■ 論 文 ■

Analysis on the Driving Safety and Investment Effect using Severity Model of Fatal Traffic Accidents

대형교통사고 심각도 모형에 의한 주행안전성 및 투자효과 분석

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목 차

Key Words : 대형교통사고, 심각도 모형, 주행안전성, 투자효과 분석, 편경사
Fatal Traffic Accidents, Severity Model, Driving Safety, Investment Effect Analysis, Superelevation

요 약

본 연구는 2000년 이후 대형교통사고 발생지점 112건의 자료를 이용, 다양한 교차 및 빈도분석을 통해 대형교통사고와 도로 기하구조의 관계를 규명하고, 이를 토대로 대형교통사고 심각도 모형을 구축하였으며, 주행안전성 향상을 위해 720회의 컴퓨터 모의실험으로 다음과 같은 결론을 얻을 수 있었다.

첫째, 교차 및 빈도분석의 결과 커브구간에서 43.7%, 종단경사 기타조건에서 60.7%, 곡선반경 0~24m 구간에서 57.2%, 편경사 0.1~2.0% 구간에서 83.9%, 편도2차로 도로에서 49.1%, 차종별로는 승용(33.0%), 화물(20.5%), 버스(14.3%) 순이었으며, 편경사 설치 유・무가 대형교통사고 발생에 가장 큰 영향을 주는 것으로 분석되었다. 둘째, 순서형 프로빗 모형(Ordered Probit Model)을 이용하여 다양한 도로조건에서의 피해 예측이 가능한 대형교통사고 심각도 모형을 개발하였으며, 개발된 모형을 기반으로 도로의 위험성을 사전에 예측하고, 대책 마련이 가능토록 기여 하였다. 셋째, 컴퓨터 모의실험(Simulation) 결과, 이미 대형교통사고가 발생한 장소에 편경사를 설치했을 경우 약 85% 이상의 지점들에서 대형교통사고가 발생하지 않는 개선효과가 있는 것으로 분석되었으며, 이 분석결과를 통해 도로의 구조・시설 기준에 관한 규칙(해설 및 지침)의 편경사 설치 예외규정을 더욱더 강화시킬 필요가 있다고 사료된다.

In this study, we discuss a fatal accident severity model obtained from the analysis of 112 crash sites collected since 2000, and the resulting relationship between fatal accidents and roadway geometry design. From the 720 times computer simulations for improving driving safety, we then reached the following conclusions:.

First, the result of cross and frequency-analyses on the car accident sites showed that 43.7% of the accidents occurred on the curved roads, 60.7% on the vertical curve section, 57.2% on the roadways with radius of curvature of 0 to 24m, 83.9% on the roads with superelevation of 0.1 to 2.0% and 49.1% on the one-way 2-lane roads; vehicle types involved are passenger vehicles (33.0%), trucks (20.5%) and buses (14.3%) in order of frequency. The results also show that the superelevation is the most influencing factor for the fatal accidents.

Second, employing the Ordered Probit Model (OPM), we developed a severity model for fatal accidents being a function of on various road conditions so as to the damages can be predicted. The proposed model possibly assists the practitioners to predict dangerous roadway segments, and to take appropriate measures in advance. Third, computer simulation runs show that providing adequate superelevation on the segment where a fatal accident occurred could reduce similar fatal accidents by at least 85%.

This result indicates that the regulations specified in the Rule for Road Structure and Facility Standard (description and guidelines) should be enhanced to include more specific requirement for providing the superelevation.

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Ⅰ. Introduction

1. Background and Object of Study

Korean Road & Expressway has been developed in quantitative. However, as the development plan has focused only on the improvement in mobility & supply, the problem of traffic stability is rearing its ugly head recently. The total number of vehicle supply in Korea is 16.79 million in October, 2008 at present, and the number have been increasing rapidly. With this, lots of problems such as traffic congestion, air pollution and car accidents are raised.

