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ESTIMATION OF REGIONAL ATTRACTIVENESS BY STRUCTURAL MODEL OF ENVIRONMENTAL FACTORS AND NEURAL NETWORK MODEL, AND COMPARISON OF MODELS

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In recent regional and urban planning, life activities of citizens have been considered to be more important than previously. Analyzing factors which make up regional attractiveness is useful for future planning. In this study, in order to analyze the relationship between regional attractiveness and its related factors, a structural model and neural network model which include the environmental factors as exogenous variables, are proposed and estimated by using regional preference data of migration. As a result, two models which can measure attractiveness are obtained and show important factors for life activity. The merits and possible applications of the models are described by comparing them to a popular linear attractiveness function model.

Key Words : *regional attractiveness, environmental factors, structural model, neural network model*

1. INTRODUCTION

(1) Purpose of study

In recent years, concepts placing importance on daily life have been taken into account more than before when local environments are improved. Such concepts have stemmed from a high level of employment and economic growth together with the need to look for ways to accommodate aged society in the 21st century and to find some means to achieve fulfillment in life. One of the fundamental postures related to the above is considered to be regional development taking into account the consciousness or activities of the local people. In this situation, explaining to what extent a local region is attractive enough for the people and how the constituents of such attractiveness influence them, could well be effective information for regional development in the future. With this in mind, two models are proposed with the aim of analyzing regional attractiveness and its related factors. The models are estimated using data of regional preference in migration. Also, the results from analysis using these models are discussed. In connection with this, a new method which has, up to the present, been unavailable is proposed in this study.

(2) Contents of study

In order to explain what the factors that make up a local environment and their indexes are like and how the said factors will influence regional attractiveness, a structural model of environmental factors is proposed. Also, application of a neural network model is proposed as a model to estimate the attractiveness of a local environment. In analysis using these models, all the cities, towns and villages of Tokushima Prefecture in Japan are dealt with as the case study region. Relationships between indexes of local environment and migration between cities, towns and villages is explained from a viewpoint that regional preference in migration is dependent on the attractiveness of the local environment. Furthermore, not only applicability of the models is investigated, but also comparisons are made between three models including a linear attractiveness function model which has conventionally been used as a preference model in the past.

2. EXISTING STUDIES AND SIGNIFICANCE OF THIS STUDY

The principal aim of this study is to explain factors that make up regional attractiveness viewed from the residential environment and to develop a model that can measure attractiveness using such related indexes. With regard to this, previous studies are hereby analyzed. First, past research methods for analysis of the living environment and related factors has principally utilized multiple regression analysis or quantification theory based on data from questionnaire surveys completed by citizens1),2),3). In this method, evaluation of the living environment is ascertained by means of questionnaire surveys and the evaluation value of the environment is expressed as a linear function model consisting mainly of environmental factors as exogenous variables. A positive feature of this method is the fact that it is straight forward and to the point and results are easily understood. However, deficiencies do exist. Namely, a questionnaire survey is required and the true accuracy of the models is difficult to ascertain.

In this paper, a new trial is carried out taking the following two points into account: (i) Expressing the regional environment with a model which possesses a high degree of explanatory capability dealing with the composite factors of the environment as exogenous variables and (ii) Using data replaced by the questionnaire survey in model estimation.

(1) Application of new models

A structural model of environmental factors and a neural network model are proposed, and their applicabilities are investigated.

a) Structural model

First, based on the assumption that a relationship between environmental factors is composed of either substitution or supplement, a structural model expressing what kind of structure attractiveness creates due to environmental factors is proposed. With respect to this structural model, the evaluation structure of the living environment is expressed as a circuit structure to which Boolean algebra is applied and is estimated with data obtained from the questionnaire survey4). This method has the distinguishing feature of being able to express the structure of the urban environment clearly and simply. On the other hand, some problems are noted regading utilization as an index of the living environment of cities because the data dealt with in the model is comprised of discrete values of 1 or 0. Concerning the structural model proposed in this paper, not only continuous values can be dealt with but also the importance of the individual factors in the structure of the environment can be explained. In addition to the above, it is possible to use the model as an index of environmental evaluation.

b) Neural network model

Another approach related to application of new models is to apply the neural network model to estimate regional attractiveness. The neural network model is effective for processing pattern information and has a nonlinear nature. Features of the model are described at length in the literature5). Its application to travel pattern analysis6), traffic control methods7), estimation of traffic congestion volume8) and scheduling problems9), has already been made in the field of urban and transportation planning. Based on data concerning factors of environment as input variables and attractiveness as the output variable, the model is developed in this study by expressing the relationship between both of the variables with the neural network model.

