ANALYSIS OF PERCEPTION OF HAZARD FOR TRAFFIC ACCIDENTS

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abstract: In the traffic accident analysis, the physical data, such as road width, slope and curvature, are used to examine the causes of accident occurrence.. This approach made it possible to obtain many findings related to the policy of making the road infrastructure. However, the relationship that the most dangerous road sections perceived are actually not dangerous could not be only explained from the analysis that includes the physical data. It is necessary to include the human factor in traffic accident analysis. This paper shows the necessity of utilizing the data of human perception of hazard for traffic accidents.

1. INTRODUCTION

In Japan, there is a serious problem with regards to the number of traffic accidents. The number of fatalities exceeded 11,000 in 1990, and this brought the government take action to decrease the number of fatal traffic accidents. There is a need to investigate the factors of accident occurrence in detail, because the number of fatalities did not decrease significantly in spite of many efforts by the government.

In this paper, the analysis of human perception of hazard for road sections is incorporated in the traffic accident analysis, while the former analysis only includes the physical and environmental road factors, although there are three factors, such as road structure, human factor and vehicle factor, which should be included in the analysis. It can be seen that human perception of hazard for road sections explains the occurrence of traffic accident. This paper aims to make a better policy for roads from the results of identifying the factor of accident occurrence.

2. CURRENT CONDITION OF TRAFFIC SAFETY RESEARCH IN JAPAN

2.1 Importance of Traffic Safety Research

There are two reasons why the problem of traffic accidents is so serious in Japan. One reason is the difficulty of finding effective countermeasures to decrease the number of fatalities compared to the countermeasures in the early 1970's. Fig.-1 shows the trend of the number of annual fatalities in Japan. There are three characteristics in this trend. The first is the peak of fatalities in the early 1970's, then dipping to low level in the late 1970's, and the last is the gradual growth in number until recently.

In the early 1970's, the government launched a campaign against traffic accidents, due to the number of fatalities which exceeded 16,000. At that time, many ministries implemented special countermeasures for the traffic accidents, for example, the Ministry of

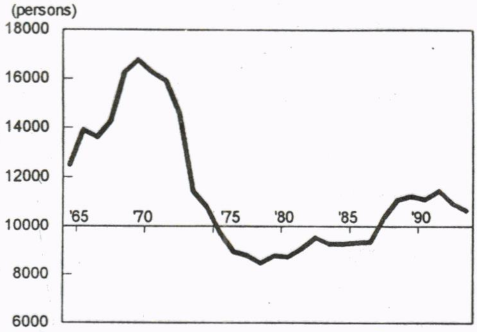


Figure-1 Trend of the number of fatalities in Japan

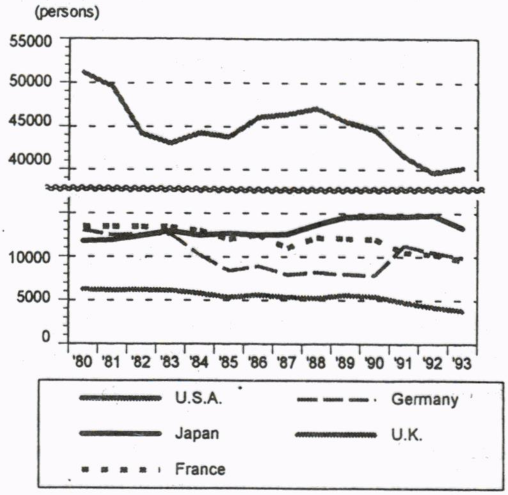


Figure-2 The number of fatalities in each developed country

Construction built pedestrian overpasses and guardrails in order to separate vehicles and pedestrians, and this successfully brought a decrease in the number of fatalities down to almost 8,000 persons. The gradual increase of the number of fatal accidents recently shows that the countermeasures implemented in the early 1970's are not suitable to the current conditions of the traffic accident occurrence. That is, the pattern of accident in the early 1970's is different from the pattern in the late 1980's, for example, the person-to-car conflict was high in early 1970's while the car-to-car conflict became significant in the late 1980's. These countermeasures are already outdated in terms of the pattern of accident. It is important to research the traffic accident in detail at the first step, and then devise effective countermeasures that match the current pattern of accidents.

