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TOPIC 12
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SYSTEMS AND DATABASES

TRAFFIC ACCIDENT ANALYSIS USING GIS ORIENTED DATA

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Abstract

Under current circumstances in Japan, there is a need to investigate traffic accidents through the microscopic view. In this study, several factors, such as hierarchy of the road, illegal parking along the road and obstructions which make shorter the sight distance, are determined by the microscopic investigation of the places where the accidents occurred.

INTRODUCTION

In 1970, Japan experienced its worst record in the number of fatalities related to traffic accidents. However, Japan made a big progress in 1980 in decreasing the number of fatalities which was reduced to close to half of the 1970 figures while other developed countries were having difficulties in reduction. After the number of deaths increased gradually after 1980, it exceeded the 10,000 mark again in 1988. There are differences in characteristics of traffic accidents which occurred at different years. In the 1970s-1980s, accidents were characterized by pedestrian-vehicle collisions but in recent years, vehicular collisions had become the trend. Therefore, the countermeasures implemented before did not significantly decrease the number of fatalities even until recently. There is an urgency in the formulation of new policies for building the new urban road infrastructure from the various viewpoints of countermeasures in order to solve this problem. However, before doing this, the characteristics of traffic accident occurrence must be studied in detail firstly.

The formulation of countermeasures to decrease the traffic accident rate significantly important to see the location where the accident took place in each case. To realize this a map which shows the accident locations and distinguishes accident occurrence by type is necessary. The GIS (Geographic Information System) is therefore built for these purposes. In the statistical analysis of accident data, the models made in the past did not account for the characteristic of rarity of accident occurrence. Hence, the Poisson regression analysis is used to include the rarity factor. In the determination of factors affecting traffic accident occurrence, not only physical factors but more importantly, the human factors must be considered since these cause the nonlinear relationships between traffic accident rate and hazard perception. In order to investigate the effect of human factors, a survey is conduced on the individual perception of hazard of road sections.

THE REVIEW OF TRAFFIC ACCIDENT ANALYSIS

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 Gonzarez 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 accident counts 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 are so rare, it is difficult to handle very few data. 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 said rarity of occurrence of traffic accidents. To take into account this phenomenon, an alternative method that utilizes the hazard function based on the extreme theory is developed (Jones et al 1991; Jovanis and Chang 1989).

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; Imada et al 1992). In these studies, the main objectives were to cluster data based on certain characteristics of the data.

In another way, traffic accident occurs from generalized factors which come from the condition around the spot where the accident took place. However, there are few studies which considered this idea (Kawakami et al 1991). In these studies, there is a general difficulty in collecting data. Recently, GIS is progressing rapidly with the progress of computer technology and the digital base map to make the system is available. Therefore, the GIS is applied to the traffic accident analysis in this study. In this study, one objective is to make a detailed GIS that considers accident occurrences in local roads. With the utilization of the GIS, the reason of accident occurrence could be determined effectively and various kinds of data could be produced for the statistical analysis.

THE GIS FOR TRAFFIC ACCIDENT

The structure of the GIS for traffic accident analysis

In accident analysis, it is important to have a clear picture of the accident by presenting the data graphically to investigate the characteristics of the accident occurrence. In presenting the data, locations of frequent accident occurrence and the type of accident are needed to be shown. To realize this, the GIS is needed to be built. GIS conveniently integrates various kinds of data on the base map, such as traffic accident, land use, road geometry and so on. From this system, locations where many accidents occurred could be viewed and data for statistical analysis could be made.

To make GIS, digital maps are required. Recently, various kinds of digital maps are readily available, for example, the digital road map, the numerical map. The Digital Road Map which is made for the car navigation system is chosen for the GIS.

The suburban area in Yokohama City was chosen as the study area. It is located 30km south-west of Tokyo. The area is about 60 square kilometers, and there are about 250 thousands of residents in 1993.