Among these problems, traffic accident is considered one of the most serious social issues. In order to present feasibility of road & reduce car accident, we should build the accident prediction model which can be applied to real life by researching and analyzing the relationship between Highway Pavement & car accidents. Also the Economic Analysis System which can calculate, compare and evaluate the direct・indirect additional cost caused by car accidents at common use & initial cost at construction is in need. Still studies on interaction between road alignments elements & other elements, relationship between alignments continuity & accidents have been lasting, however, the efforts did not bear any fruit yet.

When a car drives on curve sections, a centrifugal force will put on the outside lane of the curve. By offset the centrifugal force to vertical slopes & cross frictional force of road, we design and construct the cross-section of roads for safe driving. However, the vehicle will slide and deviate toward outskirt of the curve, if the roads of a radius of curvature is too low or the speed of vehicle is too high or there is not enough frictional force of roads due to the deterioration weather conditions such as snow and rain.

We apply minimum radius of curvature according to planned speed on the basis of the Rule for Road Structure and Facility Standard (description and guidelines). However, some vehicles drive with higher speed than the planned one, slide to the outskirt of curve and end to deviation or overturn.

In case of expressway, this kind of accidents occurs frequently at loop connections(Lamp) at interchange. If the driver does not lower speed at connections, his vehicle will slide or turn over. The same accident may occur on the roads in city without super elevations and downhill road. Also there is high risk of accidents when a driver operates steering in hurry as spotting obstacles ahead. And if you drive with a tire which does not have enough air pressure, a rupture of tire also can be the reason of accident. There are many cases of construction with following the Rule for Road Structure and Facility Standard(description and guidelines) in minimum. And it has resulted in serious damages of car accident.

By various cross-analysis and frequency analysis with the data for fatal accidents, we specify the relationship between car accidents and the structural elements of road geometry and extracted key variables. We then present a severity model of fatal accidents with OPM (Ordered Probit Model) to enable fatal accident roads to be predicted in the future.

We reorganized key factors, e.g., vertical slopes, superelevation, radii of curvatures and the like extracted through analysis like the points where fatal accidents have actually occurred in 3D models to see a possible speed at which a vehicle may deviate the roads or be overturned through computer simulation.

We extracted the possible speed of vehicle deviation and overturn when 2 to 6% superelevation was provided to the severity model of fatal accidents developed in the above. We will also calculate the amount of damage in the fatal accidents on 20 simulation spots, considering the amount of damage in car accidents presented by the Korea Transport Institute and Korea Expressway Corporation.

The object of this study is to compare the cost of improvement construction on the spot where the superelevation are provided by means of actual construction after fatal accidents and then to analyze the result in order to enhance the accident roads more by analyzing the effect of improvement in accident reduction considering the amount of damage by car accidents before and after the provision of superelevation and by applying the smart highway currently under development to the design standard of superelevation for optimum road construction considering economical efficiency and driving safety.

2. Research Trends at Home and Abroad

First, representative studies conducted at home include: A Study on Effects of Highway Geometric on Traffic Accidents by Kang J.K.(1985); A Study on Description Schemes of Traffic Accidents by Kim H.S.(1987); A Study on Classifying, Determining and Modeling Influential Factors around Big Traffic Accident Scenes by Kim B.G.(2005); A Study on Characteristics of Traffic Accidents Relevant to Horizontal and Vertical Profile of Highways and Accident Prediction Models by Kim S.H.(2005); An Analysis on Accident Severity Using Ordered Probit Models by Ha O.G.,·Oh J.T.,·Won J.M., and Seong N.M.(2005); A Study on Developing Traffic Accident Prediction Models Using Fuzzy and Neural Network Theory by Kim J.W., Nam G.M., Kim J.H. and Lee S.B.(2006); and A Study on Developing Accident Prediction Models Considering Complex Linearity by Lee S.G.(2008).

