of Tokyo Metropolitan Office. The coordinate of the mean center of type $\underline{l}$ is derived from the equations (14) and (15).

$$\overline{X}_l = (\Sigma Z_{li} X_i) / \Sigma Z_{li} \qquad i=1,\cdots,n , \qquad (14)$$

$$\overline{Y}_l = (\Sigma Z_{li} X_i) / \Sigma Z_{li} \qquad i=1,\cdots,n , \qquad (15)$$

where $\underline{n}$ is total number of cities.

2) SD_l, the standard distance of type $\underline{l}$, is derived from the equation (16).

$$SD_l = \{[\Sigma Z_{li}(X_i - \overline{X}_l)^2 + \Sigma Z_{li}(Y_i - \overline{Y}_l)^2] / \Sigma Z_{li}\}^{1/2} \qquad i=1,\cdots,n \qquad (16)$$

The standard distance which is equal to the one-dimensional standard deviation, is a measure to indicate the areal extent of the posterior probability for each city to fall under type <u>1</u>.

3) The standard distance including all the types is then calculated. Comparison of the areal extents among the types is easily made by employing the ratio of the standard distance of each type to the standard distance of all the types, i.e., the coefficient of dispersion.[13] If the coefficient of dispersion is close to unity, it means that the areal extent of posterior probabilities is on the average. If the coefficient of dispersion is much larger than unity, it means that the distribution of the posterior probabilities is dispersed widely outward from the mean center and high probability values are distributed in the fringe of the study area. On the other hand, if the coefficient of dispersion is much smaller than unity, it means that probability values gather around the mean center and therefore they concentrate on the central parts of the study area.

The locations of the mean centers are shown in Figure 14. As the standard distance including all the types is 42.5 kilometers, the coefficients of dispersion are calculated as shown in Table 11. The maximum value of the coefficients of dispersion is 1.682 (type <u>CZ</u>) and follows 1.346 (type <u>BZ</u>), 1.252 (type <u>BY</u>), 1.181 (type <u>DZ</u>), 1.075 (type <u>CY</u>), 0.659 (type <u>AY</u>), 0.581 (type <u>AX</u>), and 0.386 (type <u>DY</u>). From a viewpoint of the locations of the mean centers and the coefficients of dispersion, the tendency of concentration and dispersion of the Bayesian posterior probabilities by each type is described as follows.

TABLE 11

STANDARD DISTANCE AND COEFFICIENT OF DISPERSION FOR EACH TYPE OF AUTOMOTIVE TRAFFIC REGION

Type	Standard distance	Coeff. of dispersion
A X	24.7	0.581
A Y	28.0	0.659
B Y	53.2	1.252
B Z	57.2	1.346
C Y	45.7	1.075
C Z	71.5	1.682
D Y	16.4	0.386
D Z	50.2	1.181
Total	42.5	1.000

Note : Units of standard distance are given in kilometers.

The higher probabilities of type AX are concentrated in the areas between the western parts of the city of Tokyo and the deep southern parts of Saitama prefecture. This local concentration forms the highly dense belt of cities, which occupies central parts of the southern Kanto. The other higher probabilities of this type are also scattered in Zushi-shi, Narashino-shi and Abiko-shi. The mean center of type AY, which is located near the boundary between Tokyo metropolitan prefecture and Saitama prefecture, is close to that of type AX. The tendency of concentration and dispersion of the distribution of type AY is similar to that of type AX. However, the local concentration of type AY in Saikyo of the southeastern parts in Saitama prefecture and in the central parts in Kanagawa prefecture is a prominent feature, which is not recognized in type AX's distribution.

The distribution map of type BY does not show the local concentration. Comparatively high probability values are widely scattered in the Kanto district. The mean center of type BZ is near Oyama-shi in Tochigi prefecture, whose location is in the northernmost with type DY in the eight types. As the coefficient of dispersion of type BZ is the second largest after type CZ, it confirms that comparatively high probability values are scattered in the northern Kanto.

The coefficient of dispersion of type CY is the closest to the average of eight types. The probability values except for Kawasaki-shi, Yokohama-shi, Chiba-shi and Katsuta-shi are quite low. It is characteristic of this type that small number of cities with high values are prominently distributed. The mean center of type CZ, whose coefficient of dispersion is the highest, is located near Kashiwa-shi in Chiba prefecture. The cities with higher probability of type CZ are dispersed in the fringe of the Kanto district. The cities with higher probability of type BZ are scattered widely in the northern Kanto, while the distribution of type CZ is dominant in the eastern Kanto, especially in the Boso peninsula. And the isolation of Chichibu-shi is noticeable.

The coefficient of dispersion of type DY is the lowest in the eight types. It is characteristic that type DY has only small number of cities whose probability values are very high and this is a great difference with types AX and AY which have also the tendency of concentration. In other words, the cities but for the city of Tokyo and Yokohama have very low probability.

Lastly, the mean center of type DZ is located near Tanuma-machi in Tochigi prefecture. Only Mito-shi, Utsunomiya-shi, Maebashi-shi and Takasaki-shi have remarkably high probability values. The prominent distribution of type DZ in the northern Kanto is a common feature with type BZ, though it differs from type BZ in that only a few cities have high probability values together with types CY and DY.

The tendency of concentration and dispersion on the distribution map has been examined by each type through employing the method of centrography. With all results, it is obvious that the distribution of the posterior probabilities differs greatly with the differences of types. That is to say, both types AX and AY are similar in the point that cities with the higher probability values are distributed around the city of Tokyo like a doughnut shape and form the dense zone, but type AY surrounds a little bit outward parts of this zone. In contrast with these facts, both types BZ and CZ, which have high degree of dispersion, do not form the densely distributed zone. In the case of type BZ the core of the distribution lies in the northern Kanto, and in the case of type CZ in the eastern Kanto. Type BY is uniformly distributed in the Kanto district, whose index of dispersion is close to the average. In the cases of three types of CY, DY and DZ, only a few cities are prominently distributed in the map. These few cities are Kawasaki in type CY, the city of Tokyo and Yokohama in type DY, and three prefectural cities in the northern Kanto and Takasaki-shi in type DZ. The distribution maps of these three types are peculiar in the sense that most cities show very low probability values close to zero.