In building the GIS, data such as accident reports from the local police, land use from the urban planning map, road geometry (slope, width, curve, etc) from the large-scale map and field investigation, traffic environment (traffic flow in the trunk road, the number of roadside parking and traffic signals, etc) were used. The procedures to build GIS are shown in Figure 1. There are several databases incorporated in this GIS, and utilizing these data, three main databases, namely, all-road, trunk road and local road, are created. In the all-road database, factors which cause the accidents at the black spots in the map could be analyzed. In the trunk road database, the relationship between the traffic accident occurrence and the generalized risk of traffic accident occurrence from the data of road geometry, roadside land use and traffic environment such as roadside parking, number of pedestrians, is considered. Utilizing the local road database, the relationship between the vehicle accidents in the zone of size of about 500m x 500m and the zone indices such as road density and the hierarchy of the road is compared.

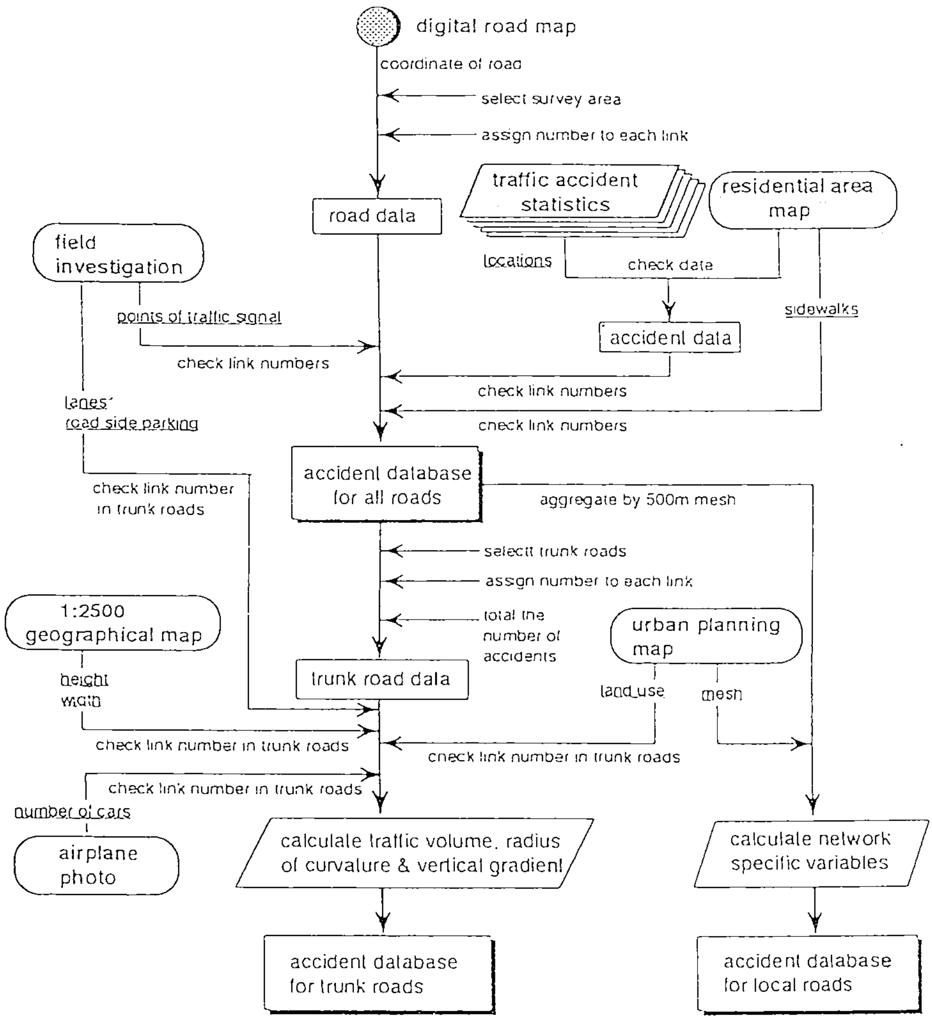


Figure 1 Data flow for GIS

The analysis using the all road data

It is important to determine the characteristics of traffic accident occurrence by the accident type to consider the effective countermeasures for the road. In this section, the characteristics of locations of accident occurrence are investigated using the GIS and field investigation on the location where the accident occurred.