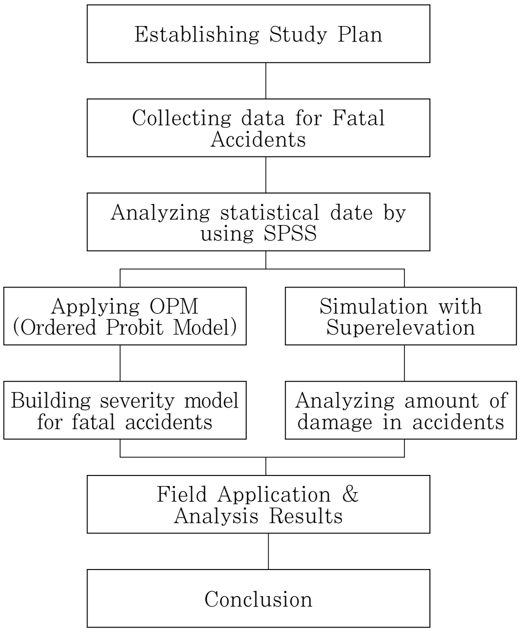
As for overseas studies, Aitchison·Silvey (1957) and Ashford(1959) suggested building an ordered probit model with standardized cumulative normal distribution; and Gurland, Lee·Dahm(1960) embodied an ordered logit model by adopting a general form of cumulative distribution function. Aitchison·Silvey(1957) used a model proposed to deal with ordered discrete variables. Aitchison·Bennett(1970) and Ashford·Sowden(1970) applied diverse methodological discussions, and Duncan·Khattak·Council(1998) analyzed injury severity in collision accidents between trucks and passenger cars by applying an ordered probit model.

Most of studies that have been conducted till now are limited to a few variables related to traffic accidents, thereby placing a limit on selection and application of variables affecting traffic accidents. Also, without taking into account the characteristics of distribution between selected variables and accidents, general linear regression models have been used in most of studies. Accordingly, the present study collects data on diverse road conditions and surrounding environmental ones affecting traffic accidents, and performs accident prediction modeling and severity analysis considering those conditions.

3. Method and Scopes of Study

In this study, we would like to specify and suggest an economic analysis considering amount of damage in car accidents & severity model for fatal accident which can result deviation & turnover with provision of superelevation as 〈Figure 1〉 research process. The method of this study is like as follows.

First, we collected 112 crash point cases of the accidents from January 1^{st}, 2000 to December 31^{st}, 2007 and specified the relationship between



〈Figure 1〉 Research Process

fatal accidents and geometrical structure of a road by means of various cross-analysis and frequency analysis. Second, with the OPM (Ordered Probit Model), we developed a severity model for fatal accidents by which the damages can be predicted on various road conditions. Third, we reconstructed the spot where a fatal accident already occurred in three dimension by using Traffic Accident Reconstruction Program with main factors such as vertical slope, superelevation, radius of curvature etc which are extracted from cross-analysis and frequency analysis. Through the computer simulation, we deducted a possible speed for deviation & overturn. We can also draw the possible speed for deviation & overturn for severity model for fatal accidents with 2~6% super elevations. Finally, we calculated the amount of damage in the fatal accidents on 20 simulation spots, considering the amount of damage in car accidents presented by the Korea Transport Institute and Korea Expressway Corporation.

Also we compared the cost of improvement construction on the spot where the superelevation are provided by means of actual construction after fatal accidents and then to analyze the result in order to enhance the accident roads more by analyzing the effect of improvement in accident reduction considering the amount of damage by car accidents before and after the provision of superelevation and suggested the design standard of superelevation for optimum road construction considering

4. Ordered Probit Model

The present study uses an Ordered Probit Model and analyzes consequences and severity of damages resulting from big accidents due to road and environmental factors based on frequency and cross-tab analyses, both of which are conducted to enhance reliability and accuracy of 112 items of data on big traffic accidents. In view of the basic concept of this, the ordered probability model may be represented as in the expression (1).

$$y = \beta x_i + \varepsilon_i \qquad \varepsilon_i \sim N[0,1] \tag{1}$$

Here, the case where ϵ_i is assumed as the Standard Normal Distribution is called the Ordered Probit Model, while the one where it is assumed as the Standard Logistic Distribution is the Ordered Logit Model. The present study adopts the Ordered Probit Model where ϵ_i is assumed as the Standard Normal Distribution. Here, the selection probability of each alternative can be represented as in the expression (2).