(2) Data for model estimation

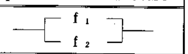
With respect to use of data to be replaced with the questionnaire survey in model estimation, migration data between regions is used. It is assumed that migration depends on the attractiveness of a local region, and preferences of a particular region in migration can be explained by the attractiveness of the region in question. Based on this assumption, the regional preference model is developed. The model to estimate attractiveness is included in the regional preference model and is estimated using migration data. With regard to the regional preference model, various behaviour models, such as modal choice models10) and residential location models11) have been developed. The model proposed in this paper is considered to have a similar idea in modelling.

3. REGIONAL PREFERENCE IN MIGRATION AND MODELS

(1) Modelling of regional preference in migration

Regional attractiveness as assessed by people, is expressed as U_i and U_j for 2 local regions i and j. If it is assumed that the degree of preference of regions

Table 1 Fundamental relationship in the structural model of environmental factors

Relationship	Attractiveness function	Expression of structure
Sum	$V = a_1 \cdot z_1 + a_2 \cdot z_2$	
Product	$V = b_1 \cdot \log z_1 + b_2 \cdot \log z_2$	— f_1 — f_2 —

i and j by people depends on their attractiveness, then the relationships shown below can be established in the location choice of migration.

$U_i > U_j$: Region i is preferred to region j (1)

$U_i < U_j$: Region j is preferred to region i (2)

$U_i = U_j$: Regions i and j are undiscriminated (3)

With regard to this connection, it is considered that attractiveness U_i and U_j felt by people is, as shown in equations (4) and (5), given by the sum of the deterministic terms V_i and V_j of attractiveness comprised of proper environmental factors of regions i and j and the random terms e_i and e_j providing values of attractiveness with dispersion owing to the individuals.

$$U_i = V_i + e_i \tag{4}$$

$$U_j = V_j + e_j \tag{5}$$

If it is assumed that the random terms e_i and e_j in equations (4) and (5) are independent and Gumbel distributed, and also that the amount of proportions obtained as a result of the preference to regions i and j by the people are expressed as p_i and p_j, equations (6), (7) and (8) can be derived. These equations show the relationships between p_i and p_j explained by the deterministic terms V_i and V_j of attractiveness.

$$\frac{p_i}{p_i + p_j} = \frac{\exp(V_i)}{\exp(V_i) + \exp(V_j)} \tag{6}$$

$$\frac{p_j}{p_i + p_j} = \frac{\exp(V_j)}{\exp(V_i) + \exp(V_j)} \tag{7}$$

$$\therefore \ \frac{p_i}{p_j} = \exp(V_i - V_j) \tag{8}$$

(2) Structural model of environmental factors

The environment of local regions is composed of many factors related to daily life. If it is considered that these factors make up the regional environment as one system, then there should exist something to mutually supplement or to be substituted in the individual factors. Here, a relationship between these factors is explained and a structural model is proposed which can estimate the structure of the local environment.

a) Fundamental structure

The fundamental structure of the structural model is shown in **Table 1.** If it is assumed that two arbitrary factors composing the local environment are f_1 and f_2, a relationship of the sum shown in the table means that these two factors are related for substitution. In this case, the indexes z_1 and z_2 composing the attractiveness of the region are summed with a_1 and a_2 to which coefficients are attached as shown in equation (9). On the other hand, a relationship of the product means that the attractiveness of the local region is not magnified in the case of one element being lost even if the other factor remains at an acceptable level. In this case the function composing the attractiveness is expressed as the logarithmic linear sum of the indexes into which the coefficients b_1 and b_2 are applied as in equation (10).