Figure 2 shows the number of cases of traffic accident occurrences in the study area. As shown in Figure 2, the number of traffic accidents in this study area is 1948 from the year 1988 to 1991. The black circle indicates that the accidents occurred at the intersections, and the dark border signifies the accidents which occurred in the road sections. From these, the black spots were identified. In this map, the central border from upper right to lower left shows the national trunk road (R246). In this road, traffic volume is very high which could produce a high probability of accident occurrence. It can be noticed that there are many accidents at the upper left area because of poor road geometry. Specifically, those accidents happened due to poor road geometry at intersection approaches. In certain areas, the roads are used as alternate roads or bypasses because of heavy traffic congestion at R246. Initially, these roads are only designed to be used as local roads (low traffic volume), but due to the congestion, much traffic uses these roads. In some instances, there are places that have short sight distances which cause the accident occurrence mostly of the crossing conflict type to be frequent at intersections in these local roads. From making various kinds of map, many specific cases could be identified below.

- the accident in the byway
- the accident at the intersection: (the lack of the right-turn lane, low sight distance by the object)
- the usage of the road: (difference between the design plan of road and actual use)
- the geometry of the trunk road: (eye doesn't move frequently because of the monotonous road geometry)
- the hierarchy of road
- problem of illegal roadside parking

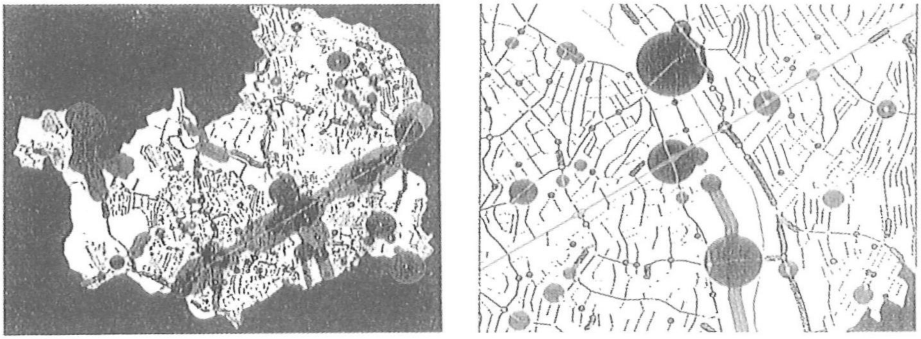
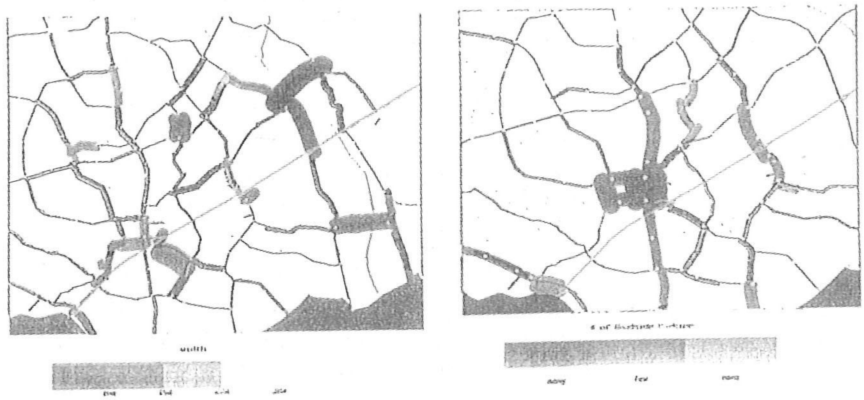


Figure 2 Map of locations of traffic accident occurrence

The analysis using the trunk road data

In the following section, the relationship between the accident occurrence and the locations considered. However, the last way could not compare with the weight of each factor. In this section, the models are made to handle the weight of the factors.

