APPLICATION OF NEURAL NETWORK MODEL TO ANALYZING SIGHTSEEING TRAVEL BEHAVIOR

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Abstract: Sightseeing travel subject to this study is non-steady, non-routine transportation behavior, which varies by day of the week, season and time of day. Because selection of sightseeing routes is particularly dependent on personal opinions, there is a limit to analysis if rational behavior is used in its process. There is also a great divergence between the reality and models used in conventional analysis. In this study, therefore, a model to reproduce sightseeing travel behavior was constructed using a neural network model.

Key Words: Sightseeing travel behavior, Neural network model, Road network

1. INTRODUCTION

Sightseeing travel behavior depends on people's choice of hours/time, destinations, order of visits and routes between destinations. What is generally important in transportation planning is to know when, where and how much sightseeing demand should arise. For example, sightseeing travel patterns vary by changes in attractiveness of sightseeing areas and routes. It is therefore necessary to accumulate research results concerning sightseeing travel itself. Although disaggregate analysis and various other types of analyses have been conducted in addition to conventional trip chain analysis, analysis of cases with many groups of options, such as actual travel behavior, has not shown remarkable progress.

Based on the above facts, the purpose of this study is to examine the usefulness of a neural network model (NN model), which is supposed to excel in expressing phenomena, by applying it to sightseeing travel behavior instead of using a conventional structural model. More specifically, combinations of attractiveness of sightseeing areas and routes between destinations were recognized as patterns and studied using an NN model. Then the model's performance of reproduction was confirmed and measures were evaluated by sensitivity analysis. Data used for analysis were collected through independent research in Hokkaido, and the basic research schedule was designed in accordance with the national sightseeing and traffic condition survey. This study is an analysis of broader-based, single-day sightseeing travel behavior.

2. REVIEW OF EXISTING STUDIES AND NN MODEL

2.1 Review of existing studies

Analysis of sightseeing travel behavior in the 1980s and earlier was explained in detail in the study by Morichi et al., which indicated the difficulty of estimating the effects of personal attributes on trip generation, dealing with traveling nature in trip distribution and the selection of non-minimum paths in assigned traffic volume. As this difficulty imposes a limit in analysis using a four-step travel estimation procedure, it is necessary to come up with some new ideas. One of such ideas is trip chain analysis, for which research has been conducted. In a recent study conducted by Nishii et al., an absorbing Markov chain model was applied to analyze the behavioral characteristics of sightseeing travel. Although the origin-destination volume by zone was calculated in this study, there was a problem of continuously grasping differences in travel behavior with changing time zones. Disaggregate analysis was first applied in 1983 and has been used for development of actual plans. Recent studies include a study by Morikawa et al., which took the scheduling stage before departure into account as one of the multi-stage selection behavior models. Although this study modeled personal selection behavior with extreme precision, application of the model to a large group of multi-stage options was not achieved.

The above is merely a review of leading studies from the viewpoint of techniques. However, a variety of analyses have recently been conducted on sightseeing travel behavior, and their number has also been increasing. What is important in this study is the fact that most past studies used structural models and aimed to "predict" travel behavior. Although the authors do not object to structural models, application of phenomenon "description" type models, such as the NN model explained below, is also considered important due to the above-mentioned problems concerning models.

2.2 Why NN model?

The NN model in this study uses its self-organization ability to suit the external environment, and learns independently only from the past input/output results. It is therefore a method for analyzing structures as black boxes. It is widely known that NN models are, in general, highly effective in reproducing known data. Why using an NN model for analyzing sightseeing travel behavior is therefore an important point, along with the argument on the precision of model estimation. This point can be summarized from the following two aspects:

(i) Sightseeing travel behavior captured by pattern recognition
(ii) Planning process model which is not a predictive model

(i) Sightseeing travel behavior captured by pattern recognition: Because the purpose of an NN model is to represent advanced nonlinearity, its original idea is different from that of structural models in general. The purpose of this study was to capture sightseeing travel behavior as spatial pattern data and to describe its dynamic changes. An NN model was used because it was thought to be possible to make effective use of its ability to "distribute and accumulate collected data, and classify and output such data when pattern data are input again."

(ii) Planning process model which is not a predictive model: In many cases, structuring of models for civil engineering plans in the past was prediction-oriented, and lacked discussions on diagnosis and abduction. NN models are closer to descriptive than to predictive models because they only consider the conformity of input and output without examining input data. Many factors concerning NN models have not been theoretically established, and many parameter identification processes necessary for the determination of layer structures are still unclear. Fundamentally, however, this is what the exact idea of NN models is. Although many discussions will be necessary to know how to use NN models in the field of transportation planning, the authors think that discussions on abduction related to the planning process are important, and considers the use of NN models as a method for analyzing it. This is not a predictive model to observe the output behavior by changes in input conditions. It is therefore considered necessary to use a model, which captures the input-system-output process as one system (pattern) and studies and describes the dynamic pattern of the entire system.