$$V = a_1 \cdot z_1 + a_2 \cdot z_2 \tag{9}$$

$$V = b_1 \cdot \log z_1 + b_2 \cdot \log z_2 \tag{10}$$

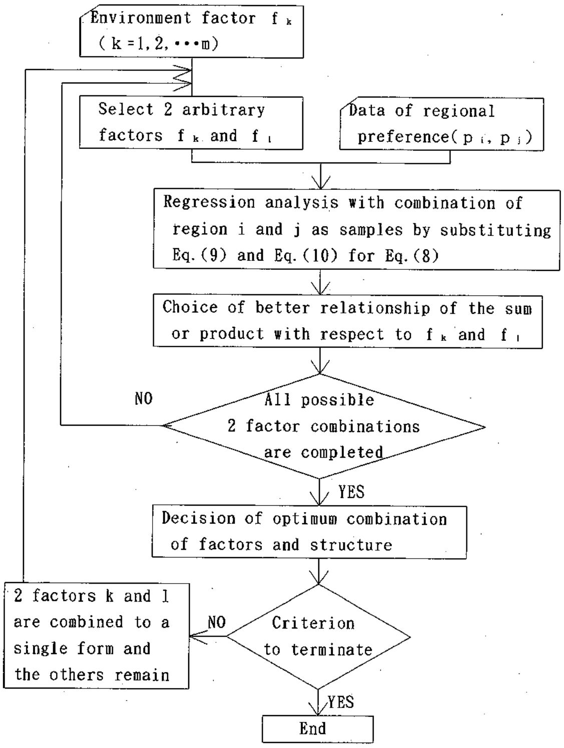


Fig. 1 Flowchart to estimate the strctural model

b) Estimation method of structural model

The regional environment is considered to be made up of a combination of individual types of fundamental structures. Based on this assumption, an estimation method of the structural model is explained next.

A flowchart of the estimation process of the structural model is shown in **Fig. 1**. First, regression analysis is carried out using the equation obtained by substituting equation (9) for equation (8). In this analysis, two arbitrary factors f_k and f_l are taken as variables and combination of the two from the total number of regions are taken as samples. In the same way, the regression analysis is carried out using the equation obtained by substituting equation (10) for equation (8). Based on the results of these two kinds of regression analysis, the relationship with higher compatibility is chosen as a fundamental structure between f_k and f_l. This is the relationship of the sum presented by equation (9) or the relationship of the product presented by equation (10). By carrying out this operation with respect to combination of the two from the total number of composite factors, two environmental factors and the fundamental structure between them can be ascertained. This result provides their optimum relationship. The two factors which are obtained using this procedure are then combined to form a new single factor using equation (9) or (10) depending on their relationship. As a result, the number of environmental factors inputted in this operation is decreased by one. This denotes the end of one cycle of the operation and the next cycle of calculation is continued. By repeating this procedure, the environmental factors are combined with the relationship of the sum or product and the structural model forms. The calculation is finalized with a degree of enhancement of accuracy brought about by combination of the factors as a criterion. The structural model is presented and the combined structure is composed of environmental factors as a single system.

If the order of factors to be combined is changed intentionally when the model is being structured, it is possibe to obtain a different structure of the model from the one built up by the procedure shown in **Fig. 1**. In the algorithm proposed in this study, however, as the optimum model can be obtained in each cycle where the variables incorporated into the model and their relationship are decided at the same time, the final structure built up in this algorithm is singular. If all of the combination of variables and structures are used to estimate the model, an enormous amount of time would be required. On the other hand, we can estimate the structural model simply in a short time using the procedure proposed in this study.

(3) Neural network model[5),6)]

Neural network models are recognized to be adequate when solving pattern information processing problems. The applicability of this kind of model to the analysis of regional preference based on attractiveness is investigated in this study. The model is estimated through a learning process where data of all of the input and output variables are used together. Whereas in the structural model, independent variables are taken into each step of the procedure by two in order to find the optimum variables. Thus the model is being built up to a better one by incorporating chosen variables step by step.