The other reason is the trend of the number of fatalities compared to other developed countries. The number of fatalities in developed countries is on the decreasing trend, while the trend is still increasing in Japan. Fig.-2 shows the number of fatalities in each developed country. It is easy to understand that the number of fatalities increases year by year only in Japan except in 1993. In other countries, there are many efforts to decrease it, for example, there is a helicopter service for rescuing persons involved in traffic accidents in Germany, and there is a special judgment scheme to clarify the cause of traffic accident in France.

In the Asian countries, it is hard to collect the time-series data of the number of traffic accidents. It is difficult to compare the accident condition, and to understand the characteristics of accident occurrence in each of the countries. Hence, it is necessary to have the time-series traffic accident data.

2.2 Review of Traffic Safety Research

It is well known that vehicle accident occurrence depends on various kinds of factors such as geometric design of road sections, traffic management, driver error, weather conditions, vehicle performance and many others. It can be seen that there are many kinds of viewpoint to study traffic accidents. The main purpose of this research is to determine the relationship of traffic accident generation and road infrastructure. The papers dealing on the viewpoint of road geometry and roadside environment are reviewed.

Regression analysis is mainly used in the case of traffic accident analysis aimed to identify the reason of accident occurrence (Jara-Diaz and Gonzalez, 1986). In this analysis, roads are divided into many links, and then regression models are made with these link-based data. In this model, the dependent variable is the ratio of traffic accident (number of accidents per traffic flow and road length) and independent variables are road geometry, roadside land use and other necessary factors. The reason why regression model is used in this study area is that it has a simpler structure for analysis of data which are link-based.

Since the occurrence of traffic accidents is so rare, it is difficult to consider traffic accident data as the data from a large population. However, if the data are link-based, the frequency of traffic accidents will increase and the restrictions on data would be relaxed. Hence, reasons could be identified which are related to the road index. The aggregation of data into links is accompanied by the loss of detailed information of accident occurrence such as the exact point where it happened. When the regression model is used, the data are considered to be from a population of a large size. There are many difficulties in using this particular method because of the rarity of occurrence of traffic accidents. To take into account this phenomenon, an alternative method that utilizes the Poisson distribution is developed (Morichi and Hamaoka, 1993).

The determination of the relationship between the traffic accident occurrence and road index is difficult in spite of simplicity of the model. There are many researchers who used the concept of clustering of traffic accident occurrence. One particular research clustered accident data by link characteristics using the qualitative theory III (Imada et al., 1991). Another research did the transformation of accident data into the accident injury scale (AIS) to provide accident data with many responses (Carlson, 1979 and Imada et al., 1992). In these mentioned studies, the main objectives were to cluster data based on certain characteristics of the data.

2.3 Recent Topics for Traffic Safety Analysis

There are three topics about traffic safety analysis. Firstly, the traffic accident data is getting more open to the public, because the importance of traffic safety research was shown. It was not open to the public to keep the privacy of the driver, although it is necessary to collect the traffic accident data in the traffic safety research. From the results of the Institute for Traffic Accident Research and Data Analysis (ITARDA) and many outcomes from research institutions, such as universities, the traffic accident data which excluded human privacy data are becoming more open to the public. From this improvement, the problem in collecting data is being eased, and this brings many possibilities in research on traffic accident analysis.

Secondly, there has been a rapid progress in data processing technology. There are many factors that causes the traffic accident, such as driver, car, road geometry, roadside environment, weather and so on. It is necessary to make the common database to analyze the relationship between traffic accident occurrence and those factors from the viewpoint of efficiency. The lack of technology is the reason why traffic accident analysis did not progress too much. Utilizing the advantage of data processing technology, the GIS that can show the many aspects of traffic accident can be made for traffic accident analysis.

Finally, the digital road database was made nationwide by the Digital Road Map Association (DRMA) arising from the needs of the intelligent vehicle system. It was impossible to make the common database because of the mismatch in the items of the data and the precision of the data that each researcher collects. This digital map keeps same format and precision in each map in order to provide support for car navigation systems. This digital road map is suitable for making the GIS for traffic accident analysis. There is a study that used these advantages (Morichi and Hamaoka, 1993).

