MEASURING EFFECT OF TRAFFIC SAFETY IMPROVEMENT MEASURES USING ITS

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1.Abstract

Usually what traffic safety information refers to gradient or accident points, where advanced car navigation systems, nowadays, provide real-time presentation of this kind of information. This study's aim is to find out what kinds of traffic safety information are needed by users. In this report, 'point information' is defined to represent traditional traffic signs situated on the road and 'linear information' is defined to represent continuous information regarding the course of the road. Upon seizing how movements of vehicle change according to the quality and the quantity of the 'linear information', the study aims mainly to estimate the value of 'linear information'.

2. Introduction

While development of hardware is progressing for research on evaluation of information using ITS, there are several problems concerning its practical use. The largest problem is, as the relationship between information and people's travel behavior is still unclear, determining how much and what kind of information should be provided to drivers. This is a problem because excess information may lead to reduced driving speeds and lower reliability of information, with the net result of deterioration in the traffic environment. Regarding information provision methods, FHWA in the U.S.A. has already begun research on a traffic safety system to provide sectional traffic information. This is called the Interactive Highway Safety Design Model (IHSDM) and indicates points of frequent traffic accidents and other data on a GIS for drivers. Its effectiveness has already been investigated through social experiments.

Regarding research on ITS, regional ITS is a field in which Japan is falling behind other countries. "Region" is one of the elements of regional ITS in addition to "drivers," "roads" and "vehicles" that constitute ITS in general. There are two types of information depending on its providers - running environment factors (alignment of road, traveled surface condition, road congestion condition, etc.) provided mainly by road administrators and information prepared and provided by regional authorities (e.g., regional analysis and compilation of road information using interactive vehicle information as a platform).

The purpose of this study was to develop a simulator to understand how drivers would evaluate information on alignment of road, traveled surface condition, road congestion condition and other aspects by providing it as linear information. More specifically, its aim was to consider development of a traffic simulator as a platform of interactive vehicle information to understand the effectiveness of linear information, as well as regional management and the provision of information in a transition period between the present and the time when interactive vehicle information (effects of an ITS network cannot be expected unless equipment is in common use to a certain degree) will be realized. In the study, linear information using a Neural Network-Cellular Automata (NN-CA) simulator was prepared from the results of a social experiment conducted at Nakayama Pass, Hokkaido, in 1999. Effectiveness of the linear information was evaluated by conducting a social experiment (Fig. 1).