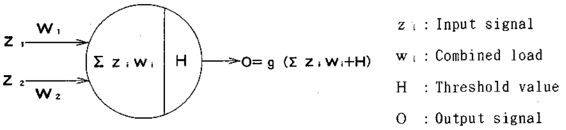


Fig. 2 Fundamental structure in neuron model

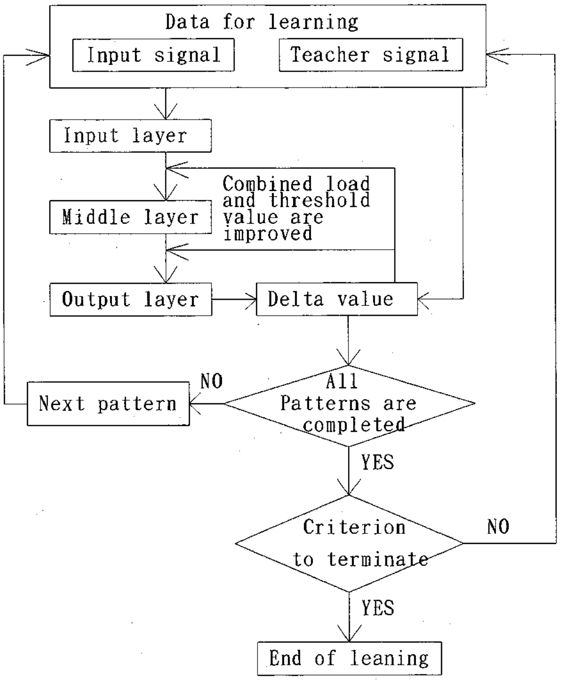


Fig. 3 The method of learning in BP rule

The fundamental structure of a neuron model is shown in **Fig. 2**. An output signal O is obtained, by converting the value obtained by adding a threshold value H to the weighted linear sum of the combined load w_i for the input signal z_i with a function $g(\cdot)$. A sigmoid function shown in equation (11) is used for the function $g(\cdot)$ in this study. The output value of the function is dependant on the parameter u_0 of the gradient of the function.

$$g(z)=\frac{1}{1+\exp\left(\frac{-2z}{u_0}\right)} \tag{11}$$

For the gradient u_0 of the sigmoid function, 0.5 is used in this study in order to obtain reliable values with ease.

A back propagation rule (BP rule) is used as a learning method in this study and the flow of the learning procedure is shown in **Fig. 3**. The BP rule is a regulation for repetition allowing combined load and threshold in individual layers to be altered using the delta value in a direction where the delta value, which is given as the difference between the value outputted via the middle layer from the input layer and the teacher signal, is decreased. The learning method used in this study is a rectified moment method. The method is not used for rectification of combined load and threshold settled from the individual learning patterns. Rather, in the present study, rectification of them is carried out all at once based on previously-arranged aggregation of all patterns after a single set of learning patterns is completed. When this has been done, the combined load and threshold value to be used in the next learning cycle is settled with the value obtained by adding the value of multiplication of the moment value, m, to the rectification amount obtained from the learning cycle in the previous occasion. The moment value, m, in this method is given exogenously and the advantageous feature, that is, the fact that progress speed of learning is heightened, should be noted.

Table 2 Life environment facilities and their spheres of utilization

Environment	Facility	Sphere of utilization
Safety	Police station	Within concerned town
Health	Health center	Within concerned town
〃	Hospital	Within concerned town
Social welfare	Home for aged people	Within concerned town
〃	Nursery school	Within concerned town
Leisure	Theater	Within one-hour areas
〃	Recreation park	Within one-hour areas
〃	City park	Within concerned town
〃	Concert hall	Within one-hour areas
Education and culture	Culture center	Within one-hour areas
〃	Library	Within concerned town
〃	University	Within one-hour areas
〃	Museum	Within concerned town
Retail and business	Retail store	Within concerned town
〃	Restaurant	Within concerned town
〃	Supermarket	Within concerned town
〃	Banking agency	Within concerned town
〃	Department store	Within one-hour areas
〃	Office(manufacture)	Within one-hour areas
〃	Office(service)	Within one-hour areas

4. ESTIMATION AND OBSERVATION OF THE MODELS

(1) Application of the models

a) Case study area

To analyze the attractiveness of local regions together with investigation of applicability of the models, Tokushima Prefecture in Japan is chosen as a case study area. As the sample for analysis, 50 localities, including cities, towns and villages are used.

b) Data of regional preference

The result of the choice of city i or city j in migration can be considered to reflect regional preference as shown in equations (1)~(3). When migration flows from city k to cities i and j are expressed as x_{ki} and x_{kj}, the preference ratio of region i to j can be calculated from the equation of x_{ki}/x_{kj}. When this ratio is expressed by using data of migration flow to i and j from all the regions excluding i and j, n-2 pieces of the equations in total are obtained. Where n is the total number of regions. They are x_{1i}/x_{1j}, x_{2i}/x_{2j}, ……, x_{ni}/x_{nj}, exclusive of x_{ii}/x_{ij}, x_{ji}/x_{jj}. Equation (12), which shows average ratio of regional preference between i and j based on the migration flow data for the whole area, can be obtained from (n-2) parts of the equations.

$$\frac{p_i}{p_j}=\left\{\prod_{k=1}^{n}\frac{x_{ki}}{x_{kj}}\right\}^{\frac{1}{n-2}} \qquad (12)$$

Where, $k=i$ and $k=j$ are exclusive.