3. COMPOSITION OF THE STUDY AND ANALYSIS DATA

3.1 Composition of the study

As shown in Fig. 1, this study consisted of the following five processes:

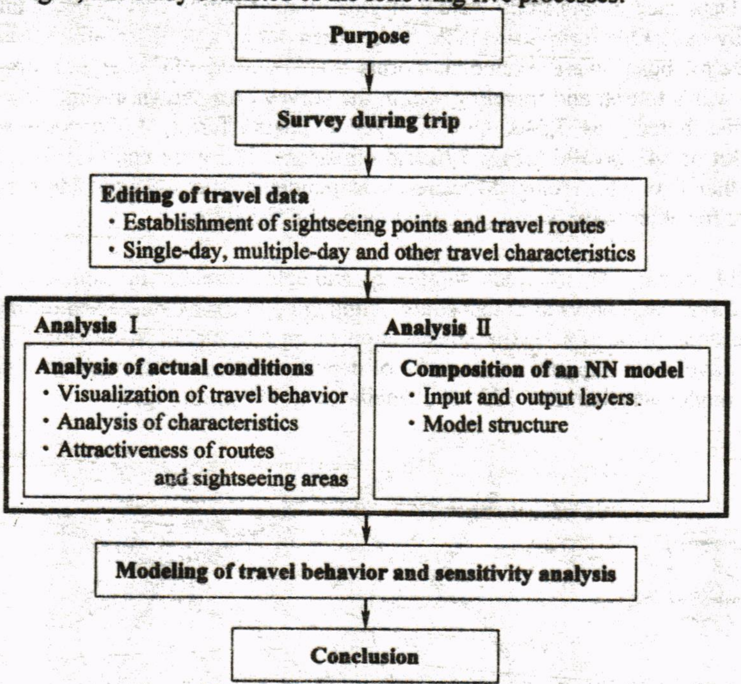

Figure 1. Flowchart of the study

(1) Investigation: In this study, sightseeing travel behavior had to be studied with limited cost and time. Survey forms were therefore distributed during the trip and collected later by mail.

(2) Editing of travel data: A survey form consisted of a face sheet and a map on which the travel route was to be indicated. Then the respondents were asked to choose the sightseeing points they had visited from the given choices in order of their visits. Because omissions and contradictions may exist in such a complicated survey, it is important to select valid forms. After checking collected data, sightseeing points and travel routes were

determined using data considered valid, taking into account travel characteristics such as single-day travel, multiple-day travel and type of activity.

(3) Analysis of actual conditions: To classify travel behavior patterns, it is necessary to establish sightseeing points and routes to generate the patterns. After that, analysis of travel patterns will become possible by forming groups of several sightseeing points and routes. In this study, groups of sightseeing points are called sightseeing areas.

(4) Composition of an NN model: The actual method of neuron composition based on "why an NN model?" in the previous section is an important issue to be considered.

(5) Modeling of travel behavior and sensitivity analysis: Here, the performance of reproduction of an NN model was evaluated using actual data to confirm the model's effectiveness. Next, attractiveness of sightseeing areas and time distance of routes (e.g., opening of new routes) were changed to analyze their effect on travel behavior.

3.2 Survey and editing of travel data

This study was conducted for four days from August 5 (Fri.) to August 8 (Mon.), 1994. Survey sites were main parking lots on ten sightseeing points and their links shown in Fig. 2 (Fig. 2-2). Data used in this study were collected by distributing survey forms and collecting them later by mail. One form per vehicle (to be filled out by a representative) was distributed, and sightseeing buses were excluded. Forms were handed out after confirming that the respondent was a tourist and traveling within the survey area shown in Fig. 2-1. The number of forms distributed was 7,540. Out of 1,927 collected forms, 1,384 were valid (18.4% validity). Out of 543 invalid forms, 276 had omissions, 112 were contradictory, 78 included activities other than sightseeing, 57 were by respondents who went outside the survey area and 20 were for other reasons (e.g., returned by public transport).

Out of valid forms, 538 were for single-day and 846 were for multiple-day travel. Only single-day travel was analyzed in this study. Although 538 forms were used for the analysis of actual conditions in Section 4, the construction of an NN model in Section 5 was only for single-day travel with Sapporo as the point of departure/arrival. The number of samples used for the NN model was therefore 323. The details are as shown in Fig. 3.