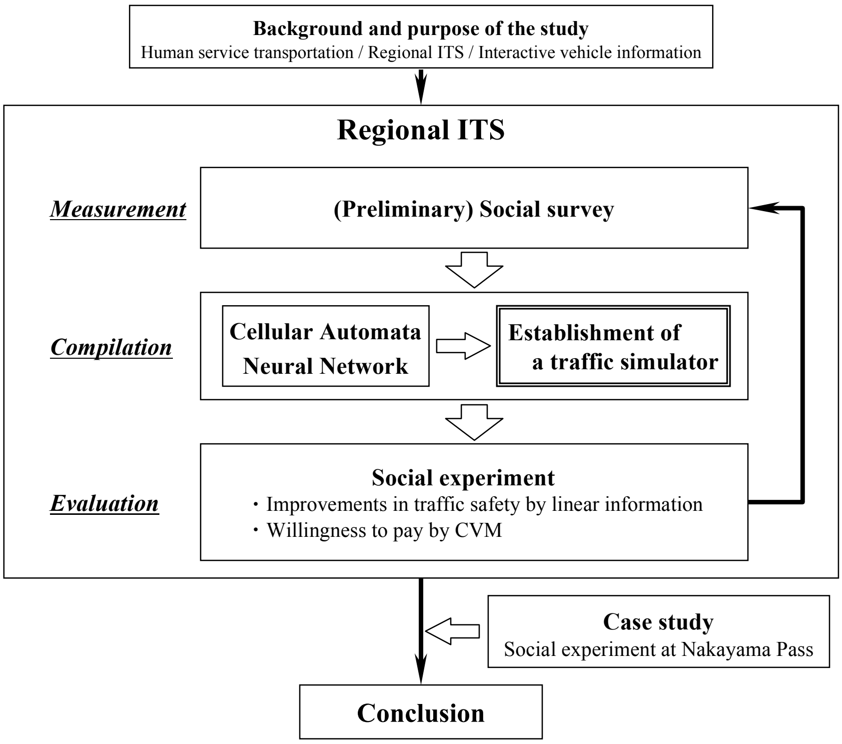


Fig. 1 Study Process

3. Interactive Vehicle Information

In current traffic networks, real-time information can be provided using sensors or cameras on the road. However, it is only for sections equipped with sensors or cameras and spatial restrictions have not been eliminated. There is also a managerial problem because the amount of information is enormous, even if it is available. Information exchange by equipment loaded on each vehicle (hereinafter referred to as interactive vehicle information) was therefore considered as a method for expanding the space in which information would be managed from collection to distribution. It is a system to enable the establishment of dynamic local road information networks by repeating exchanges of observation information among devices loaded on vehicles that happen to pass by the area.

Due to the simple network structure, easiness of management and other factors, interactive vehicle information was considered effective as a platform for regional ITS. In a study of Kobayashi (Ref. 4), it is mentioned that "a dense and complex network with diverse modes is necessary to satisfy the complex demand of people (regional ITS) in a knowledge society." There are, however, many pending problems, such as the fact that effects of an ITS network cannot be expected unless car-loaded equipment is in wide use to a certain extent.

4. Regional ITS

A road information system using regional ITS may be designed in three phases - (1) measurement, (2) compilation and (3) evaluation of road information. It is considered that more advanced ITS can be completed in cycles by repeating these phases (Fig. 1).

(1) Measurement of road information

Conventional road information consists of data obtained from road design, road traffic census and original survey data of traffic accidents. When technologies are developed in the future concerning acquisition of positional information on moving traffic, vehicles themselves may be able to serve as observation devices to measure detailed road information by establishing interactive vehicle information.

(2) Compilation of information

The measured road information will be compiled (analyzed) into information service that can be provided. In the past, information was provided as in the form of point information with signs placed at dangerous sections by road administrators. With the development of information technology in recent years, however, it has become possible to provide linear information such as alignment of road (Fig. 2), two-dimensional information with spatial expansion, as well as multidimensional information (e.g., GIS). When using such information in the form of regional ITS, however, it is necessary to (1) apply flexible technical skills to keep up with the progress of technologies so as to fully understand the problems concerning information service and improve service on a continuous basis and (2) give sufficient consideration to users, especially drivers who are constantly at the risk of road traffic accidents.

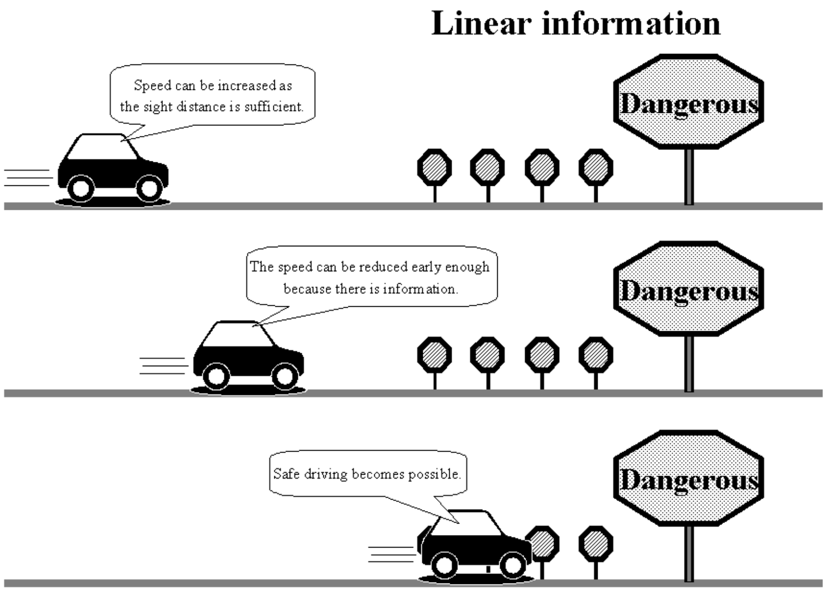


Fig. 2 Image of Linear Information

In this study, therefore, information was compiled using an NN-CA traffic simulator using a cellular automata traffic simulator established in the study of Sasaki et al. (Ref. 1) and a neural network model (NN model) as its internal rule. The NN-CA simulator was thought to be effective for compilation of regional ITS because (1) it is a simple model that can be continuously updated, (2) information can be generalized by eliminating noises (e.g., speed maniacs) using the NN model and (3) the local rule by NN can be spatially expanded using CA.