3. THE DATA

The roads to be analyzed should include both constructed long time ago and recently, because the purpose of this study is to determine the relationship of traffic accident generation and road infrastructure. In this study, northern area of Midori Ward (now changed to the Aoba Ward) in Yokohama City, suburban area of Tokyo metropolitan area, was chosen as a case that satisfies this condition. This city is located southwest of Tokyo, and has one national trunk road (Route 246) traveling from the east end to the west end.

In this study, the human perception of hazard and driver's eye movement are considered related to the occurrence of traffic accident. The data consists of the traffic accidents which occurred from 1988 to 1991, the human perception of hazard data and data from eye movement of the driver.

3.1 Traffic Accident Data

The traffic accident data form of the police was used as the traffic accident data. This sheet includes a decoded data of the characteristics of accident occurrence in order to make a report of the characteristics of traffic accidents and to serve as a fundamental data source. In this study, data were collected for 4 years, from 1988 to 1991, in cooperation with the police. Because the detailed database was not complete before April, 1988 and 1989, 14 items, such as date of accident, collision type and so on, only were collected. The detailed database which contains 36 items are used for the data in 1989 and 1990. Fig.-3 shows the number of accidents occurred in each year. It is easy to understand that the accidents occurred in 1988 is short in number because of the lack of data before April.

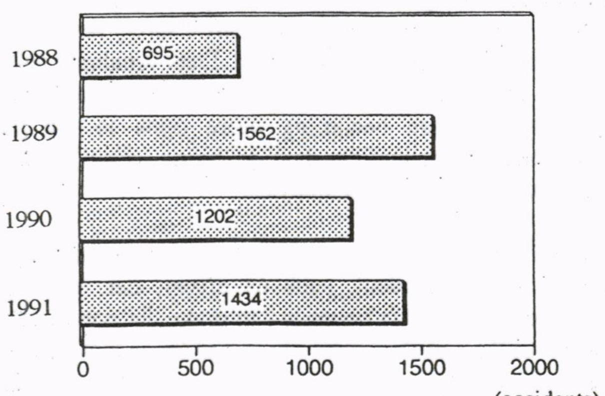


Figure-3 The number of accidents occurred in each year

Traffic accidents are divided into two groups, such as those which occurred in the trunk road and those which occurred in local roads. In the trunk road, data are considered to be significant, because there were many accidents due to the large traffic volume, while in the local road, it cannot be seen as significant because of the low traffic volume. Therefore, traffic accidents which occurred in the trunk road are used in this study, because the main purpose of this study is to evaluate the hazard.

Traffic accidents which occurred in the trunk road can be divided into two groups, such as intersection and road section. The division is necessary, because the pattern of traffic accidents is different between accidents that occurred at intersections and accidents occurred in road sections. However, accidents which occurred at intersections were included in the accidents that occurred in road sections, because of the small number of accidents that happened per one link in this case. A total of 1586 samples are used in this study.

3.2 Human Perception of Hazard Data

It is necessary to consider not only the physical factor, such as road width, slope, curvature and so on, but also the effect of the driver behavior in order to analyze the factor of traffic accident occurrence in detail because the relationship derived between the perception of hazard and number of accidents is generally positive linear except for the region of high hazard perception where the relationship becomes negative. This can be imagined when one drives a car in a dangerous section, he tends to decrease his speed and the decrease in speed increases traffic safety. In the same way, in roads with good geometry, the driver passes through this road with lesser caution which tends to increase the number of accidents deviating from the number estimated by the model. It can be seen that this relationship decreases the fitness of the model. However, it is hard to obtain the data of driver's perception of hazard for road links, the interview of residents' perception of that was held under the assumption that the driver's perception of hazard for road sections was same as the residents' perception who lived near the specific road section.

The main objective of the personal survey is to identify the reasons which cause accident occurrence at the black spot. The person who must answer the questions must be residents in this area. For each respondent, five road sections in the vicinity of his residence were selected. These 5 nearest road sections were presented to the respondent and then, he ranked them in terms of 5-rank rating of hazard level. The total number of items of the answer sheet is 15, for example, perception of hazard, sight distance, road congestion, pedestrians, etc. There were 203 samples obtained out of 300 distributed questionnaire and with the exclusion of meaningless samples, the number of data totaled to 788.