The ratio of regional preference between i and j, as shown in equation (12), is given as the geometric mean of migration flow ratio coming into i and j from all the other cities, towns and villages. The ratio of regional preference calculated in this equation is used as data for the ratio of regional preferences between two arbitrary regions i and j in the structural model and neural network model.

The cities, towns and villages used to calculate the ratio p_i/p_j in equation (12) are chosen if they meet the following two conditions regarding the number of migration flow between the cities, towns and villages for 10 years ranging from 1980 to 1990: (i) both x_{ki} and x_{kj} correspond to each other exceed 20 persons and (ii) both x_{ki} and x_{kj} correspond to each other exceed 1% of all the people going out from the local region in question.

This is due to the possibility that the value of the whole of equation (12) may be, when there is a small value in the amount of migration, greatly influenced by the value in question.

c) Regional environmental factors and indexes[12]

In order to obtain regional environment data, facilities for safety, health, social welfare, leisure, education and culture, retail and business, etc. as shown in **Table 2** were chosen as the institutions that mainly make up the living environment in local regions. Furthermore, regarding the utilization range of such facilities, the numbers of these facilities in every area and those facilities present in surrounding cities within a one-hour range from it are included. The number of individual facilities is counted in 1980.

With regard to the above, the number of the individual facilities within a one-hour range among the indexes concerning the life environment facilities listed in **Table 2** is calculated using the following equation.

$$A_{ik}=\sum_{j=1}^{n}\delta_{ij}\cdot m_{jk} \qquad (13)$$

where, A_{ik}: The number of one-hour-range facilities k in region i.
n: The whole number of regions

Table 3 Indexes concerning population, employment and transportation

Index	Method of measurement
Interchangeable population in one day	Total number of population in 3-hour areas from the objective city
Employment opportunity	Total number of employees in 30-munite areas from the objective city
Travel time to Tokushima City	Travel time via shortest route to Tokushima City

δ_{ij} : The dummy variable becoming 1 if travel time from region i to j remains within one hour, or 0 if travel time exceeds one hour.

m_{jk} : The number of facility k in region j.

On the other hand, the interchangeable population in one day, employment opportunity, travel time to Tokushima City which is the largest city in the case study area, were added to the indexes for the facilities in order to explain conditions concerning population, employment and transportation. The interchangeable population in one day is an index that has been used in regional and land development planning[13]. It is also the total number of people in areas that can be reached by people from the area in question within 3 hours. This index implies the general attractiveness of a city and can be used to measure the potential level of interchange between people.

Employment opportunity can be expressed as the total number of employees of secondary and tertiary industries in the areas reached from the objective city within 30 minutes. The areas from the objective city are restricted to 30 minutes in this index. Reasons for this definition are that the percentage of comuters to other cities decreases and the rate of dissatisfaction with commuting time increases dramatically when the time from the objective city exceeds about 30 minutes in the study areas. Furthermore, the shortest travel time to reach Tokushima City from the individual cities, towns and villages in the road networks, comprised of national and prefectural roads, is also adopted as an index. As is mentioned above, the indexes listed in **Tables 2** and **3** are those to be dealt with in the present study.

Some degree of correlation is expected between the indexes concerning the facilities. Prior to using these indexes for model estimation, classification of the indexes is made by explaining the mutual connection among the indexes by means of the principal component analysis and cluster analysis. The results obtained in the above are shown in **Table 4**. From **Table 4**, it can be seen that group 1 consists of the living environmental facilities offering the basis to the local region. Facilities in group 2 are closely related to daily life and exist in almost every city, town and village. Group 3 contains facilities where the range of services is large although importance with relation to daily life is weaker than that for the facilities in group 2. In addition, group 5 has facilities restricted to a single place shared by more than one city. Based on the result of this classification, the indexes used for model analysis are dealt with as being representative of individual groups ranging from 1 to 5 as shown in **Table 4**. With regard to this, all indexes not related to facilities, as shown in **Table 3**, are used for the model analysis.