(3) Evaluation of information

The compiled information was evaluated. It was assumed that information provided would be socially evaluated by the market. In other words, information concerning the cost of special equipment for obtaining information and the method of obtaining information by paying would be exchanged through the market. In this case, price and demand would be high for information required or considered useful by people. In this study, therefore, the above NN-CA model was evaluated by the CVM (contingent valuation method).

5. Traffic Simulator Using CA

(1) Positioning of this simulator

The traffic simulator was first classified into three types and their respective characteristics were listed (Figure 3 shows the three concepts that will be explained below).

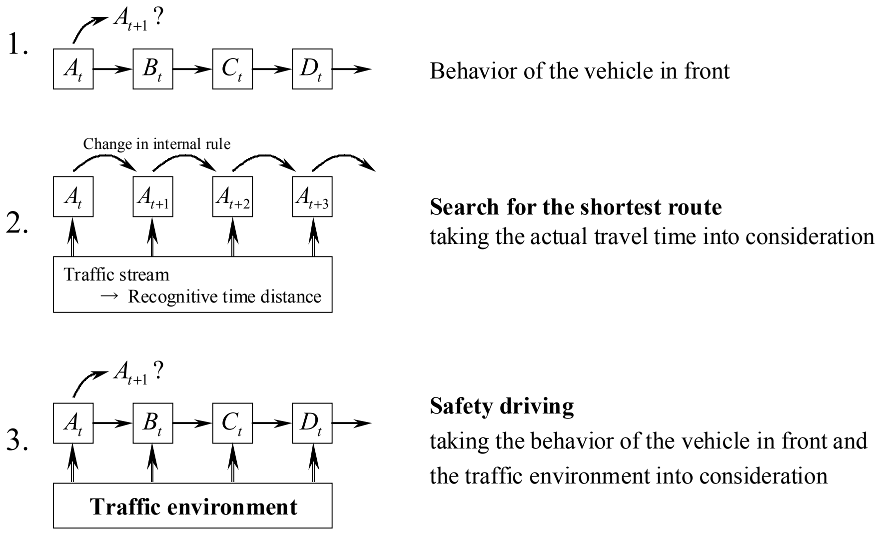


Fig. 3 Conceptual Drawing of A Traffic Simulator

1 With the conventional type of simulator, the behavior of vehicle A is determined by the traffic stream of the previous period, influenced by vehicles B and C in front of it.

$A_{t+1} = f(A_t, B_t, C_t, \cdots)$ $\cdots(1)$

In this case, vehicles A, B and C have a common local rule. It is a behavior to maintain a certain vehicular gap to avoid a collision with the vehicle in front. If the driver of the vehicle in front (B_t) applies the brakes, the driver of the vehicle behind it (A_{t+1}) does the same. The traffic stream represented is using this concept.

2 Although the study of Fujii et al., which is an advanced study of complex systems, aimed to address the route selection of individual drivers, it can be positioned, if expressed by the concept of CA, as a means to experience and learn the recognitive time distance (t_{ij}) from driving patterns on the previous day, under a daily time interval basis, to change the internal rule as well as to shift to the next time zone.

$A_{t+1} = f(A_t, t_{ij})$ $\cdots(2)$

3 CA proposed in this study is the analysis of changing behavior with the changes in the surrounding environment on assumption that the internal rule is uniform (common to all drivers). The surrounding environment refers to information on the existence of a vehicle in front ($B_t, C_t, \cdots$), alignment of the road, point of frequent traffic accidents and other items.