Looking at Figure 3, the relationship between frequency of traffic accidents and roadside parking is shown. It can be seen that the great number of roadside parking increases the frequency of traffic accident. The other output shows the relationship between accident and physical factors such as land use, width and slope of the road. In the case of the analysis of accident and slope of road, it was found that most accidents which occurred were of the rear-end collision type.



width roadside parking

Figure 3 Map of relationship between the accident and physical factors

In the classical traffic accident analysis, the regression models are used to determine the cause of accident occurrence. However, these models are based on the samples from the population having the large number of data, as mentioned earlier. Traffic accident occurrences are rare such that regression models are not suitable for application. In this study, a Poisson regression model was used to consider this particular aspect of traffic accident occurrence. The probability of y-times accident occurrence for road section i is formulated using the probability function of Poisson distribution (Equation 1). Here lambda shows the mean for the distribution which equals the exponential of the summation of the attributes (Equation 2). The parameters are estimated by the maximizing the likelihood function L (Equation 3).

$$P(y_i) = \frac{e^{-\lambda}\lambda^{y_i}}{y_i!} \tag{1}$$

$$\lambda = e^{\sum_i a_j x_j} \tag{2}$$

$$L = \prod_i p(y_i) = \prod_i \frac{e^{-\lambda}\lambda^{y_i}}{y_i!} \tag{3}$$

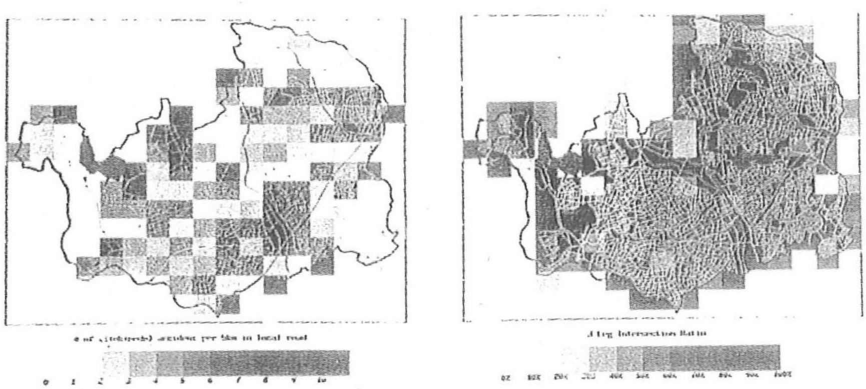
The models are calibrated using traffic accident characteristics such as head-on collision, rear-end collision, right-turn, left-turn, etc. To compare the results of both regression and Poisson regression models, the same dependent variables are selected. Table 1 shows the output of both models. It can be seen that the parameters of both models are almost same. However, the significance of parameter (t-statistics) in the Poisson regression model is greater than that of the regression model. This suggests that the capability of the regression analysis is limited because it did not consider the rarity phenomena. The parameter from Poisson regression model was significant. Comparing the goodness-of-fit measures, the R-squared value in the regression model and the roh in the Poisson regression model, the Poisson regression model seems to be better than the regression model. Judging from the parameters of these model, the most effective countermeasure is to reduce steep slopes through the construction of bypass roads.

Table 1 Estimation results of multiple regression model and Poisson regression model

	Multiple regression model				Poisson regression model			
	All	Veh-Ped	Rear-end	Crossing	All	Veh-Ped	Rear-end	Crossing
Down stream	-0.9193	0.02935	-0.4265	-0.1597	-0.04360	0.05423	-0.04804	-0.3529
slope (%)	(-4.988)	(1.183)	(-5.688)	(-1.190)	(-4.11)	(1.62)	(-2.71)	(-1.59)
Traffic signal	1.164	0.001784	0.1167	1.307	0.004604	0.000119	0.03034	0.07144
(/km)	(11.07)	(0.1260)	(2.727)	(13.56)	(6.14)	(0.11)	(2.59)	(8.21)
Width (m)	-0.5122	0.02057	-0.2181	-0.1946	-0.04868	0.01965	-0.1068	-0.03411
	(-2.725)	(0.8126)	(2.852)	(-1.422)	(2.56)	(1.02)	(-2.83)	(-0.97)
Dummy var.	4.789	2.148	0.9161	-2.243	0.6297	1.207	0.5576	0.2643
(commercial)	(2.025)	(6.746)	(0.9520)	(-1.303)	(4.15)	(6.10)	(2.02)	(0.90)
Dummy var.	16.00	-1.016	0.2797	4.816	1.162	-0.7877	-0.1423	0.6326
(R246)	(3.619)	(-1.707)	(0.1555)	(1.497)	(5.83)	(-3.02)	(-0.40)	(1.55)
Constant	6.910	0.7093	3.491	-0.4540	2.257	0.2595	1.704	-0.4743
	(2.576)	(1.964)	(3.198)	(-0.2325)	(8.05)	(0.093)	(3.02)	(-1.04)
R	0.5130	0.3360	0.3151	0.5501	0.3037	0.1061	0.1593	0.4695
# of links	430	430	430	430	430	430	430	430
# of accidents	1963	254	488	354	1963	254	488	354