3.3 Data from Eye Movement of the Driver

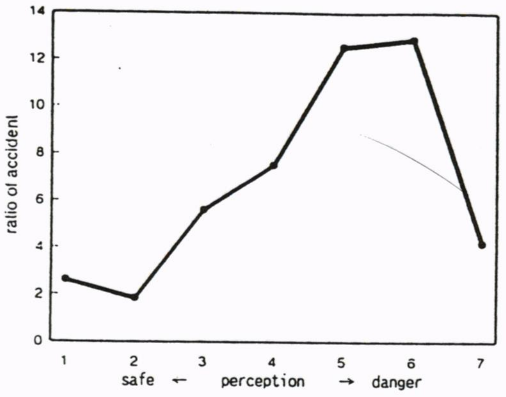
Even if the response of danger is same in a road section, there is a difference in the number of traffic accidents. Therefore, data from human perception of hazard for road section can not distinguish the dangerous section from the safe section in such a case, although this data can identify most of the dangerous sections. It is important to use the driver's eye movement data in order to make up for the human perception of hazard for road section, as a kind of driver's characteristic data. This can evaluate the real dangerous road section. The relationship among the driver's eye movement, the number of traffic accidents and human perception of hazard for road section will be determined from the experiment of eye movement of the drivers. The locations of the experiment are same as the interview of driver's perception of hazard for road section in order to analyze the relationship between driver's eye movement and human perception of hazard for road section. This experiment in which 6 respondents were selected was held for 11 days in October 1994. In the experiment, respondents run a determined route with the eye-mark-recorder attached to their heads in the day time, and filled up the perception for road section after driving the car. The questionnaire had the same format as that of human perception of hazard for road section in order to relate to both perception of hazard for residents and perception of hazard for drivers. The respondents did not run all road sections in the study area but about 20% of the road sections because of the limitation of battery consumption of the eye-mark-recorder.

4. ANALYSIS OF THE RELATIONSHIP BETWEEN THE PERCEPTION OF HAZARD AND TRAFFIC ACCIDENT OCCURRENCE

4.1 Characteristics of the Perception of Hazard for Traffic Accidents Data

The main objective in using the perception of hazard for traffic accident data is to understand its relationship with traffic accident occurrence. The data were obtained from the personal survey mentioned in chapter 3. It can be seen that the answers of the questionnaire may have the bias, for example, one tends to answer 1 and 5 separately even if the road section seems to danger or safe, or one tends to answer 5 even if the road section seems to be safe. To remove these biases, the answers of the questionnaire are standardized by an individual's mean and standard deviation which are calculated using the individual's responses to the perception of hazard for 5 road sections. The standardized human perception of hazard for road sections data is divided into 7 categories, and Fig.-4 shows the relationship between the perception of hazard and the average of the ratio of accident occurrence using the answers of the individual's for each road section where the ratio of accident occurrence is equal to traffic accident counts divided by the road length. In this figure, it could be understood that if one perceives hazard, the number of accidents increases. However, in category 7 (high hazard perception) the ratio of the accident is lower than category 6. This means the most hazardous road section is not really that dangerous because the high hazard perception causes drivers to lower their speeds and drive cautiously which lowers the number of accident occurrence. Also, the ratio of the accident in category 1 (perceived as safe) is higher than category 2. This means the safest road section is not really that safe because the low hazard perception brings drivers to decrease caution which increase the number of traffic accident occurrence.

Fig.-5 shows the mean and standard deviation of the perception of hazard and the ratio of traffic accident occurrence in each road section. From this figure, there are cases wherein human perception of hazard is high but the corresponding accident occurrence is quite low and cases wherein human perception of hazard is low but the number of traffic accidents per road length is very high. Therefore, the relationship between the human perception of hazard and the real hazard is not directly proportional as assumed earlier. For roads with poor geometry, the logical thing to do is to improve them. However, for roads with good geometry, accident frequency was observed to be higher, which counters the logical countermeasure which is to improve the road geometry. Therefore, it is very important to concentrate on these road sections which are perceived as safe by drivers.