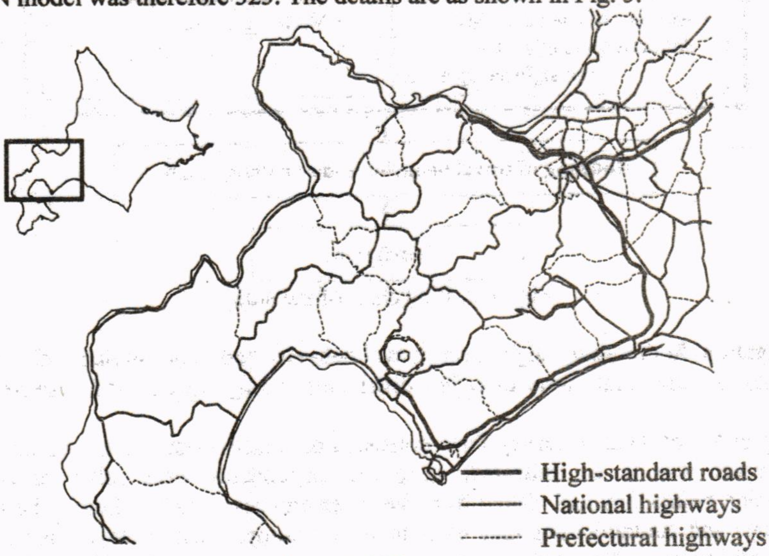

Figure 2-1. Survey area

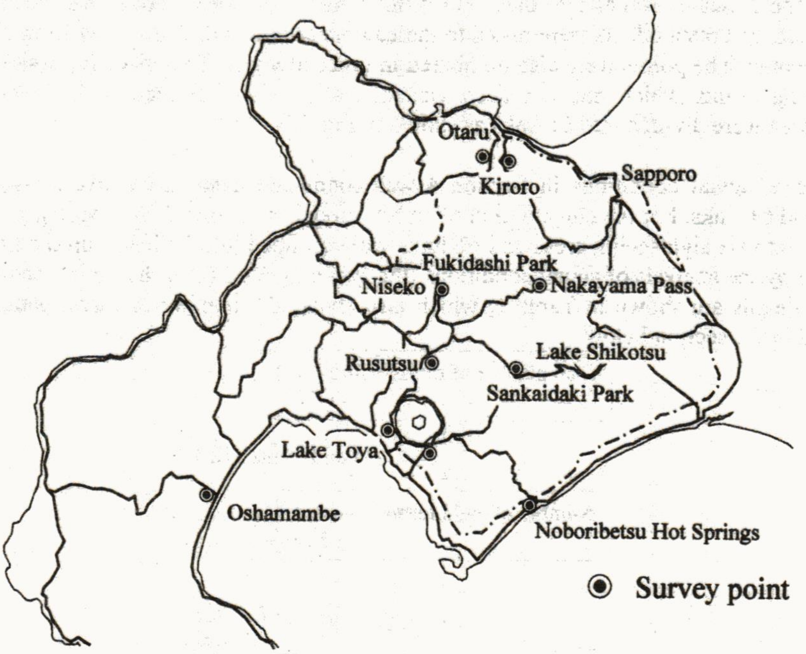

Figure 2-2. Survey sites

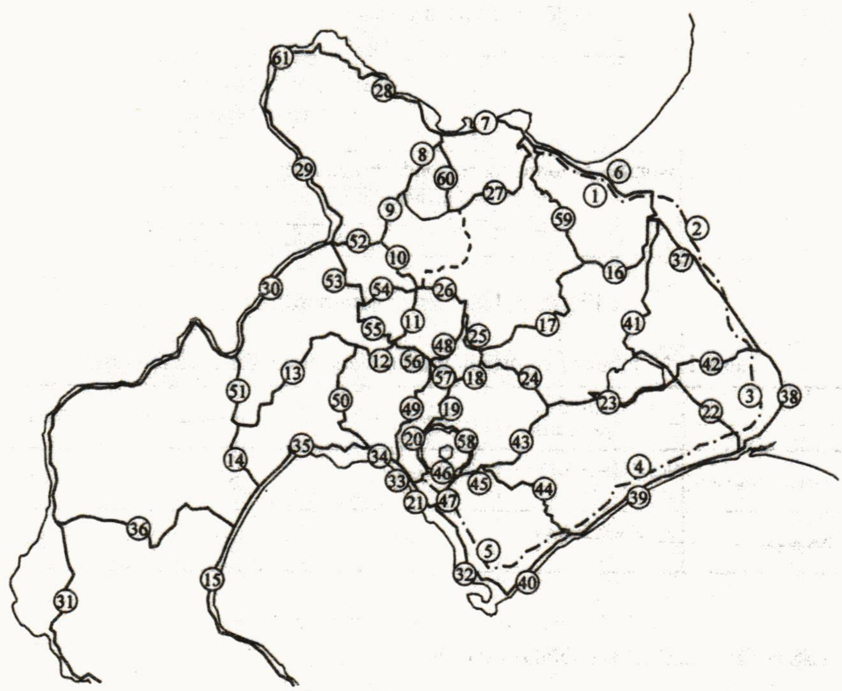

Figure 2-3. Link numbers

Travel data was collected by getting the respondents to indicate their travel routes on a map. Selection of sightseeing points and division of road networks into links were necessary to

convert the indicated routes into data. Thirty-four main sightseeing points had been selected in advance, and respondents were asked to indicate these points on the survey form separately from the map. The points were also numbered in order of visits. This made it possible to omit sightseeing points which had not been visited. National and prefectural highways in the survey area were divided into 61 links as shown in Fig. 2-3.

Analysis of actual conditions in Section 4 was conducted using the above 34 sightseeing points and 61 links. For the construction of an NN model in Section 5, sightseeing points were grouped into six sightseeing areas and 61 links were grouped into 18 based on the knowledge obtained by the analysis of actual conditions (the grouping method is shown in Sections 4 and 5). The details are shown in Table 1, which also shows the number of travel patterns to be revealed in the section below.