As a result of applying the centrographic measures to the distribution maps of the Bayesian posterior probabilities, it became clear that some types have the regularity in location with the distance from the city of Tokyo and that some types have the directionality from the city of Tokyo like a rivet of a fan, or a pivot. Then it is indispensable to analyze these dual components.

3. Analysis by Rings and Sectors Centering around the City of Tokyo

First of all, to clarify the regularity in distribution with the distance from the city of Tokyo, we built eight rings demarcated by each circular arc, with the radii of 10, 20, 30, 40, 50, 70, 90, and 110 kilometers respectively centering around the Tokyo Metropolitan Office (Figure 15). The rings are those of

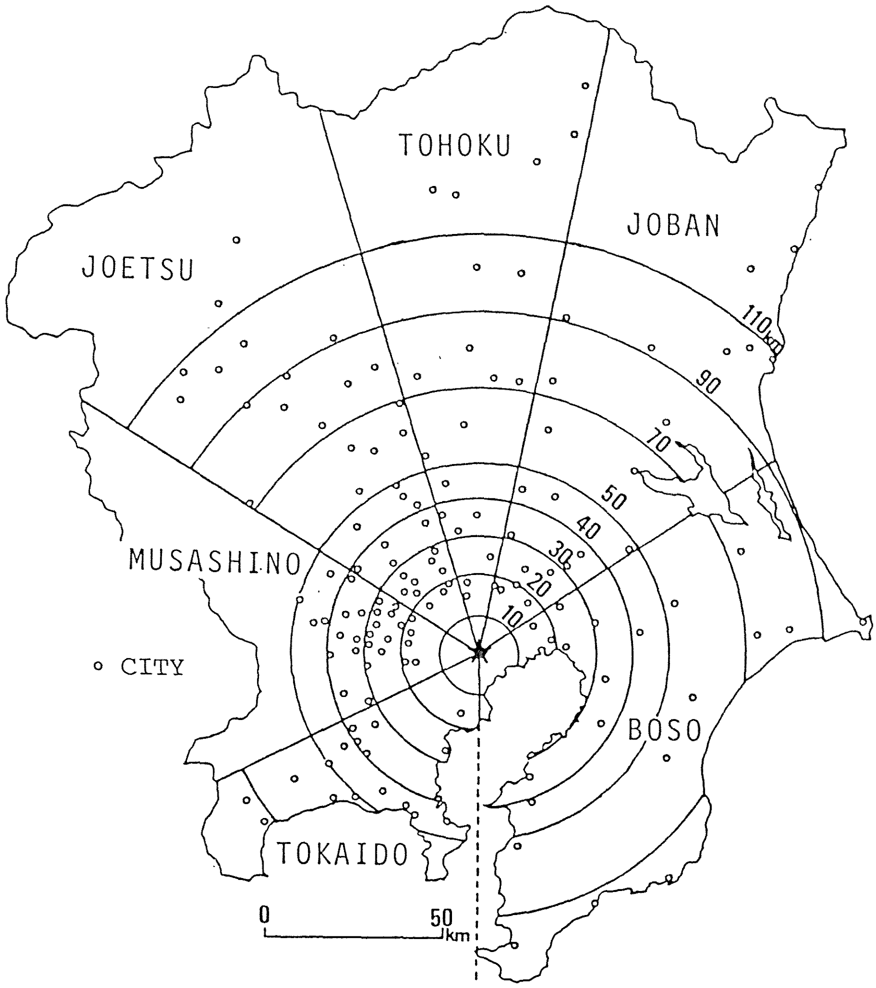

Figure 15. Zonal division map showing the eight rings and the six sectors centering around the city of Tokyo.

1) 10 to 20 kilometers, 2) 20 to 30 kilometers, 3) 30 to 40 kilometers, 4) 40 to 50 kilometers, 5) 50 to 70 kilometers, 6) 70 to 90 kilometers, 7) 90 to 110 kilometers and 8) 110 kilometers and over, in order of the distance from the center. For the purpose of equalizing the number of cities included into each ring, the concentric circles are drawn every 10 kilometers inside the area of 50 kilometers radius where the distribution density of cities is high, and drawn every 20 kilometers outside the area of 50 kilometers radius where the distribution density of cities are comparatively low.

After this procedure, sectors are demarcated by drawing the radial lines originated from the Tokyo Metropolitan Office. This zone division is established to clarify the directionality from the city of Tokyo as the pivot. Based on the longitude line drawn due southward from the Tokyo Metropolitan Office, five radial lines are drawn clockwise at the interval of the angles of 65, 58, 40, 29 and 44 from this longitude line (Figure 15). And then, six sector are demarcated. They are called 1)Tokaido, 2)Musashino, 3)Joetsu, 4)Tohoku, 5)Joban and 6)Boso. The way of establishing this kind of sectors is based upon the research by Naito(1975), whose point is that the population distribution in the Kanto district is agglomerated along the main transportation network stretching radially from the city of Tokyo. Though the Boso sector forms the wider angle as compared with other sectors, this sector does not seem to differ much from other sectors in areal extent because of its curved shape.