Table 4 Result of classification of environmental factors

Group	Index	Representative
1	City park, Library, Museum, Police station, Day nursery	City park
2	Hospital, Banking agency, Supermarket, Home for old people, Retail store, Restaurant	Hospital
3	Culture center, Theater, University, Department store	Department store
4	Office (service), Office (manufacture)	Office (service)
5	Recreation park, Concert hall, Health center	Concert hall

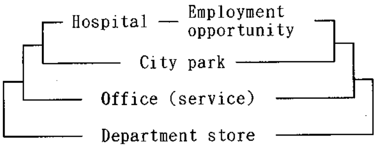


Fig. 4 Estimated structural model of environmental factors

Table 5 Result of estimation of attractiveness function in the structural model

Step	Relationship	Factor	Parameter	t-value	R^2
1	Product	Hospital	0.9018	54.204	0.8918
		Employment opportunity	0.3404	24.278	
2	Sum	City park	0.0131	9.248	0.8992
		Function U_1	0.8901	–	
3	Sum	Office(Service)	0.000051	8.435	0.9049
		Function U_2	0.9258	–	
4	Sum	Department store	0.0050	0.263	0.9049
		Function U_3	0.9976	–	

Function $U_1 \sim U_3$: Composite functon in each step

(2) Structural model of environmental factors

As a result of estimation of a structural model in accordance to the method in **Fig. 1**, the model shown in **Fig. 4** is obtained. For the termination criterion in this estimation, the coefficient of determination R^2 is used and repetition is made until the extent of increase in the coefficient becomes greater than 0.0001 compared with the value of the step in the previous case. The equation of the model at that time is shown in **Table 5**. The coefficient of determination in step 4, as the final one, is 0.9049 and it can be said that the model obtained here is sufficient. On the other hand, when attention is paid to the t-value, it

Table 6 Teacher and input signals in neural network model

Teacher signal	Input signal
$\frac{exp(V_i)}{exp(V_i)+exp(V_j)}$	$\frac{z_{ki}}{z_{ki}+z_{kj}}$ (k=1,2,3,...)

z_{ki} : Value of index k in region i

can be seen that the t-value of a department store in step 4 is small. This indicates, statistically, that the variable exercises little influence on the explained value. Even though the model is terminated in step 3, in consideration of the above fact, this model is found to be significantly accurate.

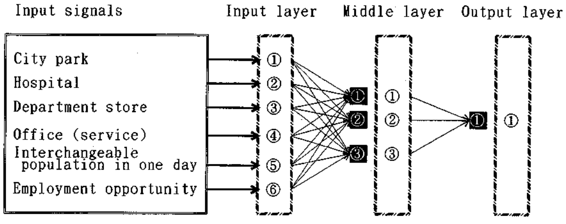
When the model structure is examined, it can be seen that the facilities in group 2 of **Table 4**, represented by a hospital, and the index concerned with employment, having a relationship to the product, are recognized as important conditions. The facilities in group 1, represented by a city park, and in group 4 by an office, which are connected with a relationship of the sum, are also considered to be important.

(3) Neural network model

In order to apply a neural network to the regional preference model, input signals and teacher signals are required. In this study, environmental indexes are used as input signals and, at the same time, the ratios of attractiveness between regions are used as teacher signals. However, since a sigmoid function, as shown in equation (11), is used in the present study as a function of the neuron model, the output values are restricted in the range of 0 to 1. In such a condition, the teacher signals and input signals are settled as shown in **Table 6**. Since equation (14) is obtained by altering equation (6), the values of the teacher signals in **Table 6** were calculated by substituting equation (12) for (p_i/p_j) in this equation with the use of migration flow data.

$$\frac{\exp(V_i)}{\exp(V_i)+\exp(V_j)}=\frac{(p_i/p_j)}{(p_i/p_j)+1} \tag{14}$$

At the same time, the input signals were obtained by substituting the index values in **Tables 2** and **3** for z_{ki} and z_{kj} in **Table 6**. The attractiveness of a local region is not estimated directly in the neural network model, but rather estimated by using the ratio of attractiveness between regions and the ratio of individual environmental factors. With regard to this, each individual layer of the neural network used in this study is comprised of three layers, i.e. the output, middle and input layers. With a single unit limited to the output layer, the number of units in the input and middle layers was variable.