$$\begin{aligned} \mathrm{Prob}[y=0] &= \Phi(-\beta X) \\ \mathrm{Prob}[y=1] &= \Phi(\mu_1 - \beta X) - \Phi(-\beta X) \\ \mathrm{Prob}[y=2] &= \Phi(\mu_2 - \beta X) - \Phi(\mu_1 - \beta X) \\ &\vdots \\ \mathrm{Prob}[y=J] &= 1 - \Phi(\mu_{J-1} - \beta X) \end{aligned} \tag{2}$$

As the method to verify the goodness-of-fit of the model, the final model derived is tested in view of the relevance of variables, and ρ^2 (likelihood ratio) and χ^2(Chi-Square) are used to verify the explanatory power and relevance of the model in terms of whether statistically appropriate methods are used in applying the model expression.

Ⅱ. The Main Discourse

1. Inspection of Data for Fatal Accidents

We inspected 112 car accidents which had occurred between 2000 and 2007 for fatal accident materials. The data before 2000 were excluded as they had lots of missing due to the insufficiency in accident investigation materials of National Police Agency(form economical efficiency and driving safety. no.104), police officer's omission on accident investigation reports and etc.

According to the degree of injuries, the material investigation is divided into 3 steps; death, injuries and physical damage. And the type of roads is classified into straight lane, curve lane, double curve, intersection and etc. For the kind of vehicles, it is classified passenger vehicles, vans, trucks, buses, two wheeler, tank truck, trailer and so on. Furthermore, we examined in various ways with division of road surfacing & median strips. The general outline for these is shown in 〈Table 1〉 below.

In particular, the Taguchi method which is one of the design of experiments was applied for analysis and we used both the data for fatal accidents and the data for estimating order to present feasibility of road investment projects considering road deviation accidents and the amount of damage in car accidents for driving safety in superelevation.

Due to the limitation of collecting materials for developing prediction model of deviation accidents, this study have tested it in small & full sized cars among vehicles with design criteria. And semi trailer was excluded cause of the difficulty in test.(jack knife phenomenon in towed trailer, length of trailer, changes in the center of gravity etc)

We reconstructed the spot where a fatal accident already occurred in three dimension, and tested with the experimental vehicles; 5-seater EF Sonata which has the first best selling record, 7-seater Terracan, 12-seater Star Lex and 47-seater express bus. Among the geometrical structure of a road, vertical slope, radius and length of curvature are set as fixed variables. We conducted experiment the speed of deviation possibility with Traffic Accident

〈Table 1〉 Outline of Material Investigation

Investigation Period	January 1, 2000 ~ December 31, 2007
Subject of Investigation	Fatal accidents received and processed in Road Traffic Authority
Investigation Contents	Severity of Injuries(physical damage, injuries, death) Types of roads(straight lane, curve lane, double curve, intersection) Types of vehicles(passenger vehicles, vans, trucks, buses, Two wheeler, tank truck, trailer) Road surfacing(asphalt, concrete etc) Median strips(crash barrier, double-yellow line, yellow line, yellow broken line, nothing) Types of crash(crash, collision, fall) Others(identical straight, opposed straight, side straight, nothing)
Number of Investigation	Numbers of valid model, 112 cases

Reconstruction Program(PC-Crash 8.0), as changing the center of gravity.

Also the roads are limited to asphalt. Especially, cause the risk of accident is higher on wet roads than dry one, we apply a coefficient of friction on roads(0.5~0.7) for wet condition. And as the risk of accident is higher at maximum riding capacity than at one driver, we assumed that maximum riding capacity gets in and set the weight for 65kg per a passenger.

2. Analysis of Result in Fatal Accidents

To improve the accuracy & reliability on data for 112 fatal accidents, we did cross-analysis for road shape & extent of injuries and the result showed 43 straight roads(38.39%), 30 right curves(26.78%), 19 left curves(16.96%), 9 of 4-lane intersections(8.03%). Even though the frequency of car accidents at straight road has the highest rating, the accident causes are mostly due to the driver's mistakes such as failure in safe driving, assuring a safe distance etc.