,ure-4 Ratio of accidents corresponding the range of hazard perception

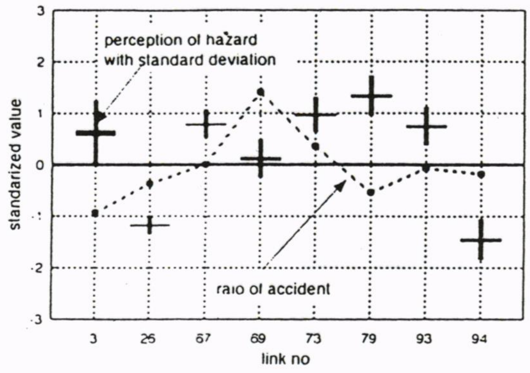


Figure-5 Comparison between perception of hazard and ratio of accidents

4.2 Modeling the Perception of Hazard for Traffic Accidents

The relationship between the human perception of hazard and the ratio of accident occurrence are now determined. There is a necessity to understand the methodology of the perception of hazard to make better standards for road design and planning. The model of perception of hazard leads to the understanding of better models which include the factor of human perception which will provide better estimation for the traffic accident occurrence model. The hazard perception is still qualitative and therefore, it must be quantified in order to be included in the various models available.

In this research, LISREL was used to consider the factor that could not obtained from the personal survey and also to make the paths of generation of the perception of hazard from the external and latent variables. LISREL is a model linking the factor analysis and the regression model. There is a linear relationship between the latent variables (Eqn.-1) and relationship with the factor analysis between the latent and observed variables (Eqn.-2,3). In the equations below, X is the observed external variable, Y is the observed internal variable, ξ is the latent external variable, η is the latent internal variable, δ, ε and ζ are random terms, Λ_x, Λ_y and Γ are parameters which to be estimated.

$$\eta = B\eta + \Gamma\xi + \zeta \tag{1}$$
$$X = \Lambda_x \xi + \delta \tag{2}$$
$$Y = \Lambda_y \eta + \varepsilon \tag{3}$$

The estimated covariance matrix Σ is shown in Eqn.-4. The parameters are estimated by maximizing the function F (Eqn.-5), where S is the covariance matrix of observed data.

$$\Sigma = \begin{bmatrix} \Lambda_y (B^{-1}(\Gamma\phi\Gamma' + \psi)(B')^{-1}\Lambda_{y'} + \theta_\varepsilon & \Lambda_y B^{-1}\Gamma\phi\Lambda_{x'} \\ \Lambda_x \phi\Gamma' B^{-1}\Lambda_{y'} & \Lambda_x \phi \Lambda_x + \theta_\delta \end{bmatrix} \tag{4}$$
$$F = \log|\Sigma| + tr(S\Sigma)^{-1} - \log|S| \tag{5}$$