$A_{t+1} = f(A_t, B_t, C_t, \cdots, I)$ $\cdots(3)$

(2) Method of inputting traffic information

Traffic information presented here is characterized by the fact that it is linear information concerning the running section. By providing this information to the driver in advance, changes in the vehicle's running speed was analyzed. Interesting points regarding this method of providing information are (1) how people recognize continuous information and react to it and (2) consideration of ways to provide continuous sectional information. The proposed traffic simulator will be established to analyze these two points. More specifically, an attempt will be made to construct a model to reproduce the traffic stream conditions in different road traffic environments by dividing each road traffic environment into the "existence of vehicles in front (traffic flow volume)" and the "method of providing traffic information (including the existence of such information)." Although this idea has already been presented by FHWA, the implementation of modeling is unique to this study.

6. Case Study (Social Experiment at Nakayama Pass)

(1) Preliminary social survey

Based on the measurement data obtained in the study of Iimura et al. (Ref. 2) conducted at Nakayama Pass in 1999, two samples with or without information under the same running conditions were used.

(2) Construction of a traffic simulator

Using the above two types of data, an NN-CA simulator was prepared. As shown in Fig. 4, explanatory variables of the NN model were the speed, road factors and sight distance with the target variable as the variation of speed.

Here the amount of information obtained by drivers was considered to be sight distance. This was input into the model. For example, if sight distance of up to 100 meters is secured, 1 was input for neurons of up to 100 m and 0 was input for sections after that. This enabled the model to be used to discuss when the appropriate time would be to provide information to drivers.

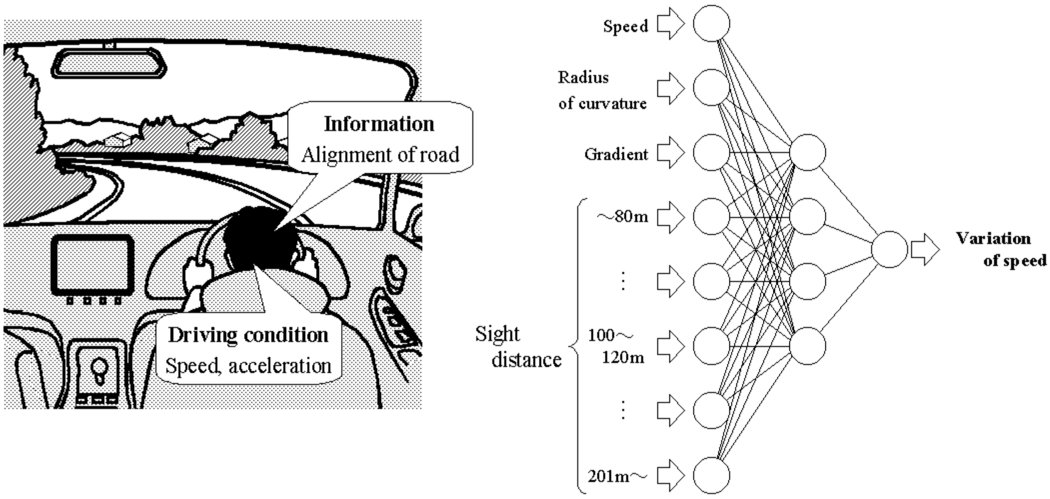


Fig. 4 NN Model

As shown in Fig. 5, the structure of the CA traffic simulator is such that the speed (position) at time t + 1, which was determined by the running environment factors, reciprocal factors among vehicles and ITS and other information technology factors at time t, is mapped in a space and re-mapped in the relationship among drivers. In other words, it means that the above NN model is running on the CA that includes the road environment. This was a concept to represent the effectiveness of linear information. Figure 6 shows the results of an NN-CA simulator using this. Also, a video monitor to plot the hourly NN-CA simulation results on a map was produced and used for provision of linear information.