①~⑥ : Unit number in each layer

❶~❸ : Number of threshold value in each layer

Fig. 5 Estimation result of neural network model

When estimating a neural network model, one of the subjects is investigated to ascertain whether the model behaves properly. That is to say, when an arbitrary index that is proportionally related to the attractiveness of a local region is used as an input signal, the model cannot be said to be proper in the case where the estimation value as the output value is not monotonically increased as the index increases. When estimating the neural network model, we examine the model's behaviour as we do the appropriateness of the sign of estimated parameters in the multiple regression analysis. Therefore, when the learning procedure of the network is completed, whether the output value is monotonically increased or not is tested by changing an index from 0 to 1. All of the other indexes are fixed to a mean value of the whole data of the individual indexes. When abnormality was confirmed by such a test, the model was estimated again by changing the unit number of the middle layer or removing the index from the input pattern. The model with which estimation could be most accurately made among the models that have, as a result, successfully been estimated, is shown in **Fig. 5**. We ceased repeating in the procedure of model estimation explained in **Fig. 2** when the amount of improvement in the average error over one cycle is less than 1×10^{-6}.

As illustrated in **Fig. 5**, this network model has 6 units in the input layer, 3 units in the middle and a single unit in the output layer. The environmental indexes as the input signals are comprised of 6 indexes, i.e. the indexes of the facilities of a city park, hospital, department store and office (service) in addition to the interchangeable population and employment opportunity. The correlation coefficient of the output value of the model with the teacher signal is given as $r=0.865$, and the number of samples is 1,176.

Results of the normality test are shown in **Fig. 6** and **Fig. 7**. In compliance with the variation of all of the 6 indexes, the output value also varied normally. When the results of the test are examined, it is clear that the facilities in groups 2 and 1 represented by a hospital and city park and employment opportunity

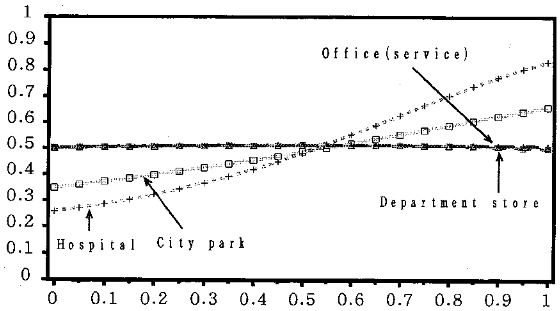


Fig. 6 Normality test of neural network model (1)

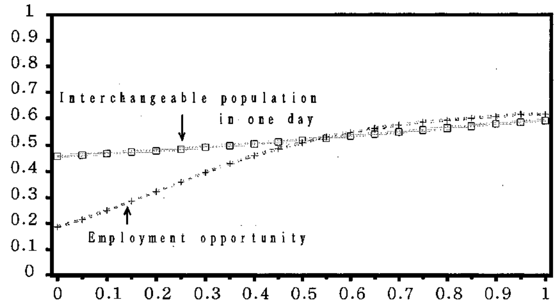


Fig. 7 Normality test of neural network model (2)

Table 7 Result of estimation of linear attractiveness function model

Variable	Parameter	t-value
City park	0.0293	10.55
Hospital	0.0223	7.75
Office(service)	0.000018	8.25
Employment opportunity	0.00053	7.58
Travel time to Tokushima City	-0.355	-4.90
Coefficient of determination	0.799	
Number of sample	1,176	

have a relatively great influence on regional attractiveness.

(4) Comparison of the models

Both the structural and neural network models have been applied to the regional choice model. Next, these models are compared. When comparing models, a model where the attractiveness function in the regional choice model as shown in equation (8) is a linear function, is also included. This model shall hereafter be called a "linear attractiveness function model". By also using the same data with the linear attractiveness function model, the results shown in **Table 7** are obtained.