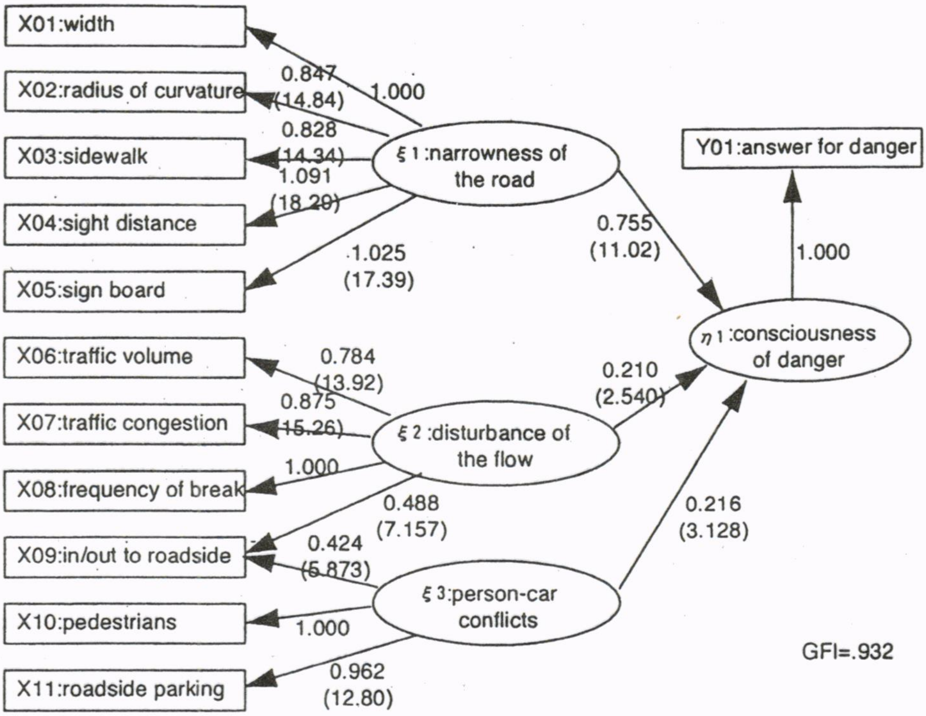


Figure-6 The output of LISREL model

The result of the LISREL model is shown in Fig.-6. This diagram shows the path of the generation of consciousness of danger. From the results of the LISREL model, it could be understood that the consciousness of danger is explained by the three latent variables, namely “narrowness of road”, “disturbance of the flow” and “vehicle-pedestrian conflict”. It is easy to understand that “narrowness of road” has the strongest influence on the perception of hazard for traffic accident among the three latent variables from the comparison of each parameter from the latent variable towards the perception of hazard for traffic accident. It can also be understood that “narrowness of the road” is shown by mainly the sight distance and the visibility of sign board to see the parameters from the “narrowness of the road”.

5. ANALYSIS OF THE HUMAN REACTION THROUGH THE ROAD SECTIONS

5.1 Characteristics of Driver's Eye Movement Data

Driver's eye movement has much correlation with the traffic accident occurrence. In this chapter, through the driver's eye movement, the consciousness for danger or the high ratio of accident occurrence is shown.

The data of what the driver watches were obtained in each 1/30 second in the driver's eye movement experiment. The data of driver's eye movement were not analyzed in each 1/30 second but characterized the pattern of eye movement in each road section that was same with the road which human perception of hazard interview was held, because the aim of this research is to analyze not what the driver observes but how the driver's eyes move while driving.

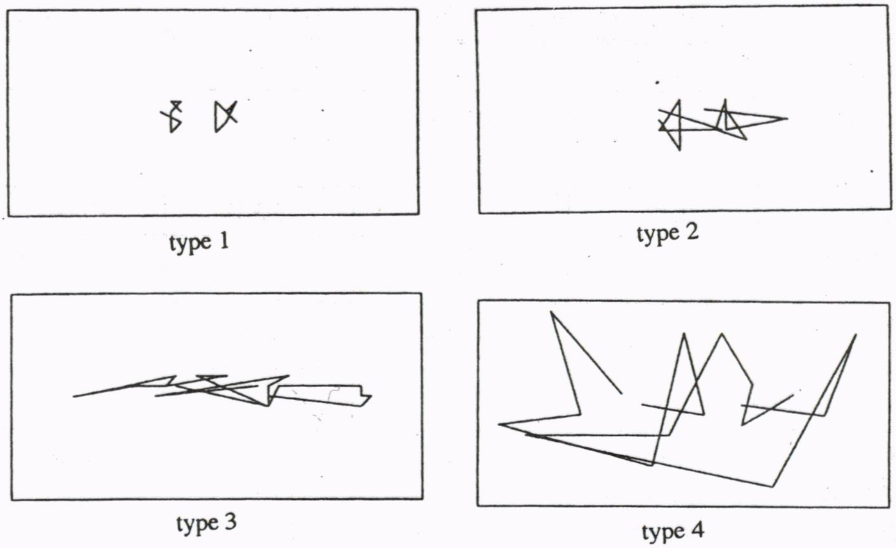


Figure-7 4 patterns characterized by the eye movement

As the record of driver's eye movement was shown repeatedly, it was found that the driver's eye movement can be classified into 4 patterns as follows (Fig.-7):

pattern 1: eye does not move too much
- driver runs at a high speed
- long sight distance

pattern 2: eye moves slightly
- driver runs at a low speed
- long sight distance

pattern 3: eye moves right and left
- driver runs at a low speed
- short sight distance
- there are many parked vehicles along road side