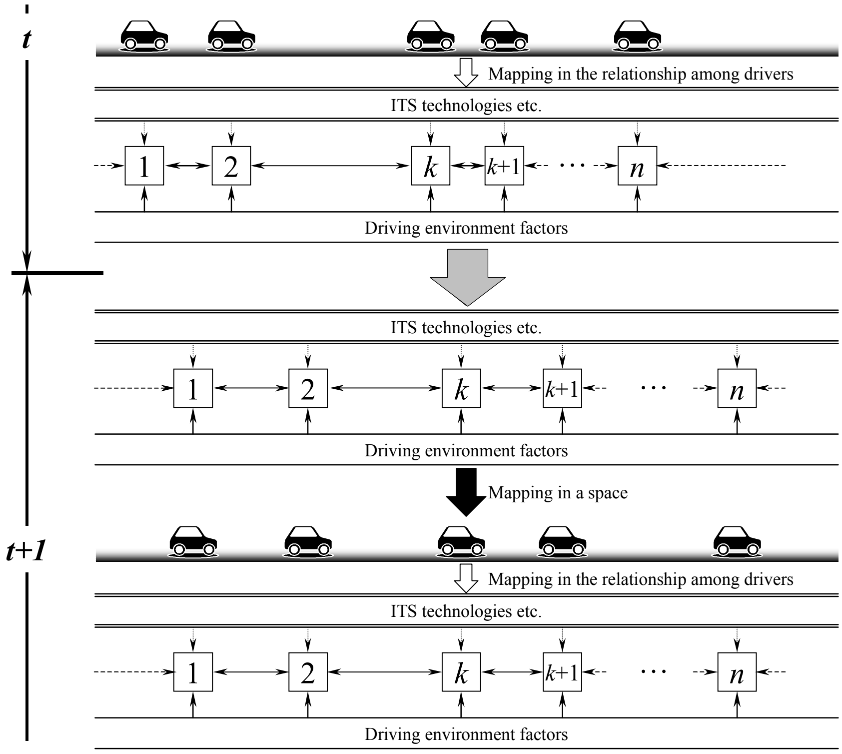
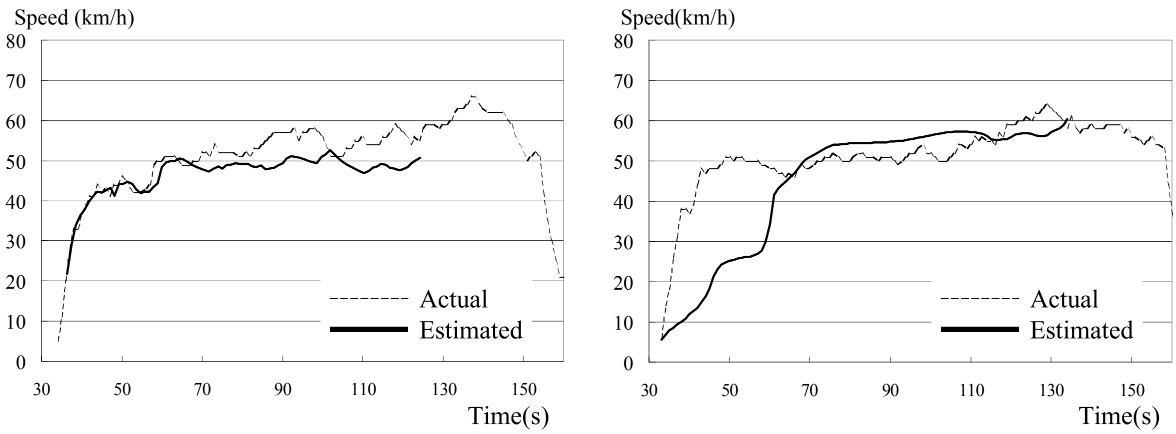


Fig. 5 Conceptual Drawing of CA Traffic Simulator



NN-CA simulator (without information, reproduction)

NN-CA simulator (with information, estimate)

Fig. 6 Results of NN-CA Simulation

Although the results of the actual running and the simulator were consistent in the case with information, divergence was observed in the case without information, as shown in Figs. 5 and 6. This was thought to be caused by the reproduction of information by the NN model on the supposition that drivers already had information on the entire section (12 km) in the results with the simulator. In other words, actual drivers are driving using information on limited parts. The other reason is that they are driving only with information on sight distance of 100 meters or less when receiving information.

(3) Social experiment

The social experiment was conducted from October 30 to November 2, 2000. The research site was a section of National Route 230, approximately 12-km long, starting from the

Michinoeki at the summit of Nakayama Pass toward Kimobetsu Town. The subjects of the research were ordinary drivers who visited the Michinoeki. A safety recorder was used to measure driving behavior. The research was conducted by the face-to-face method. "A map of the road on which the drivers would run (Fig. 7)," "oral explanation of information on dangerous sections" and "a video monitor of the traffic simulator that was prepared in (2)" were provided as "linear information" at the Michinoeki. After that, the drivers were asked to drive on the target section, and an opinion poll concerning road information and a CVM questionnaire survey were conducted at the collection point.