The analysis using the local road database

It is useless to manage accident data by making the node-link division to determine the relationship between the accident occurrence in local roads and road characteristic data, because the frequency of occurrence of the accident is quite small due to low traffic volume. Therefore, accidents are accumulated in an area (500m by 500m) which increases the frequency of accident occurrence and the relationship between the accident occurrence and road network characteristic indices, such as the road density, hierarchy of the road, etc, easier to determine. Figure 4 shows the number of calculated accidents per area, and the ratio of 3-leg (T-shaped) intersection to the total number of intersections. From this figure, as the 3-leg intersection ratio increases, the traffic accident occurrence decreases because the 3-leg intersection always has a priority flow, while the 4-leg (+-shaped) intersection does not have this priority flow. From the another figure, the correlation between land use and vehicle-pedestrian accident are positive. The regression models are calibrated to confirm these mentioned relationships. The rarity phenomena may be disregarded because the number of accidents are rather large due to the aggregation. Table 2 shows the results of the models. The parameter sign of the 3-leg intersection is negative which indicates safety, but the t-statistic is not high which indicates it may not be significant.



traffic accident occurrence　　　　ratio of 3-leg intersections

Figure 4 Map of traffic accident occurrence and ratio of 3-leg intersections

Table 2 Estimation results of regression model

Attributes	Model 1	Model 2
Length of roadway (m)		0.002043
		(0.2245)
Length of sidewalk (m)		0.07070
		(2.566)
Sidewalk ratio (%)	0.07915	
	(4.287)	
# of 3-leg intersections		-0.2017
		(-1.059)
# of 4-leg intersections		0.9719
		(2.395)
3-leg intersection ratio (%)	-0.01260	
	(-0.7466)	
Exclusive residential area (type 1)	-2.011	-6.733
	(-2.878)	(-1.991)
Exclusive residential area (type 2)	-1.607	-7.410
	(-1.246)	(-1.245)
Residential area	0.7045	16.74
	(1.562)	(3.235)
Neighbourhood commercial area	-2.347	-0.7604
	(-1.331)	(-0.1015)
Commercial area	4.193	69.07
	(1.120)	(4.426)
Dummy (R246)	7.157	
	(7.063)	
Constant	2.787	5.060
	(2.348)	(1.735)
R	0.6686	0.6129
# of mesh	158	158

THE PERSONAL SURVEY

From the models stated before, the factors of accident occurrence were determined. 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 relationship becomes negative. This can be considered when one drives a car in a dangerous section, he will tend to decrease his speed and the decrease of the 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 from the model. The main objective of the personal survey is to identify the reasons which causes accident occurrence at the black spot. The personal surveys are conducted to verify this assumption, and to model the flow of the one's perception of hazard with the perception of road section. The survey sites are the same as the area where the GIS was applied but only the trunk road is considered.

Outline of the personal survey

The survey was held at Yokohama City in 1993. About 100 links are chosen as a sample. 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 the 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 and with the exclusion of meaningless samples, the number of data totalled to 788. The data are divided into categories, and Figure 5 shows the relationship between the perception of hazard and the number of accident occurrence. 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 number of the accidents are lower than category 6. This means 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. Figure 6 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 since the geometric design is already good. Therefore, it is very important to concentrate on the road sections which are perceived as safe by drivers.