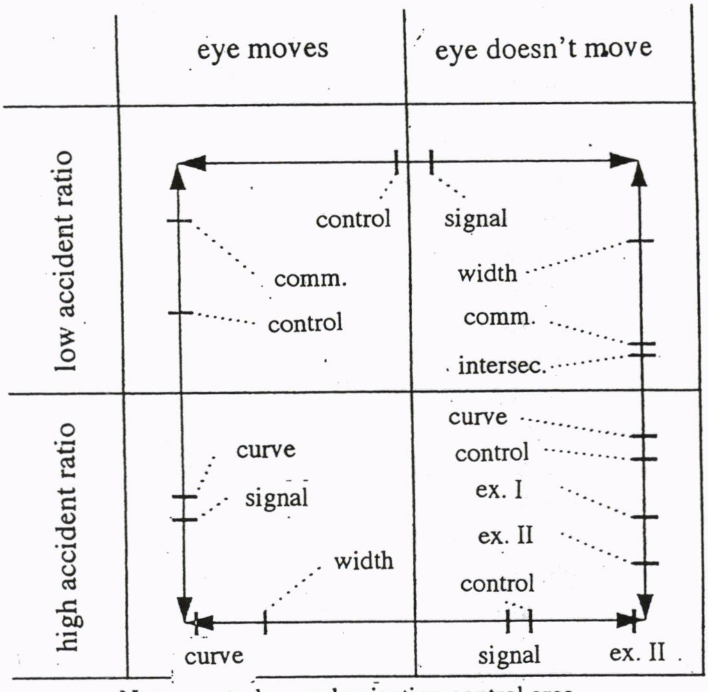
pattern 4: eye moves widely
- driver runs at a low speed
- short sight distance
- there are many curve in that section

5.2 Model of Driver's Eye Movement

The cause that makes the eye move was analyzed from the viewpoint of road structure using the characteristics of eye movement. In this study, discriminant analysis was utilized to quantify the characteristics of driver's eye movement. Tab.-1 and Fig.-8 shows 4 main results from the discriminant analysis those made in each eye movement and the ratio of traffic accident occurrence. The arrows show the output of model where the bodies of the arrows distinguish the cases.

Tab.-1 Results of discriminant analysis

dependent var.	traffic accident	traffic accident	eye movement	eye movement
condition	eyes moved	eyes did not move	high accident	low accident
width	1.831	-2.655	4.958	
curve		0.968	9.844	
# of intersections		-0.682		
# of traffic signals	2.122		-3.387	-0.449
exclusive residential area I		2.291		
exclusive residential area II		3.016	-8:991	
commercial area	-3.178	-0.874		
urbanization control area	-1.518	1.280	-4.007	0.386
goodness of fit	86.54%	93.02%	95.65%	60.87%



Note: control : urbanization control area
comm. : commercial area
ex. I : exclusive residential area (type I)
ex. II : exclusive residential area (type II)
intersec. : # of intersection
signal : # of signalized intersection

Figure-8 Result of discriminant analysis

From the model, in the case of high traffic accident occurrence, it was found out that the road curvature influences the eye movement such that the more severe the road section, there is more eye movement. The model, in the case of no eye movement, the wider width decreases the traffic accident occurrence, however, there is high traffic accident occurrence in the exclusive residential area. This phenomenon might be caused by the difference between the planning of the road and actual usage of the road. In fact, those roads are used as the byway of trunk roads. This is a problem that should be solved.

6. CONCLUSION

In this study, the human perception of hazard for road sections was adopted as one factor of accident occurrence. Human perception of hazard for road sections data could show the relationship where the most dangerous sections were not dangerous from human perception. Through the model containing the structure of the path of human perception of hazard, this is explained by the 3 latent variables, such as "narrowness of road", "disturbance of the flow" and "vehicle-pedestrian conflict". The "narrowness of road" highly influences the human perception of hazard.

From the analysis of drivers' eye movement, it was shown that the degree of curvature of the road section is significant in the case of dangerous section. An important finding is that eye does not move even if the driver is in a dangerous section in the exclusive residential area. It is therefore needed to warn the driver that it is a dangerous section. It is also shown that there was a large number of traffic accidents which happened in the exclusive residential area even though the eyes did not move, because the road was used as a byroad of the main trunk roads. The cause of this comes from the mismatch between the road planning and actual road usage.

Through these analyses, it was shown that it is important to consider the human factor in the traffic accident analysis.

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