The compositions of the posterior probabilities, which are different between rings and between sectors respectively, are outlined in Figure 16. Firstly, an attempt is made to examine how the proportions of the posterior probabilities of the eight types change outward (Figure 16-a). The proportion of type AX is high in the ring from 10 to 20 kilometers, but the highest in the ring from 20 to 30 kilometers. Furthermore, the proportion is gradually decreasing until the ring from 40 to 50 kilometers, and the proportion becomes lowest in the ring from 50 to 70 kilometers, and 70 kilometers and over. Type AY, whose change is similar to type AX, keeps the proportion of 0.4 widely in three rings from 10 to 40 kilometers, and its decline in proportion in the rings over 50 kilometers is not so prominent as type AX. Type BY accounts for constant proportions from 0.2 to 0.4 in the rings over 30 kilometers. Type BY has two peaks, the ring from 40 to 50 kilometers and the ring from 50 to 70 kilometers. Type BZ indicates high proportions in the rings over 50 kilometers, and the highest in the outermost ring over 110 kilometers. Type CZ has high proportions only in the rings over 50 kilometers. The peak of type DZ is shown in the ring from 90 to 110 kilometers. The proportions of type CY are quite low in all rings.

In this way, some types have the distinct regularity in accordance with the distance from the city of Tokyo. In short, the proportions of types AX and AY are high in the rings within 50 kilometers, in contrast to this, these of types BZ and CZ are high in the rings over 50 kilometers. Type BY shows high proportions constantly in the rings from approximately 30 to 40 kilometers to the outermost ring over 110 kilometers. The proportion of type DZ is emerged only in the ring from 90 to 110 kilometers.

Then the analysis of the six sectors is outlined in Figure 16-b. The proportion of type AX is remarkably high in the Musashino sector, but is only about a quarter of it in the Tohoku and Boso sectors. Type AY also has the highest proportion in the Musashino sector, though there exist only small differences between the Musashino sector and other sectors. The proportions of type BY are uniform except the Musashino sector. Type BZ has a high proportion in the northern sectors in Joetsu, Tohoku and Joban. The proportion of type CZ is the highest in the Boso sector. The proportions of type DZ are emerged only in three northern sectors. Types CY and DY have very low proportions in every sector.

In this manner, some types have the distinct directionality centering around the city of Tokyo as the pivot. In other words, the proportion of type AX is prominently high in the Musashino sector. The proportion of type BZ in the northern sectors in Joetsu, Tohoku and Joban, and that of type CZ in the Boso sector are also high.

Lastly, factor effects of the rings and the sectors are quantitatively tested with analysis of variance.[14] The purpose of this statistical test is to examine whether the differences of the posterior probabilities between rings and between sectors respectively are real or whether they can be attributed by chance. The number of levels is eight in rings and six in sectors, respectively. As the number of repeats (the number of cities) in each combination of levels is considerably uneven (Table 12), two-way analysis of variance including interaction was judged to be inappropriate. Therefore, one-way analysis of

TABLE 12

NUMBER OF CITIES BY RINGS AND SECTORS

Sectors	Rings (distance in kilometers)								Total
	10-20	20-30	30-40	40-50	50-70	70-90	90-110	110 and over	
Tokaido	1	1	4	7	2	2	-	-	17
Musashino	5	11	9	4	-	-	-	-	29
Joetsu	3	7	4	4	5	7	5	2	37
Tohoku	2	1	3	1	2	4	2	5	20
Joban	3	3	3	3	2	2	5	3	24
Boso	2	2	4	2	4	6	1	-	21
Total	16	25	27	21	15	21	13	10	148

Note : The city of Tokyo is excluded from the Table.

variance which deals with two factors separately, is employed here by each type.

Table 13 indicates the F-ratios which are derived from analysis of variance. The results of analysis are as follows. Both of the factor effects of the ring division and that of the sector division on types AX, AY, BZ and CZ are significant at the 1 per cent confidence level. On types BY and DZ, only the factor effect of the ring division is significant at the 1 per cent confidence level. But the factor effects of sector division on types BY and DZ, and the ring division and sector division on types CY and DY are not significant at the 5 per cent confidence level. The results of analysis of variance confirm the results of descriptive analysis in the component bar charts in Figure 16.

Comparing the F-ratios of each type among the factors, not only types BY and DZ, which are significant only in rings, but also types AX, AY, BZ and CZ which are significant in both two zonal divisions, have higher F-ratios in rings rather than those in sectors. To sum up, apart from the types CY and DY, which are not significant at the 5 per cent confidence level, the factor effect of rings centering around the city of Tokyo exceeds the factor effect of sectors in the distribution map of posterior probabilities.

In short, on the distribution maps of posterior probabilities, the regularity in accordance with the distance from the city of Tokyo is much clearer than the directionality from the city of Tokyo as a pivot.

TABLE 13

TESTING THE DIFFERENCE OF MEANS OF THE BAYESIAN POSTERIOR PROBABILITY BETWEEN THE EIGHT RINGS AND BETWEEN THE SIX SECTORS BY ANALYSIS OF VARIANCE

Type	Variance ratio (F)	
	Between the rings	Between the sectors
A X	20.3**	7.1**
A Y	13.8**	3.8**
B Y	4.2**	1.1
B Z	21.1**	5.8**
C Y	0.6	2.1
C Z	8.1**	7.2**
D Y	0.7	1.5
D Z	8.7**	1.0