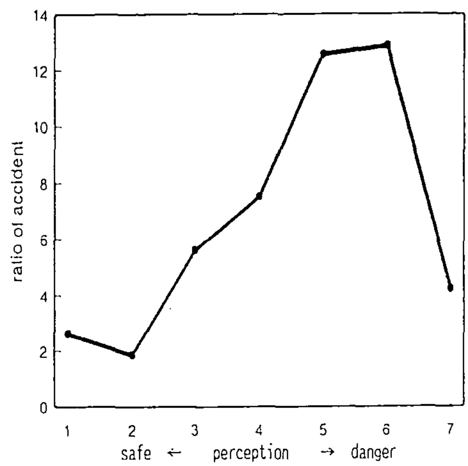


Figure 5 Ratio of accidents corresponding the range of hazard perception

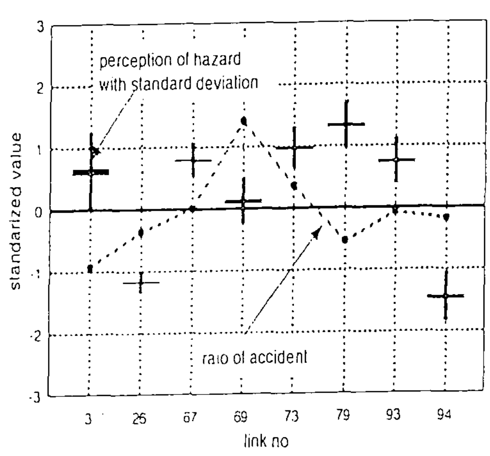


Figure 6 Comparison between the perception of hazard and ratio of accidents

Making the models

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, two models are used to quantify the perception of hazard. The first is the combination of Principal Component Analysis (PCA) and Generalized Least Squares (GLS) model, and the second is the LISREL model. The concepts of these models are basically the same in terms of the main structures. The basic structure is to make firstly a linear relationship between latent variables at first, and to quantify latent variables using the observed variables. The basic difference between the models is the process of quantifying the latent variable. The procedure used in quantifying the latent variables is PCA in the combined model, and factor analysis in LISREL. It is possible to use combined models by factor analysis. Moreover, these models are used to check whether the survey questionnaire is sufficient for the modeling or not.

PCA and GLS Based Model

The latent variables were estimated by the PCA model. There are three latent variables, such as vehicle-pedestrian conflict, the disturbance of traffic flow and the narrowness of the road, to generate the perception of hazard. The PCA model is made one at a time because if the models are made together, the latent factor will be general where there are too many variables to explain the latent variables and the latter could not be distinguished.

Table 3 shows the parameter of the model for narrowness of the road, disturbance of traffic flow and vehicle-pedestrian conflict . The weight of the 1st principal is larger than the 2nd in the output. This shows the assumption that the latent variable are explained by the variables from the items of the personal survey data. Comparing the parameters and t-statistics: the width and sight distance affect to the narrowness of the road; the number of roadside parking affects the vehicle-pedestrian conflict; the frequency of traffic jam affects the disturbance of traffic flow of the road. It was shown that the latent variables are explained by the variables of those data, because the parameters are all positive definite. These modes are suitable to estimate the independent latent variables because of value of contributions of each models are more than half. It is needed to include the physical data to estimate the future condition. The data of perception of hazard can only be obtained from survey data so there is always the necessity to conduct surveys.

The model is calibrated with numerical data from the PCA principal coefficient. The numerical data are regarded as the explanatory variables and the human perception of hazard is regarded as the independent variable. To include these characteristics, GLS is utilized to consider the variety of the data. GLS has some relaxation of the assumption that the data must have constant variance of error. GLS can include the variance of data and the correlation of variance between data. It is validated when the data have the different type of error term. In this study, the perception of hazard vary from person to person such as characteristics that one tends to answer around half (2,3 and 4) or answer separately (1,5). Therefore, there are many types of variances which are needed to be included. The method to estimate the parameters is shown in Equation 4-6.

$$y=X\beta+\varepsilon \tag{4}$$

$$V(\varepsilon)=\Sigma \tag{5}$$

$$\hat{\beta}=(X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}y \tag{6}$$

The variance in the response for each person is considered as the GLS variance because of perception of hazard vary from person to person, as stated earlier. The model is then fitted to the original data. 2 types of models, GLS and OLS, are made to check the validity of this model. In this paper, the dependent variables are the 1st principal score from the PCA model. These data are standardized for the purpose of comparison with the weights for both latent variables. Compared with these models are the independent variables which are the human perception of hazard and the ratio of traffic accident occurrence.