The three models compared here are selected finally through each estimation process and include different variables as the final model in each structure, although the exact same variables are given in the first stage of the estimation. That is to say that the variables are selected in the process of model estimation in order to obtain the optimum model starting with the same conditions. In general, variables included in the final model depend on the model type, structure, etc. In this study, we give the same conditions at the beginning of estimation and compare three models obtained finally. It can be said that this is a meaningful comparison.

Table 8 Comparison of the models

Model	Accumulated error	Mean error	Maximum error	Correlation coefficient
Structural model	144.43	0.123	0.672	0.843
Neural network model	132.36	0.113	0.638	0.865
Linear attractiveness function model	195.90	0.167	0.815	0.722

Since both the linear attractiveness function and the structural models are estimated by using equation (8), which shows the relationship between the ratio of regional preference and attractiveness function, comparison is relatively easy. However the input variable is modified by using equation (14) in the case of the neural network model, which prevents comparison with both cases mentioned above. Therefore, comparison among these three models is carried out with a sample of 1,176 of observed values in the preference ratio between region i and j and the estimated values of the model using equation (15).

$$\frac{p_i}{p_i+p_j}=\frac{\exp(V_i)}{\exp(V_i)+\exp(V_j)} \tag{15}$$

Results of the comparison with respect to accuracy of individual models are shown in **Table** 8. The accumulated error results from the accumulated value of the absolute value of the difference between the estimated value and the observed value in individual samples. The mean error is the value obtained by dividing the accumulated error by the number of samples. On the other hand, the correlation coefficient is derived from the estimated value of individual samples and observed values. From the above, the neural network model is best followed by the structural model. However no significant difference is apparent between the neural network model and the structure model.

Despite the above findings, structural and linear attractiveness function models are advantageous when analyzing the influence of environmental factors on attractiveness of a local region and the structure of such factors. Since it is necessary for the neural network model to separately investigate the relationship between the factor and attractiveness in the normality test, labor is required with regard to this point. Also, the relationship can only be comprehended qualitatively. From the above description, the proposition of the structural model, which is almost the same as the neural network model from the viewpoint of accuracy, and which can estimate the structure of the factors composing attractiveness and its degree of influence, is believed to be significant.

5. CONCLUSION

For the purpose of explaining by which environmental factors regional attractiveness is composed and how much these factors influence attractiveness, both structural and neural network models were proposed in this study. Furthermore, the models were estimated based on regional preference by analysis of migration flow data. Following that comparisons and investigations were made using these models. As a result, both the structural model and neural network model were successfully estimated. When comparing the three models by adding the linear attractiveness function model to the proposed models, positive points of the proposed models were observed.

In connection with the above, a trial was carried out based on expressing the regional environment using a nonlinear model having the environmental factors as variable. This has successfully brought about significant results with respect to individual points. With the structural model, not only variables having continuous values can be dealt with, but also the structure of the environment or the importance of individual factors can be explained. At the same time, it has been possible for the model to be used as a measuring index of environment evaluation. Moreover, when we consider the fact that the structural model was estimated as accurately as the nueral network model, the structural model can be used practically for analysis of environmental factors and estimation of regional attractiveness. The structural model can be said to have advantages of both the linear attractiveness function model and the neural network model.

It has also been possible to estimate the ratio of attractiveness between regions by means of the neural network model with which the environmental factors of the local region are used. Although in general the neural network model can be estimated accurately, the structure of the model cannot be expressed explicitly with this model. In this study, however, the practical model was estimated by investigating the relationship between the input and output variables.

As is explained above, the models proposed in this study have a feature different from the multiple regression model or quantification theory model based on the questionnaire survey data. The models hereby proposed are considered to be promising and could be applied widely in model analysis of regional planning.

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環境構成要素の構造モデルとニューラルネットワークモデルによる地域の魅力度推定とモデルの比較に関する研究

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本研究では，地域の魅力度とその構成要因との関係を分析することを目的に，地域環境構成要素の構造モデル，およびニューラルネットワークモデルを提案し，人口の社会移動における地域選好度に基づいてモデルを推定した．その結果，提案した2つのモデルとも良い精度で推定することができ，さらに，従来から良く使われている線形関数を魅力度関数としたモデルを含めた3つのモデル間の比較を行い，構造モデルおよびニューラルネットワークモデルの特徴を明らかにするとともに地域の魅力度推定への適用可能性を示すことができた．