** : $P < 0.01$.

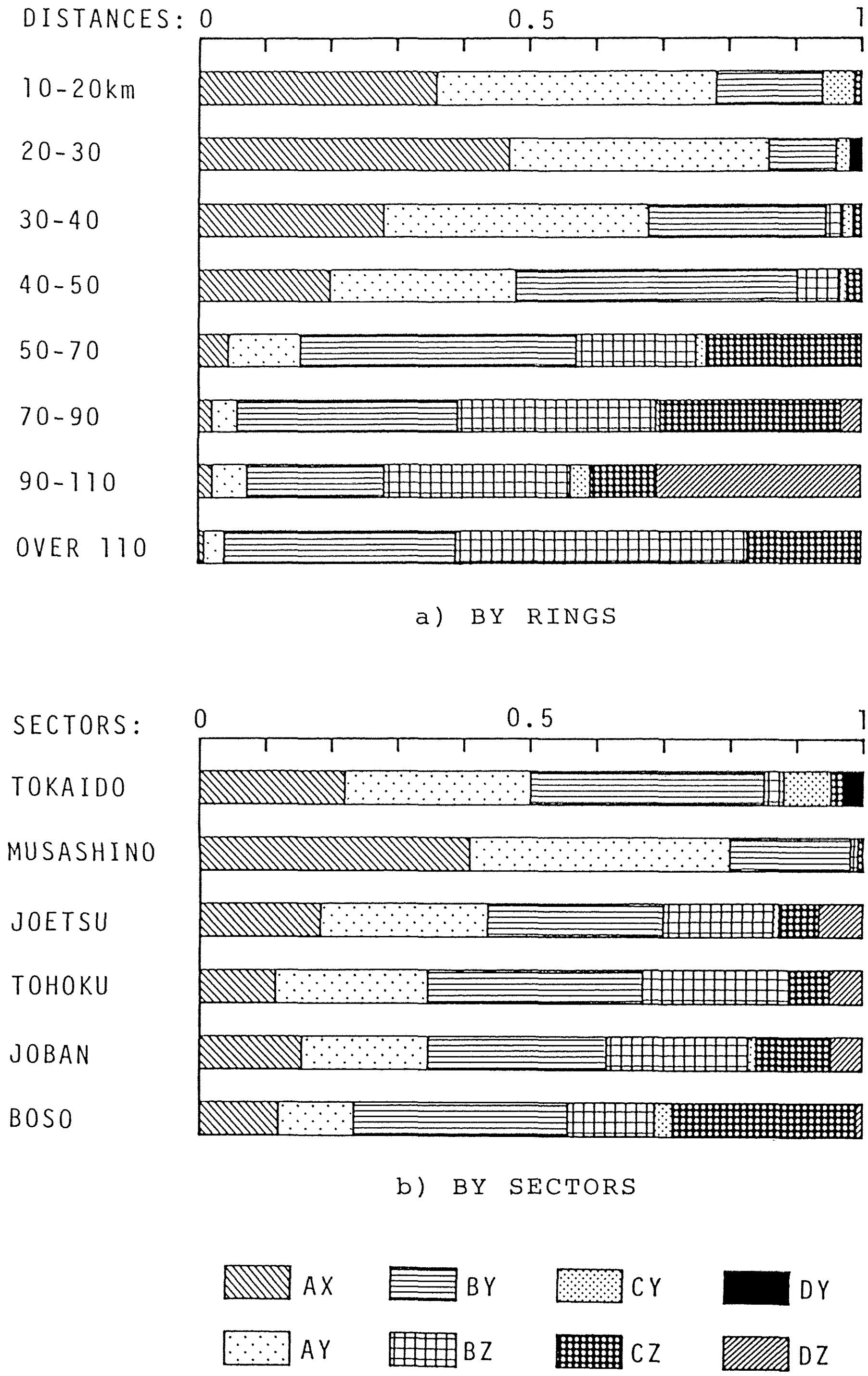

Figure 16. The Bayesian posterior probability by the type of automotive traffic region, by ring and sector.

4. Distributional Order of the Types of Automotive Traffic Region

The distribution of posterior probabilities has been considered in sections two and three of this chapter. First the tendency of concentration and dispersion of the posterior probabilities has been analyzed through the application of centrographic measures, and then the regularity in accordance with the distance from the city of Tokyo and the directionality from the city of Tokyo as the pivot have been examined with the descriptive analysis of component bar charts and the analysis of variance. Based upon the results of these analyses, the distributional characteristics of posterior probabilities, which are different by the types, are summarized in the following.

Figure 17 shows the schematic representation of the distribution pattern of posterior probabilities in the Kanto district. The distribution is mapped by calculating the mean values of the posterior probability classified by 41 zones, which are made by combining the rings and sectors centering around the city of Tokyo. The city of Tokyo occupying the central location is indicated as an asterisk on the map. As Figure 17 shows, and based on above discussions, the distributional characteristics of posterior probabilities are sammarized as follows.

In the case of type AX, there exist highly dense zones in a doughnut shape centering around the city of Tokyo, and both the regularity in accordance with the distance from the city of Tokyo and the directionality outward from the city of Tokyo as the pivot are recognizable. This highly dense zone is included

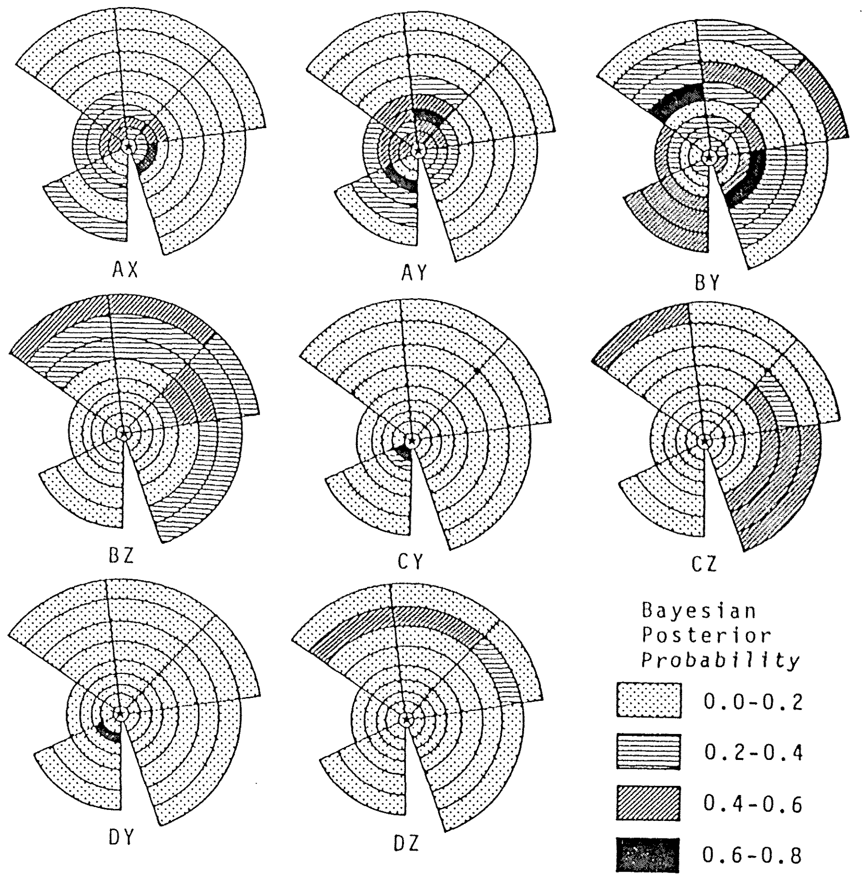

Figure 17. Distribution of mean values of the Bayesian posterior probability assigned to each of 149 cities by combining rings and sectors, by eight types of automotive traffic region.

within the zone of the 40 kilometers radius from the city of Tokyo. Within this zone, the Musashino sector shows an especially high average value.