Table 3 Estimation results of PCA model

	1st principal	2nd principal
Narrowness of the road		
width	0.460	-0.198
radius of the curvature	0.423	-0.100
condition of the sidewalks	0.419	-0.716
sight distance	0.475	0.422
visibility of the notice	0.456	0.510
Eigen value	2.846	0.708
Contribution	0.569	0.142
Disturbance of the flow		
traffic flow	0.492	-0.547
traffic congestion	0.522	-0.334
frequency of using breaks	0.520	-0.189
flow to the roadside	0.463	0.744
Eigen value	2.245	0.707
Contribution	0.561	0.177
Person-car conflicts		
pedestrians	0.594	-0.431
roadside parking	0.604	-0.318
flow to the roadside	0.531	0.844
Eigen value	1.875	0.658
Contribution	0.625	0.219

Table 4 shows the result of GLS and OLS to estimate the perception of hazard. In the models that independent variables are human perception of hazard estimates, the signs of both models are same and the significance (t-statistics) was greater in the GLS model. The contribution of the independent variables was 0.768 in GLS model while it was 0.398 in OLS model. It is important to use the GLS model to include better estimates that can consider heterogeneity of human response. Latent variables are ordered by the contribution to the human perception of hazard, that is the narrowness of road geometric design, the disturbance in the road section and the vehicle-pedestrian conflict.

Table 4 Estimation result of GLS and OLS model

Attribute	Perception of hazard		Accident ratio
	GLS	OLS	OLS
Narrowness of the road	0.4688	0.5460	-1.170
	(23.04)	(14.99)	(-3.420)
Disturbance of the flow	0.2776	0.2378	4.146
	(11.40)	(5.178)	(9.612)
Person-car conflict	0.0668	0.1304	-2.182
	(2.925)	(3.009)	(-5.360)
Constant	3.074	3.082	8.670
	(178.5)	(91.09)	(27.28)
Contribution	0.768	0.398	0.121

Looking now at the models wherein the independent variables are the ratio of traffic accident occurrence, the sign of parameters for the narrowness of the road geometric design and vehicle-pedestrian conflict was opposite. This shows that if the road becomes narrower, the hazard will also increase and then the traffic accident occurrence decreases because people tend to be more cautious. If the vehicle-pedestrian conflicts decrease, the real hazard will increase because people tend to be less cautious. However, the contribution to the independent variables is not so high (0.121), so, this effect is not significant.

These results suggest that in order for the road to be not hazardous, the road must be widened and secure a sight distance.

Estimation of Human Perception of Hazard by LISREL

In the preceding analysis, the value of latent variables was calculated by the aggregation of the survey responses. When the preceding model was utilized, it was impossible to include the unknown factors that could not be obtained from the survey. Therefore, 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 (Equation 7) and relationship with the factor analysis between the latent and observed variables (Equation 8, 9). In the equations below, X is the observed external variable, Y is the observed internal variable, ξ is the latent external variables, η is the latent internal variables, δ, ε and ζ are the random terms, Λ_X, Λ_Y and Γ are parameters to be estimated.

$$\eta = B\eta + \Gamma\xi + \zeta \tag{7}$$

$$X = \Lambda_x\xi + \delta \tag{8}$$

$$X = \Lambda_y\eta + \varepsilon \tag{9}$$

The estimated covariance matrix Σ is shown in Equation 10. The parameters are estimated by maximizing the function F (Equation 11), where S is the covariance matrix of observed data.

$$\Sigma = \begin{bmatrix} \Lambda_y(B^{-1}(\Gamma\phi\Gamma' + \Psi)(B')^{-1}\Lambda_{y'}+\theta_\varepsilon & \Lambda_y B^{-1}\Gamma\phi\Lambda_{x'} \\ \Lambda_x\phi\Gamma' B^{-1}\Lambda_{y'} & \Lambda_x\phi\Lambda_x + \theta_\delta \end{bmatrix} \tag{10}$$

$$F = \log|\Sigma| + tr(S\Sigma)^{-1} - \log|S| \tag{11}$$

The result of the LISREL model is shown in Figure 7. From the results of the LISREL model, the parameters were almost same as the output from the PCA and GLS combined model. The contribution of the latent variables were of the same order as the PCA and GLS combined model. The parameters for the narrowness of road and vehicle-pedestrian conflict became negative when the data from the survey of human perception of hazard were replaced by the observed external variables which are the data coming from the actual ratio of accident occurrence. This confirms the trend observed in earlier where at high levels of perceived hazard, the frequency of accidents decrease as the perceived hazard increases.