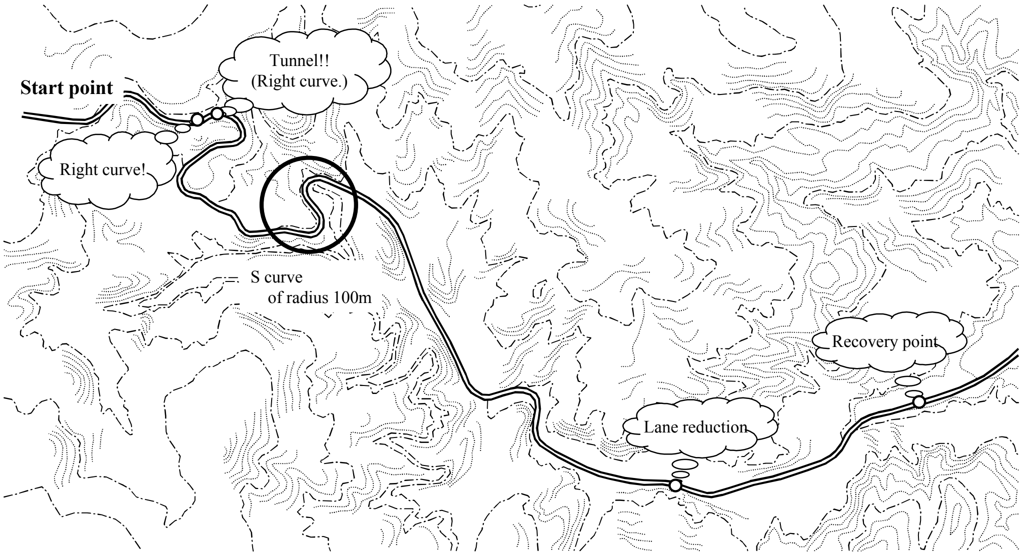


Fig. 7 Linear Information Map

To measure the effect of "linear information" on drivers, driving behavior of the subjects of this study was measured for cases with and without the provision of information.

The following information was given to the subjects:

1. The alignment is sharp in the first half of the section.
2. After the curve warning sign at point a, there is a sharp right curve and a tunnel immediately after that. The sharp right curve continues in the tunnel.
3. There is an S-shaped curve with a radius of curvature of 100 meters at point b.
4. Curves are relatively gentle after point b.
5. As there is construction work in the opposite lane, the lane at point c has been slightly narrowed.
6. Drivers with information (provided by animation) increased their speed in the latter half of the section.

(4) Research results

Data collected from 52 subjects in three days were totaled for each question and shown in a figure (Fig. 8). The vertical line of the figure shows the total number of persons for each item. Figure 7 shows sex, age, years of driving experience, frequency of driving, number of times the driver has passed Nakayama Pass, and the use of car navigation, information terminal or other systems from the upper left to the bottom. Although the rate of using car navigation and other systems was relatively low here, no one was having difficulty driving. This was probably because many of the subjects were frequent drivers due to the high dependency on automobiles in Hokkaido and because it is not necessary to use systems that only provide routine information for frequent users of National Route 230. It was thus thought that the amount of information provided was small and navigation systems were not used enough on frequently traveled roads in rural areas.