Type AY has similar characteristics with type AX. But the locations of highly dense zones differ between the two. That is, the highly dense zones of type AX are included within the 40 kilometers radius, while the highly dense zones of type AY stretch out to the 50 kilometers radius. The highly dense zones of type AY occupy wider areas than those of type AX.

In type BY, it is characteristic that comparatively high probability values are widely scattered in all directions of the Kanto district. The distribution is not disorderly but has a certain regularity in accordance with the distance from the city of Tokyo. In the area within the 30 kilometers radius centering around the city of Tokyo, probability values are comparatively lower than in other areas.

Type BZ has a characteristic that relatively high probability values are distributed in the northern Kanto. The average values are relatively high in six rings outside the 70 kilometers radius in the Joetsu and Tohoku sectors, five rings outside the 40 kilometers radius in the Joban sector and two rings outside the 70 kilometers radius in the Boso sector. On the other hand, probability values are generally low in the southern Kanto. Such kind of contrast between the northern Kanto and the southern Kanto brought about the distinct regularity in accordance with the distance from the city of Tokyo. Though not so clear as this regularity, the directionality centering on the city of Tokyo as the pivot is also recognized.

Type CZ has a characteristic that high probability values are distributed in the eastern Kanto. The domain of the distribution lies in three rings beyond the 50 kilometers radius in the Boso sector and in two rings from 50 to 90 kilometers in the Joban sector. Differences between the outer rings in the eastern Kanto and other areas bring about the regularity in accordance with the distance from the city of Tokyo and the directionality from the city of Tokyo as the pivot.

Type DY has the similar characteristic with type CY. Very low probability values are distributed widely all over the Kanto district.

Type DZ has a characteristic that high average values are distributed only in the northern sectors of Joetsu, Tohoku and Joban from 90 to 110 kilometers ring. The regularity in accordance with the distance from the city of Tokyo is brought about by the difference between the above mentioned ring and other areas.

Finally the distributional order of the types of automotive traffic region is considered by comparing the eight distribution patterns of the posterior probability. This consideration enables us to clarify the nodal regions of the Kanto district from a viewpoint of automotive traffic regions. To do this, the type under which each city has to fall, that is, the theoretical type under which each city ought to fall in terms of the measured variable values of urban characteristics, is determined with the method of Bayesian optimal discrimination.[15] Next, by mapping the distribution of such theoretical types, an attempt is made to find some order on the distribution map. The distribution patterns of the posterior probability classified by the eight types are synthesized into Figure 18 with above procedures.

Figure 18 reveals that prominent types of automotive traffic region change by stages with the increase of the distance from the city of Tokyo. Broadly speaking, this change has a regularity in all directions. Therefore it is pointed out that there exists the concentric structure centering around the city of Tokyo as the distributional order of the eight types. The concentric structure consists of the arrangement of the four ring-shaped zones as mentioned below.

1) In the core zone (the first zone) the city of Tokyo and Yokohama-shi, two foci of automotive traffic regions of type DY are located. As shown in the previous chapter (Table 10), the nature of cities falling under type DY corresponds to that of a metropolis. The size of traffic regions is the largest in proportion to the urban functional power of metropolis. In general, the share of automotive traffic volume in the total traffic volume generated between the metropolis and its suburban areas is lowered owing to the competition between automobiles and suburban trains. Accordingly in spite of their high centrality of metropolis, the gradient of distance decay is no more than the medium. The traffic region of Kawasaki-shi in type CY stands between the traffic regions in type DY.

2) The traffic regions of types AX and AY are distributed in the ring-shaped zone from 30 to 50 kilometers radius (the second zone), which surrounds directly the core zone. The nature of cities falling under these two types correspond to that of