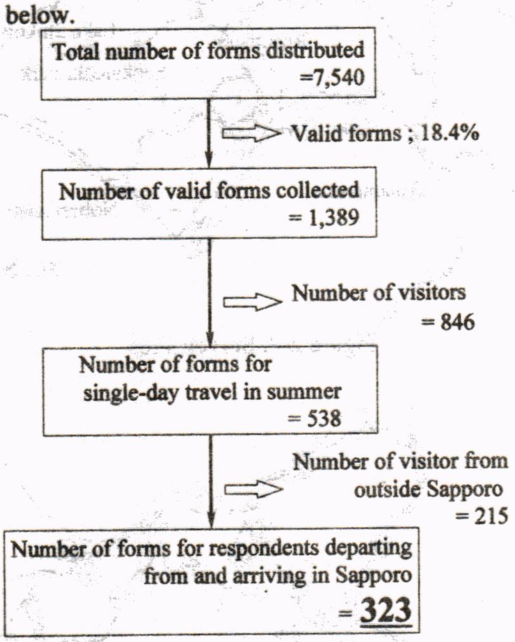

Figure 3. Number of survey forms

Table 1. Number of sightseeing points and links for each analysis

	No. of sightseeing points/areas	No. of links	No. of samples	No. of travel patterns
Analysis of actual conditions	No. of sightseeing points 34	61	538	300
NN model	No. of sightseeing areas 6	18	323	56

4. ANALISIS OF ACTUAL CONDITIONS

4.1 Actual condition of route selection (frequency of use of links)

People's sightseeing travel behavior can be illustrated using a computer, by selecting the sightseeing points visited and links used by tourists. Figure 4 shows the number of people who used each link. If a person used the same link for return, the number was counted as two. From this figure, it can be easily seen that many people used National Route 230 which runs from Sapporo to the Pacific coast through Nakayama Pass, making it the main route for tourists traveling in central Hokkaido. The second largest number of people used National Route 276 which branches from Route 230 to Niseko and Sankaidaki Park (thick lines in Fig. 4).

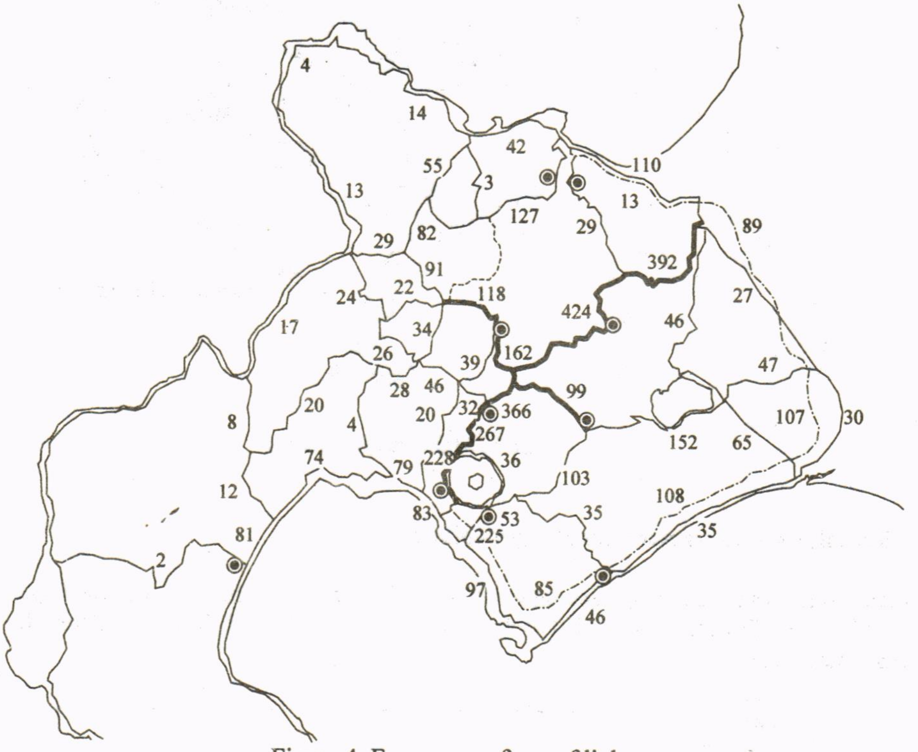

Figure 4. Frequency of use of links

4.2 Analysis of travel behavior

The number of travel behavior patterns indicated by the composition of sightseeing points and links accounted for 300 out of 538 samples for single-day travel in summer. Grouping of 61 links was therefore attempted to further clarify characteristics. First, two courses consisting of multiple links were found (there were up to four courses with multiple links). Here, the time distance of each road was calculated using a road time table, and the courses that were up to twice as long as the shortest course of a route were subject to grouping. Next, one of the two courses with fewer users was integrated into the other courses. As a result of the above grouping, 61 links were grouped into 27. By this grouping, the number of travel patterns decreased to 107. Figure 5 shows four of those patterns with the largest numbers of users, all of which were patterns departing from and arriving in Sapporo. With the link numbers in Fig. 2, the four patterns can be represented by 16-17-18-19-20-19-18-17-16 (61 samples), 1-1 (36 samples), 16-17-25-26-25-17-16 (35 samples) and 16-17-18-17-16 (35 samples), respectively (167 samples out of 538, 31% of the total).