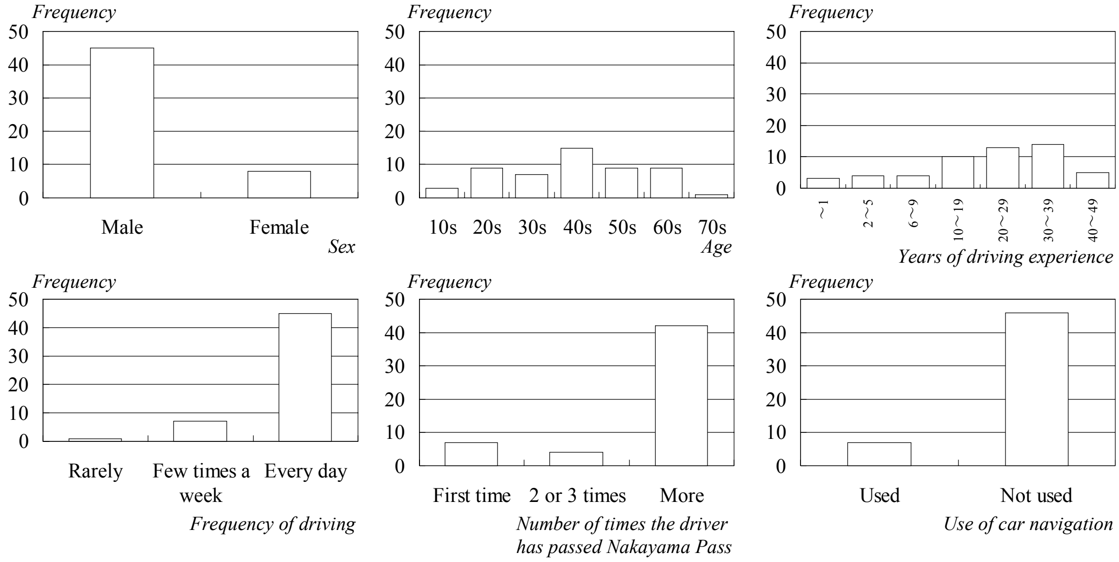


Fig. 8 Questionnaire Results

(5) CVM results

The following CVM questionnaire survey was conducted in this study:

"If alignment of road, dangerous points and other real-time traffic information becomes available in the future by car navigation or other systems as in this experiment, would you like to use such an information service?

What is the maximum charge you would be willing to pay for such an information service? (Ref: information service for portable terminals is ¥100 to 200 a month.)"

As a result, the willingness to pay was estimated to be as shown in Fig. 9 by cumulative total. Fifty percent showed a willingness to pay ¥270, which was larger than the reference amount.

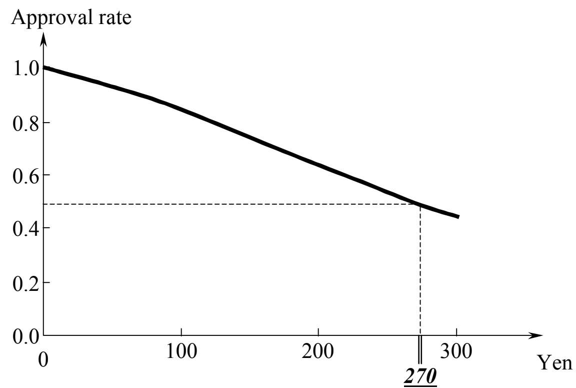


Fig. 9 Cumulative Graph of Willingness to Pay

7. Analysis of the Study

This study was conducted on the assumption that information was exchanged as interactive vehicle information, and the information exchange conditions among vehicles (provision of road information to vehicles behind) was simulated as a provision of linear information. Changes in driving behavior with the provision of information was therefore clarified by comparative analysis with driving behavior of vehicles without information using an NN model. The ideal speed was determined by using regional classification, radius of curvature, sight distance, cornering slip coefficients and superelevation from the explanation and management of the Road Structure Ordinance to randomly select samples that were significantly influenced by the existence of information from the 52 samples, excluding samples that could not be used due to their running after state or mistakes in measurement. First, the speed for each item at a certain point was found. Next, the speed was calculated in consideration of how the speed for each item placed a restriction on each other, as shown in Fig. 10.