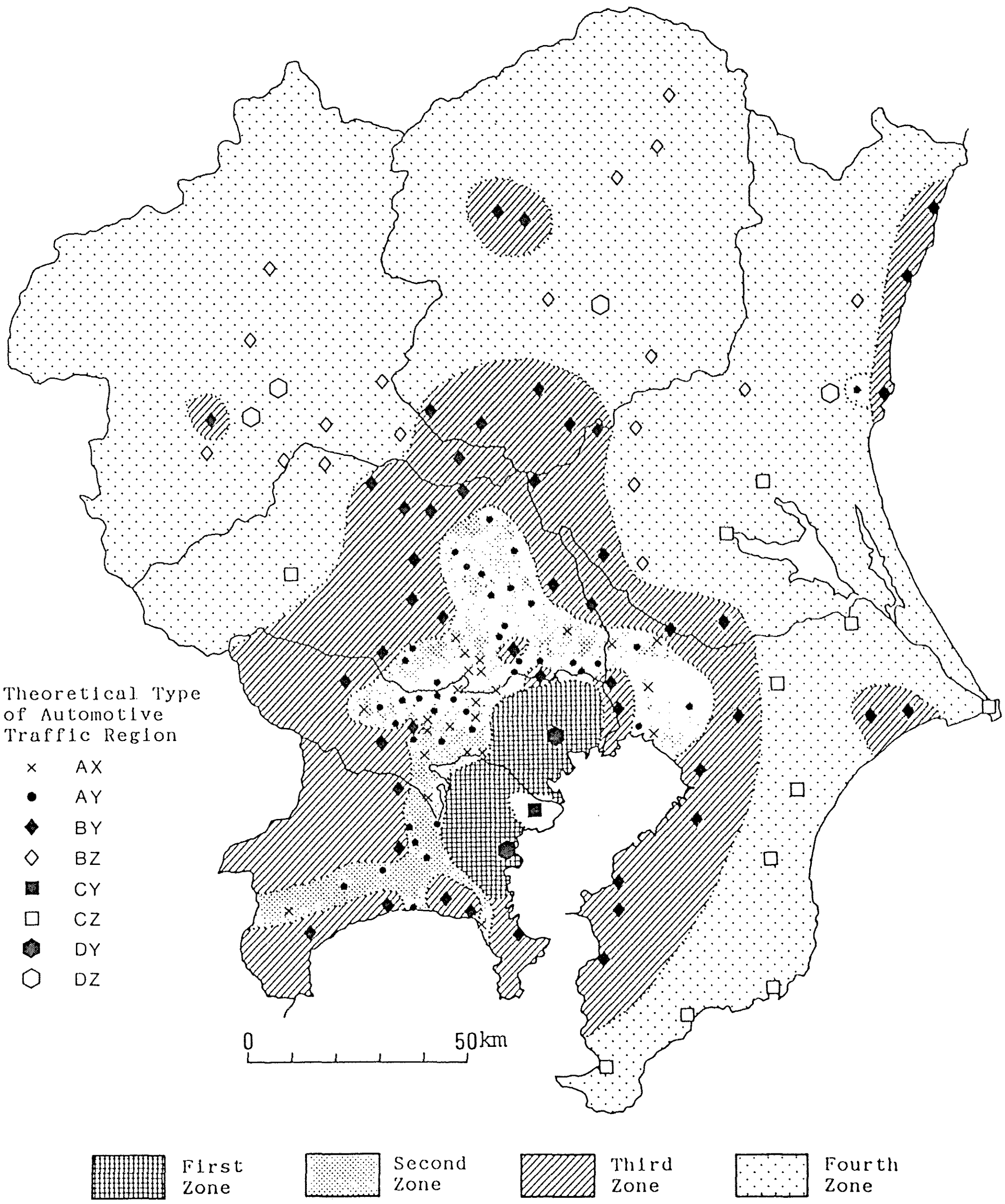

Figure 18. Zonal Distribution of theoretical types of automotive traffic region determined by Bayesian optimal discrimination in relation to the nature of the central cities.

satellite cities. Most cities in the second zone which is contiguous to the core zone, are hidden themselves in the largest traffic regions either of the city of Tokyo or Yokohama-shi. Therefore small-sized traffic regions are formed under the influence of traffic shadow, and they compete and cross one another. The gradient of distance decay differs in types AX and AY. Although the distribution of these two types are mixed, traffic regions of type AX is generally distributed within the inner side the second zone, due to the comparatively weak independency to the metropolis and the heavy dependence upon the suburban railway traffic.

3) In the zone from 40 to 70 kilometers radius, traffic regions of type BY form the belt-like third zone outside the second zone. Such major cities as Hiratsuka, Sagamihara, Hachioji, Kawagoe, Kumagaya, Tatebayashi, Tochigi, Oyama, Koga, Ryugasaki, Chiba and Kisarazu are distributed in the circular belt. Some outliers of traffic regions of type BY are found in other zones. Because the cities falling under type BY are that of the average standard cities in the Kanto district, their traffic regions show medium in size and medium in gradient. This third zone stretching over one metropolitan prefecture and six other prefectures in the Kanto district corresponds to the transitional zone between the second and the fourth zones mentioned next.

4) Traffic regions of types BZ, CZ and DZ are distributed in the outermost zone over about 70 kilometers radius (the fourth zone). The cities falling under these three types possess the characteristics of local cities. The distribution of traffic

regions of type BZ is approximately limited in the northern Kanto. The distributional range extends widely from Mitsukaido-shi, 45 kilometers away from the city of Tokyo, to Kuroiso-shi, 160 kilometers away from the metropolis. The distribution of traffic regions of type CZ, which is larger in size than type BZ, dominates in the eastern Kanto, especially in the eastern side of the line connecting the four cities of Tateyama, Mobara, Narita and Tsuchiura, where the cities are sparse. The traffic region of Chichibu-shi without a city in the short distance falls under the type CZ. The largest traffic regions of type DZ centering around the regional capitals are scattered in the northern Kanto. These three types distributed in the fourth zone have the similar gradient of distance decay. Because the cities falling under these types have high centrality and depend heavily upon the automobile traffic as compared with railway traffic, the gradient of three types becomes steeper.

CHAPTER V

CONCLUSIONS

The present study considers the types of automotive traffic region centering around each of the cities in the Kanto district and also their distribution to clarify the nodal regions of this district. The primary objectives have been to delimit the automotive traffic regions for each of the cities, to classify them into the types, to investigate factors affecting the differences between the types, and to describe the distributional order of the types. In the search for factors affecting the differences between the types and for certain order in the distribution of the types of automotive traffic region, their relationships with the nature of central cities were analyzed. The major findings are summarized in the following :

First of all, in order to lay the foundation of delimiting automotive traffic regions, the distance decay of automobile flows between a city and its surrounding areas was specified by the Pareto equation for each of the cities. It was anticipated that the Pareto equation, one of the social gravity models, could describe the functional relationship between the daily number of automobile trips weighted by 1,000 population of each surrounding as a criterion variable and the linear distance as an explanatory variable. The Pareto equation model was calibrated with the iteratively weighted least squares method for each of the 152 cities, and statistically significant parameter estimates in the equation were obtained for 150 cities except for two cities, Inagi-shi and Miura-shi. Out of the 150 equations, the one for Kitaibaraki-shi whose relative number of automobile trips with the areas outside the Kanto district was not so small was abandoned. As a result, those Pareto equations for 149 cities were used for the purpose of delimiting automotive traffic regions.