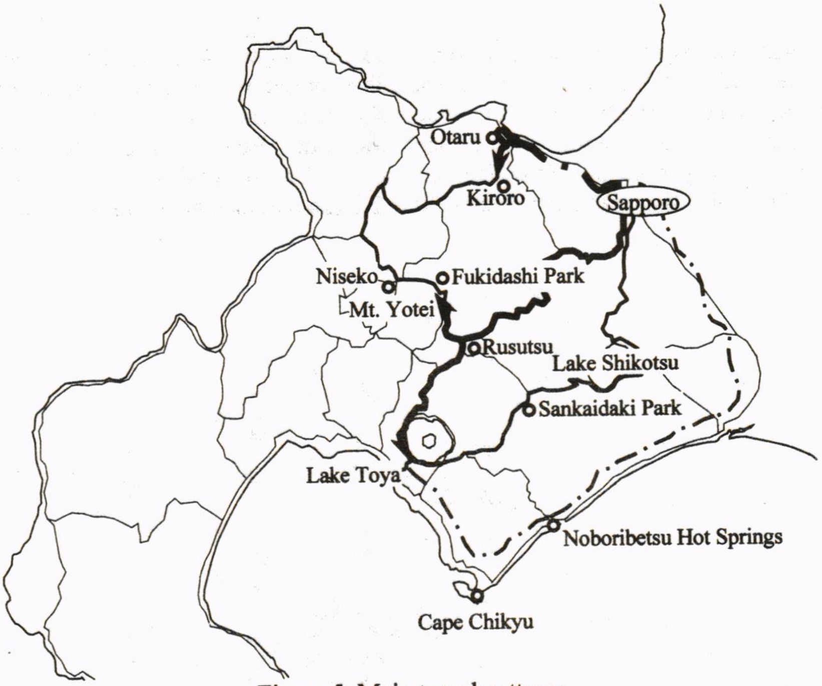

Figure 5. Main travel patterns

4.3 Analysis of characteristics of sightseeing areas

Figure 6 illustrates main sightseeing points visited by tourists. This indicates the large number of visits to Toyako Spa and Niseko highlands, which had been predicted by travel characteristics.

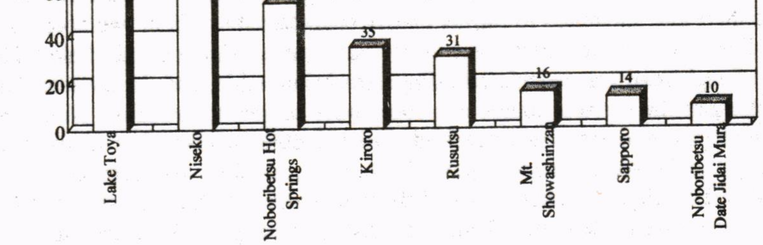

Figure 6. Number of visits to main sightseeing points

5. COMPOSITION OF AN NN MODEL

For application of an NN model, 323 samples with Sapporo as the departure/arrival point were used. This further reduced the number of applicable links from 27 groups to 18. Thirty-four sightseeing points, which were on the same courses of grouped links and at intervals of up to 20 km, were also grouped here into 6 sightseeing areas. The eighteen links and six sightseeing areas are as shown in figures (only main sightseeing points are shown in Fig. 7). By establishing the above links and sightseeing areas, the number of travel patterns became 56.