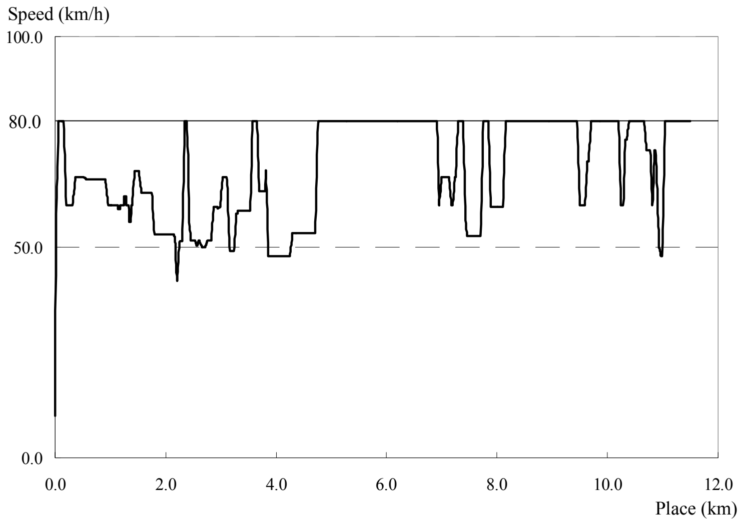


Fig. 10 Ideal Speed

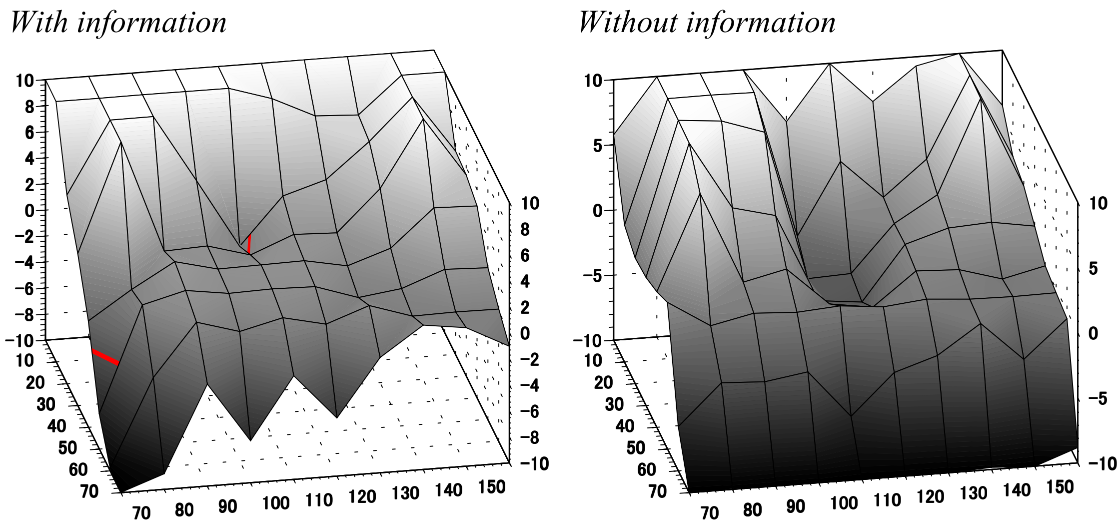


Fig. 11 Difference in Acceleration by Sight Distance and Speed

Horizontal axis: sight distance (m), Vertical axis: speed change (km/h), Depth axis: speed (km/h), Top: with information, Bottom: without information

The graphs of Fig. 11 show the results of implementing NN using representative examples with or without provision of information based on the ideal speed. On the graph with information, a gentle downward line can be seen from the condition with high speed and long sight distance to the lower and shorter condition. It was presumed that the subjects could secure a certain amount of information regardless of sight distance at a certain driving condition and showed appropriate reaction to alignment changes at the time because the alignment on the route had been given to them. On the graph of drivers without information, however, the line is sinking in the middle even though the subjects were driving every day and had passed Nakayama Pass many times. They probably did not increase their speed as they were worried about changes in sight distance and losing visibility at some parts due to the lack of accurate information on route alignment and the inability of securing a certain amount of information necessary for safe driving. This was considered to have occurred when the sight distance was 100 to 120 (m) and the speed was 30 to 50 (km/h) at Nakayama Pass.

8. Conclusion

The following three results were attained in this study:

(1) The concept of interactive vehicle information was established as an ITS platform.
(2) The method of providing interactive vehicle information in ITS was examined.
(3) Based on the data obtained by social experiment, a driving simulator taking into account interactive vehicle information was developed.

In the social experiment, it was proved that application of linear information by NN-CA on markets of portable terminals and other information services was possible. It was also indicated in comparative analysis of the test results that provision of information caused great changes in driving behavior.

There are following four future challenges:

(1) Continue information provision experiments based on the results of the social experiment in this study using an information cycle of regional ITS to achieve more advanced regional ITS.
(2) Select available data by a statistical method although random data were used for this study.
(3) Measure the changes in driving behavior and CVM evaluation by providing various types of linear information in the form of a scenario.
(4) Improve technologies such as the use of portable phones or car navigation systems to provide more real-time information.

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