Subsequently, the automotive traffic regions were determined for each of the cities, based on the specification of both the size element and the gradient element of distance decay. The size element of traffic region is equivalent to a radius, given that the traffic region takes a circle in shape. The radius, or the distance in the Pareto equation corresponding to certain weighted number of automobile trips (20 trips per 1,000 population of each surrounding), was obtained from the reverse estimation of regression for each of the cities. On the other hand, the gradient element, which is equivalent to the elasticity of the weighted number of automobile trips against the linear distance between a city and its surrounding, coincides with the negative exponent of the distance term in the Pareto equation. Then, by using numerical values of the two elements, the automotive traffic regions were determined for each of the 149 cities.

The automotive traffic regions were classified into eight types according to two criteria. First, they were divided into four classes based on the size element, i.e., classes A (small), B (medium), C (large) and D (largest). Second, they were divided into three classes based on the gradient element, i.e., classes X (lower), Y (medium) and Z (steeper). Combination of these two-dimensional classes resulted in the eight types of automotive traffic region, that is, types AX, AY, BY, BZ, CY, CZ, DY and DZ.

Factors affecting the differences between the eight types of automotive traffic region were examined through statistical discriminant functions. Because it was assumed that the classification criteria of both the size and the gradient elements had close relationships with the nature of central cities, factors of the urban characteristics were hypothesized. As the factors affecting the size element of automotive traffic region, city size, friction between the city and its neighbouring one and central functions were postulated. Then, the stepwise four-group discriminatory analysis was performed to examine whether the selected nine explanatory variables showing those three factors were valid for the discrimination between the size classes A, B, C and D. It was found that six explanatory variables, day-time population, an index of city size, distance to the nearest neighbour city, an index of friction, retail sales per 1,000 population, wholesale sales per 1,000 population, score of administrative function and value of manufacturing products per 1,000 population, indices of central functions, were statistically valid for the discrimination. Out of explanatory variables showing the central functions, the three of socio-cultural functions were useless.

With respect to the factors affecting the gradient element, local centrality and dependency upon automobile were postulated. The stepwise three-group discriminatory analysis was carried out to examine whether the selected two variables were valid for the discrimination between the gradient classes X, Y and Z. It was found that both variables, ratio of day-time population to the night-time, an index of local centrality, and share of automobile, an index of dependency upon automobile, were statistically valid for the discrimination. This indicates that the higher the city's local centrality is, and the more heavy the dependency upon automobile is, then the steeper becomes the gradient of distance decay.

Those eight explanatory variables selected through the preceding stepwise discriminatory analyses are pooled, and the eight-group discrimination between the types of automotive traffic region was performed across them with the ordinary discriminatory analysis. These discriminant functions for each of the eight types of automotive traffic region were statistically significant. It was found that there were close relationships between the types and the complex of various determinants, which were composed of not only those derived from discrimination between the size classes such as city size, friction factor and urban central functions, but also those derived from discrimination between the gradient classes such as the city's urban centrality and share of automobile (modal split).

Because it became clear that the types of automotive traffic region had the statistically significant relationships with the urban characteristics, an attempt was made to describe the nature of cities that fall under each type. The summary of the results is mentioned below : (1) cities that fall under types AX or AY have the nature like satellite cities. Comparing the two types in terms of the independency from a metropolis, cities of type AY have somewhat strong independency; (2) cities that fall under type BY have the nature like standard cities, which have a number of average urban characteristics within the system of cities in the Kanto district; (3) cities falling under types BZ, CZ or DZ have the nature like local cities. The centrality of cities falling under type CZ is somewhat higher than that falling under type BZ. The cities falling under type DZ have the conspiciously higher centrality as compared with the cities of types BZ and CZ. In brief, the cities of type DZ seem to be regarded as the regional capitals; (4) cities falling under type DY have the nature of metropolis; (5) the nature of cities falling under type CY is interpreted as exceptional one.

As the first step to clarify the distributional order of the eight types of automotive traffic region in relation to the characteristics of central cities, the degree of possibility for each city to fall under each of the eight types, i.e., the Bayesian posterior probability was calculated based on the discriminant functions and the prior probabilities. And then, the distribution of these probability values in the Kanto district was illustrated and analyzed by each type.

The tendency of concentration and dispersion of the probability values in the distribution maps was analyzed with centrographic measures. It was found that some types had the regularity in a distribution map in accordance with the distance from the city of Tokyo and that some types had the directional bias in the map from the city of Tokyo as a pivot. In short, the dual components in the distribution of the Bayesian posterior probabilities were recognized. Then, the 149 cities are divided into the eight groups (rings) with the distance from the city of Tokyo and also into the six groups (sectors) centering around the city of Tokyo, and factor effects of the rings and the sectors were quantitatively measured with the analysis of variance. It was clearly demonstrated that the differences of the probabilities between rings and also between sectors were real in some cases. That is, both of factor effects of rings and sectors on types AX, AY, BZ and CZ, and factor effect of rings on types BY and DZ were real.

The distribution of cities with the higher possibility falling under each type of automotive traffic region was summaried as follows : (1) type AX forms highly dense zones like a doughnut shape, included within the 40 kilometers radius from the city of Tokyo as a center; (2) type AY has a similar characteristic with type AX. The highly dense zones stretch out to the 50 kilometers radius from the center of Tokyo; (3) type BY is uniformly scattered in the Kanto district; (4) type BZ is distributed mainly in the northern Kanto; (5) type CY is limited to Kawasaki-shi; (6) type CZ is distributed within the 50 kilometers radius from the city of Tokyo in the eastern Kanto; (7) type DY is limited to the city of Tokyo and Yokohama-shi; (8) type DZ is limited to several cities, Mito-shi, Utsunomiya-shi, Maebashi-shi and Takasaki-shi, which are some 100 kilometers distant from the city of Tokyo. As for the comparison between the factor effects of rings and sectors, the former was much larger than the latter. In other words, in the distribution maps of posterior probabilities, the regularity in accordance with the distance from the city of Tokyo was much clearer than the directionality bias from the city of Tokyo as a pivot.