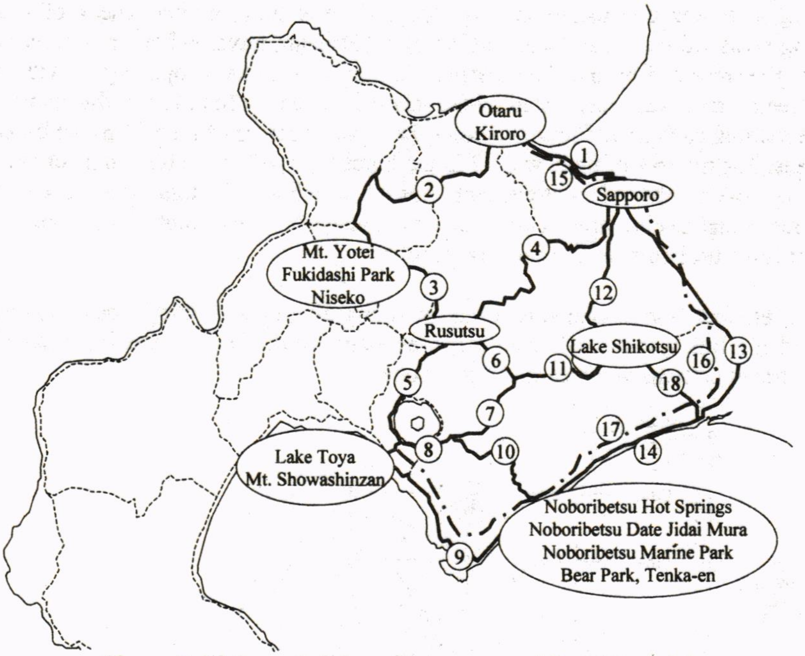

Figure 7. Links and sightseeing areas used for NN model

The multi-layered neural network model used in this study consists of a mesh network of units, which are artificial models of human nerve cells connected with lines corresponding to nerve fibers. In the multiple-input, single-output units, weight is put on outputs to form other inputs. Inputs are summed in the units and then output by response function (Fig. 8).

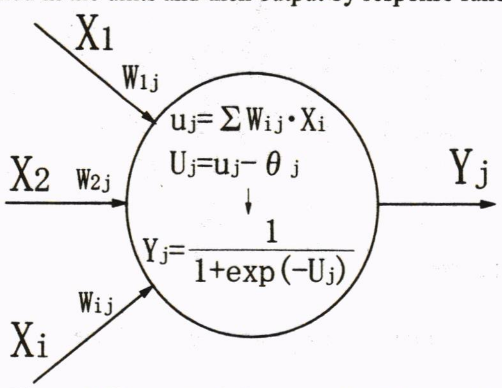

Figure 8. Conceptual diagram of an NN model

A network which minimizes the square error between the actual output value and correct output value (teacher signal) is the most suitable for an NN model. Learning of an NN model is a process to find a coupling coefficient for which this error is the minimum while correcting the initial value. This ability is called self-organization ability, and independent learning to suit the external environment is possible only from past input and output. In this study, back propagation method was used as a learning method.

In an NN model, determination of the above structure is an important matter for consideration. A model structure to know the number of users by inputting the travel patterns formed in a sightseeing area was considered in this study. At this time, attractiveness of routes and sightseeing areas were used as factors affecting sightseeing travel behavior. Attractiveness of a route was represented by the time distance (minutes) of links composing it. Attractiveness of a sightseeing area was represented by the relative frequency found from the annual number of people visiting each area. Figure 9 shows the layer structure of an NN model based on the above ideas. The number of units was 42 in the input layer, 42 in the hidden layer and 1 in the output layer. The number of input elements was 42, which was the total of 36 (2 x 18 links for return) plus 6 sightseeing areas (input as attractiveness). The output element of 1 was the number of route user counted for each travel route.

Each input element corresponded to a link or sightseeing area. Attractiveness was input into an element if a link was passed or an area was visited and, if not, 0 was input. As shown in Fig. 9, 56 travel patterns were learned one by one.