Comparing the these models, the almost same outputs were obtained. Therefore, the factors that we could not consider in the survey can be disregarded.

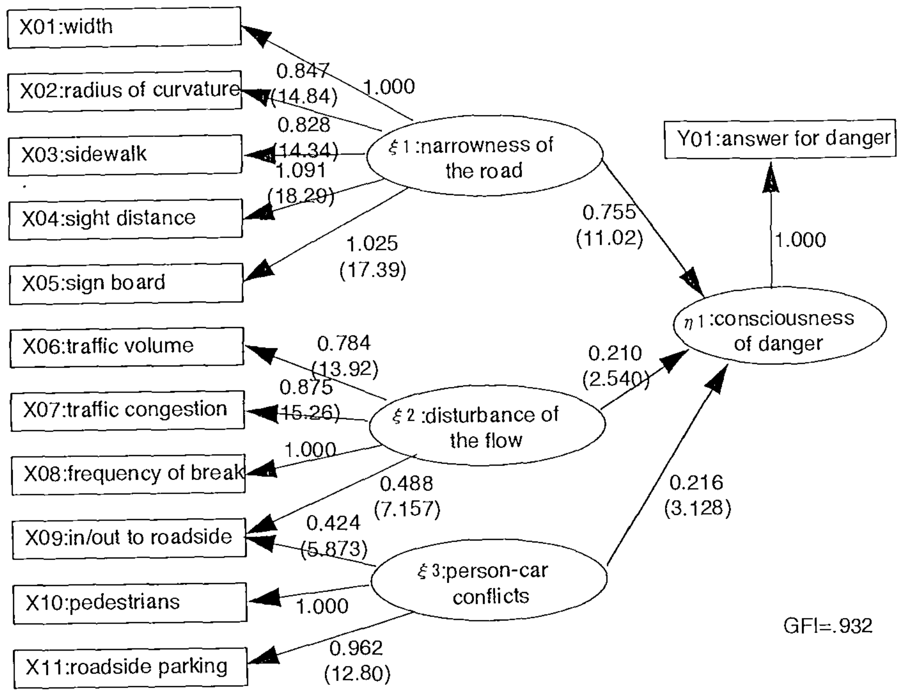


Figure 7 Result of LISREL model

CONCLUSION

In this paper, the necessity to make a GIS system for traffic accidents was mentioned comparing the situation of accident occurrence in Japan with other countries. The characteristics of traffic accident occurrence in the study area were investigated in detail by utilizing the GIS. Combining the output of GIS and field investigation, the detailed consideration can be possible and also causes of occurrence of accidents for each black spot were identified. Using a statistical model, it was found that the down slope and width affect accident occurrence. With the regards to the modeling, the Poisson regression model that considers the rarity of the accident occurrence can estimate better solution than the regression model. This shows that the factors affecting accident occurrence which were not considered in the regression model were identified using the Poisson regression models. In the local road, it is important for traffic safety to have the hierarchy of the road network.

Based on the personal survey of the human perception of hazard, the relationship between the traffic accident occurrence and the human perception of hazard was found to be not linear. Results show accidents occur in the dangerous area, and many accidents occur in the safe area. The number of the samples was significant in the dangerous area as compared to the safe area, but it was not considered important because the construction or improvement of the roads could easily solve the problem of high frequency of accidents. Two models, the combined PCA and GLS model and LISREL, were estimated in this paper to identify the paths of generation of the hazard perception. From these models the factors which consist the perception of hazard were identified, such as "narrowness of road ", "disturbance of the flow" and "person-car conflict". Comparing three latent variables, it was found that the narrowness of road greatly influences the perception of hazard. The respondents were asked in terms of factors related to the generation of perception of hazard in the personal survey.

It is important to make better standards including the effect of human perception of hazard to significantly decrease the number of fatalities related to traffic accidents.

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