Finally, the nodal regions of the Kanto district was considered in terms of the distribution of the types of automotive traffic region. The theoretical type under which each of 149 cities ought to fall in terms of the measured variable values of urban characteristics was determined with the method of Bayesian optimal discrimination. And an attempt was made to detect some order in the distribution of such theoretical types. As a result, the concentric structure centering around the city of Tokyo were found as a fundamental order in the distribution of the eight types. These concentric structure consists of the four ring-shaped zones : (1) the city of Tokyo and Yokohama-shi, two foci of automotive traffic regions of type DY are located in the core zone. The size of traffic regions is the largest in proportion to the urban functional power of metropolis. In spite of the highest centrality of metropolis, the gradient of distance decay is no more than the medium because the share of automobile traffic volume in the total one between the metropolis and its suburban areas is lowered owing to the competition between automobiles and suburban trains; (2) the traffic regions of types AX and AY are distributed in the ring-shaped zone from 30 to 50 kilometers radius, which surrounds directly the core zone. As most cities in this zone are hidden themselves within the largest traffic regions either of the city of Tokyo or Yokohama-shi, the small-sized traffic regions are formed under the influence of traffic shadow, and compete and cross one another. Although the distribution of the two types are mixed, traffic regions of type AX is distributed generally in the inner side of this zone, due to the comparatively weak independency from the metropolis and the heavy dependence upon the suburban railway traffic; (3) traffic regions of type BY form the belt-like zone from 40 to 70 kilometers radius. Because the nature of the cities falling unter type BY is related to the average standard cities in the Kanto district, these traffic regions have the medium size and the medium gradient; (4) traffic regions of types BZ, CZ and DZ are distributed in the outermost zone beyond about 70 kilometers radius. Traffic regions of type BZ are distributed mainly in the northern Kanto. In contrast to this, the distribution of traffic regions of type CZ with the larger size than type BZ dominates in the eastern Kanto where the distribution of cities is sparse. The largest traffic regions of type DZ centering around prefectural catipals stand in a row in the northern Kanto. In this zone, the three types of automotive traffic region are of uniform gradient (the steeper), because the cities falling under these types have higher centrality and depend heavily upon the automobile traffic as compared with the railway traffic.

NOTES

1. Arisue(1957) classified the eight types of railway traffic regions surrounded by the railway traffic divides in Japan, on the basis of three criteria. These are the size of central station (net revenue of passenger fares), the number of important stations and the areal extent of the traffic. This is one of a few studies to consider the types of traffic region and their distribution up to date.

2. Helvig (1964), in a study in which he considered the zonal structure of the truck movements centering around Chicago, used such a weighted number of trips.

3. Ullman(1941) said, " As a working hypothesis one assumes that normally the larger the city, the larger its tributary area." Murphy(1974) in his textbook on urban geography explained that other things being equal, tha larger the city the larger the area. Yeates and Garner(1976), in their textbook on urban geography, explained that the size of each nodal region depends on the number of goods, services, and opportunities provided by its center (the size of magnet). Takano(1963), in a study on the regional structure of city-region pattern, concluded that the city-region has an interdependent relationship with the central city's function, namely the urban power. Sawada(1978) indicated that there is a great difference of scale between the metropolitan region and the local city's region.

4. Takano(1963) pointed out some important factors which influence upon the areal form of each of the city-region. He said, "the largest city-region spreads its strong urban power potentially over many other medium-sized or small neighboring city-regions." Furthermore, he said, "the urban power tends to penetrate into those quarters where no strong rival cities lie."

5. Murphy(1974) emphasized the nature of the city. He said,"A city important chiefly as a trading center will tend to have a larger tributary area in proportion to the city's population than one depending mostly on manufacturing products for non-local markets."

6. On the one hand, the processing of raw materials drawn from the region--lumber, livestock, agricultural products, and finishing processes to manufactured products are exemplified. On the other hand, the processing of both consumers' and producers' goods manufactured in a city for distribution throughout the tributary area--agricultural machinery, fertilizers, hardware are exemplified (Dickinson, 1964, p.66).

7. With data from Statistics Bureau's "Usual Place of Residence and Place of Work or Schooling of Commuting Employed Persons and Persons Attending School 15 Years of Age and Over, by Means of Transport, Vol.5 Commutation, 1980 Population Census of Japan," the author calculated the proportion of the number of commuting employed persons by private car or bus to the total number of commuting employed ones for each city.

8. This is the grand mean, that is to say, the mean value of the eight mean values for respective types.

9. It is well-known that there are various characteristics of satellite cities, that is, those drawn from suburban cities and from local cities (Yamaga,1953 ; Kobayashi,1955 <u>et al.</u>).

10. Ogasawara(1949), in a study of functional classification of the Japanese cities, set up a type of standard city, which had an average industrial structure of employed persons in those days.

11. In general, the traffic region consists of three components, i.e., the focus, its surrounding areas and traffic flows between them.

12. Bayesian theorem is a formula to obtain the posterior probability from the prior probability and the known conditional probability (Watanabe, 1984).

13. Kanno(1983) compared the dispersion of various land use types inside the built-up areas with the coefficients of dispersion.

14. Analysis of variance is a statistical method to examine the factor effect by resolving the total variance of data (Takeuchi, 1963).

15. Bayesian optimal discrimination is a method of classification in discriminatory analysis. The posterior probability given by Bayes' theorem is applied as a criterion to classify the individual to one of k categories to which the individual should belong, as accurately as possible in terms of measured values of explanatory variables included in the discriminant functions. In short, the individual is classified into the category that has the highest posterior probability (Matsubara,1985).

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