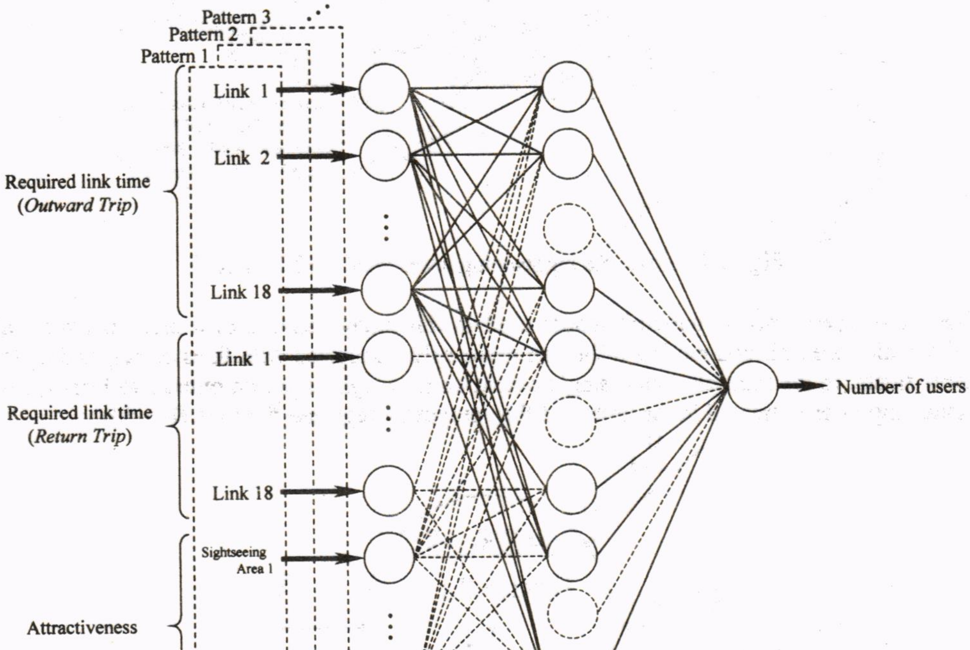

Figure 9. Structure of an NN model

6. MODELING OF TRAVEL BEHAVIOR AND SENSITIVITY ANALYSIS

6.1 Model's performance of reproduction

The following is a description of input data. Figure 10 shows the required link time (minutes) and the frequency of appearance. It requires 10 to 20 minutes for short links and 90 to 100 minutes for long links. Figure 11 shows the attractiveness of six sightseeing areas. The number of users for each travel pattern, which was used as output data, was 61 persons at the maximum, 1 at the minimum and 5.7 on average. Using the above data, learning was conducted in this study so that the error in the calculation process would be less than 10% of each output value. As a result, the average absolute value was 0.4 person for the error in output value of each pattern after 150,000 times of learning. Calculation was stopped here because the model was considered capable of fully understanding the current status. The value of 0.4 person means that the number of users on the route with average of 5.7 persons can be represented with a margin of error of ±0.4 persons. It therefore means that a model with high performance of reproduction could be constructed.

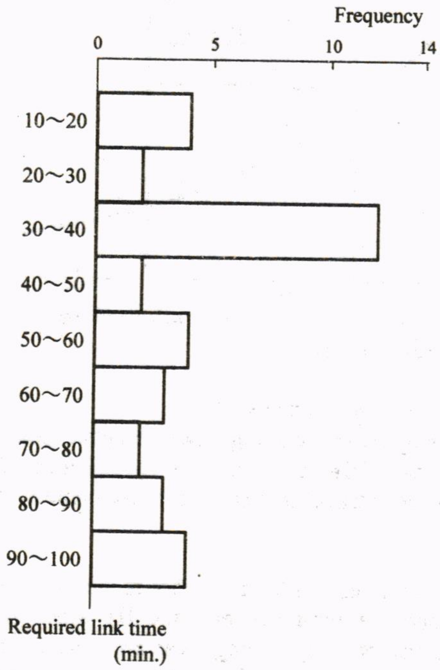

Figure 10. Input data (required link time)

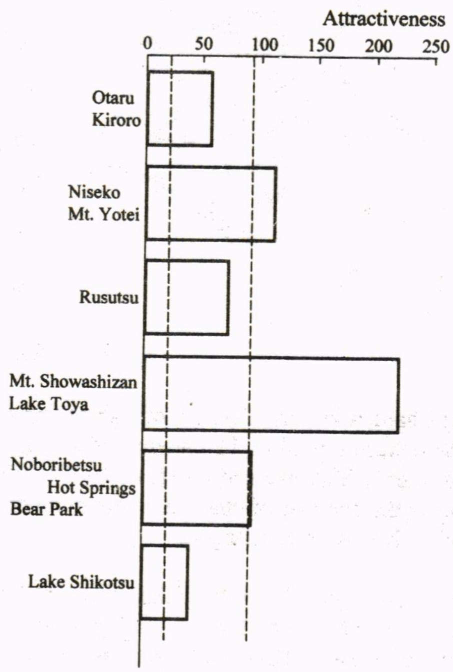

Figure 11. Input data (attractiveness of sightseeing areas)

6.2 Sensitivity analysis

An attempt was made to evaluate measures to reduce required link time or improve attractiveness of sightseeing areas using an NN model with high performance of reproduction. More specifically, the following two points were studied:

(i) Increase in users using the link which will be created when National Route 393 (currently under construction) shown in Fig. 12 opens

(ii) Changes in number of users of travel routes if attractiveness of Lake Shikotsu is improved

(i) Changes in attractiveness of a link and number of its users
When National Route 393 is fully open, the required link time of (ii) in the figure will be reduced by 20 to 30 minutes. Sensitivity analysis using this model was conducted to know the consequent increase in users of the link.

In the analysis, the required time for link (ii) was simply reduced by 20 and 30 minutes on the travel route for which link (ii) was used. Then the outputs (number of users using the travel route) were added up. The results are shown in Fig. 12. The number of users of link (ii), which was 27 when required time was 80 minutes, became 49 with a reduction of 20 minutes and 68 with a reduction of 30 minutes. The range of changes in input values is important in sensitivity analysis. It can be seen from Fig. 10 showing input data that changes in data are within the range learned with the NN model.

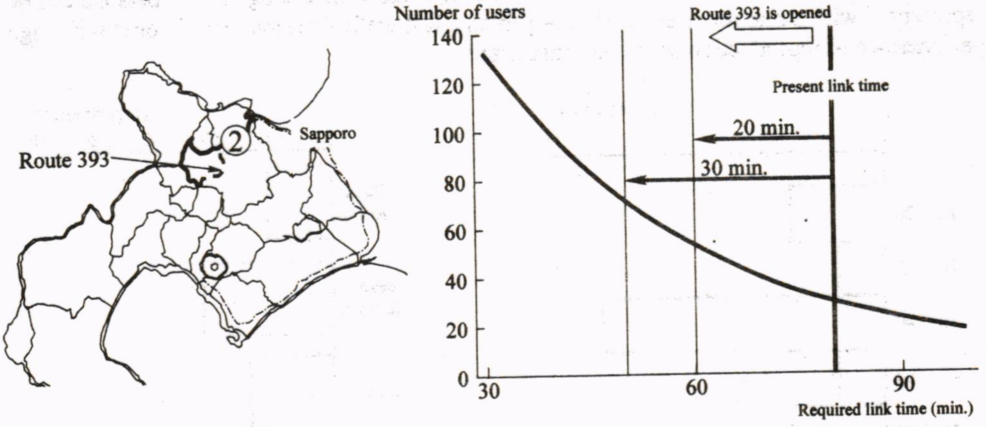

Figure 12. Sensitivity analysis (i)

(ii) Changes in attractiveness of sightseeing areas and number of users
There were a total of 11 patterns of travel behavior by people visiting Lake Shikotsu. Some chose only Shikotsu and others chose a combination with Niseko, Rusutsu or Toya. Figure 12 shows the analysis of changes in the number of visitors to travel routes when attractiveness of Lake Shikotsu was changed.

From this figure 13, it was found that the number of route users might increase monotonously (travel route I) or stop increasing when it reached the limit (travel route II) when the attractiveness of Lake Shikotsu was increased. Because two sightseeing areas are traveled in the case of route II, the number of users may not increase even if the attractiveness of one area is improved due to the time restrains of single-day travel.

From the above results of sensitivity analysis, it was found that the feasibility of the evaluation of measures would be high if the changes in input data are within the range of data changes learned by the NN model.

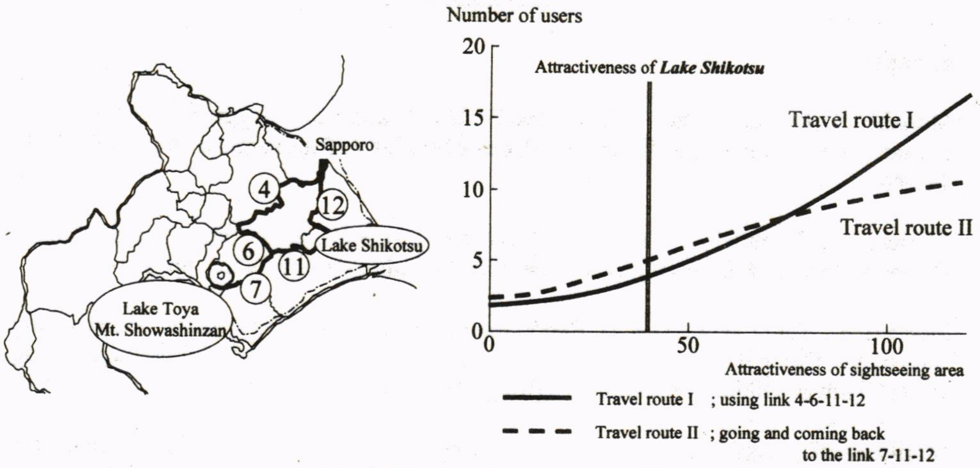

Figure 13. Sensitivity analysis (ii)

7. CONCLUSION

This study is an analysis of sightseeing travel behavior in Hokkaido using an NN model. The following results were obtained from the study:

(i) Construction of layer structures was proposed for application of an NN model for sightseeing travel behavior.
(ii) In description of travel patterns using the proposed NN model, the model showed high performance of reproduction.
(iii) By evaluating measures through sensitivity analysis of the NN model, results which could explain the phenomenon were obtained.

Although the modeling of multiple-day sightseeing travel behavior is yet to be achieved and a method for modeling the temporal continuity in this analysis has not been found, the authors believe that a basic model structure can be achieved by the method proposed in this study.

REFERENCES

a) Papers

Morichi, S., Ishida, H. and Yai, T. (1983), "Application of disaggregate analysis to non-routine transportation" (in Japanese), **Proceedings of Infrastructure Planning No.5**, pp. 442-449

Morichi, S., Tamura, T., Yai, T., and Hyodo, T. (1986), Evaluation of Recreation Trip Demand Models (in Japanese), **Infrastructure Planning Review No. 4**, pp. 125-132

Morichi, S., Yai, T. et al. (1983), Report on examination of transportation characteristics of Tokyo Bay Cross Road - estimation of holiday sightseeing traffic by disaggregate analysis, Japan Highway Public Corporation, Highway Research Association

Morikawa, T., Sasaki,K. and Azuma, R. (1995), Model Sightseeing Travel Behavior for Evaluation of Road Network Improvement in the Recreation Area (in Japanese), **Infrastructure Planning Review No, 12**, pp. 539-547

Nishii, Km, Furuya, H. and Sakai, T. (1993), "Temporal and Spatial Characteristics of Recreational Excursion Behaviors" (in Japanese), **Proceedings of Infrastructure Planning No.16 (1)**, pp. 173-178

b) Other documents

Kaoru Nakano, Kazumoto Inuma, Neuron Net Group, Shigeru Kiriya, "Introduction to Neuron Computing and Practice," Gijutsu Hyoronsha, 1989

1994 Statistics of Visitors to Sightseeing Areas in Hokkaido. (1995), Department of Commerce, Industry and Tourism, Hokkaido Government