Also car accidents in curved roads that occurred at right & left curves totals 49 cases, and it is very high rate. Furthermore, not only the driver's mistakes but also there is potential environment elements which can cause car accident in curved road. Since the severity of damage is seriously high in curved section, we conducted research on it.

Analysis on vertical slopes showed 68 cases on others(60.71%) which had the highest rate, 12 cases on 0~2%(10.71%), 8 cases on -2~0%(7.14%) and 6 cases on 2.1~4.0%(5.36%). It is uncommon for "others" section to rank the highest rate, however, it did cause lots of things were missing on the car accident materials. We assumed that the police officers in charge did not quite get the idea about vertical slopes and omitted a lot.

Analysis on the roads of a radius of curvature showed 64 cases on 0~24m(57.15%), 12 case on 90~154m(10.72%) and 10 cases on 240~499m(8.93%). It was analyzed that the smaller the roads of radius of curvature was, the higher the risk of accident was.

The analysis on superelevation showed 94 cases on the roads of 0.1~2.0% without superelevation(83.93%), each 5 cases on the roads of 0.1~2.0% & 4.1~6.0% with superelevation(4.46%) and 4 cases on the roads of -2.0~0.0% with adverse superelevation (3.57%).

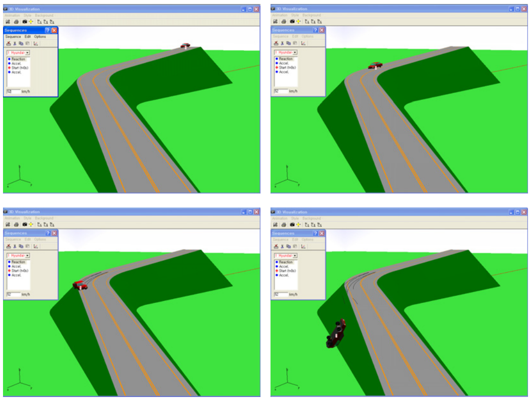
Also it showed 84% on the road with standard cross-slope of 1.5~2.0% but without superelevation. And the initial investment costs & Life-Cycle Cost of road are considered for provision of superelevation. We should take the amount of damage in car accidents into account, allowing for the fact that the average life expectancy of roads is 10~20 years.

The analysis on land roads showed 55 case on the one-way 2-lane roads(49.11%), 32 cases on the one-way 1-lane roads(28.57%) and 10 cases on the one-way 3-lane roads(8.93%) ; and 37 cases on passenger vehicles(33.04%), 23 cases on trucks(20.54%), 16 cases on buses(14.29%) and 13 cases on van(11.61%). And we did computer simulation for these vehicles(passenger vehicles, SUV, vans, buses) except trucks.

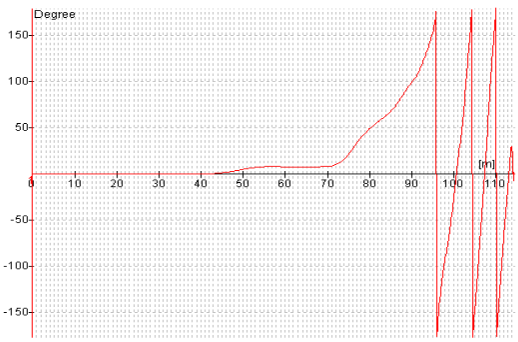
3. Simulation and Analysis of Result

1) Accident overview

- Date : June 12(Thu.), 2003
- Place : Uhmgungdong Sasanggu Busan
- Damage : 3 killed
  21 seriously · slightly injured
- Designed speed : 40km/h
  (Estimated speed at the time of accident : 70.5km/h)



〈Figure 2〉 PC-CRASH based progress of lane departure in the accident



〈Figure 3〉 Roll angle of vehicles after the accident

2) Road condition

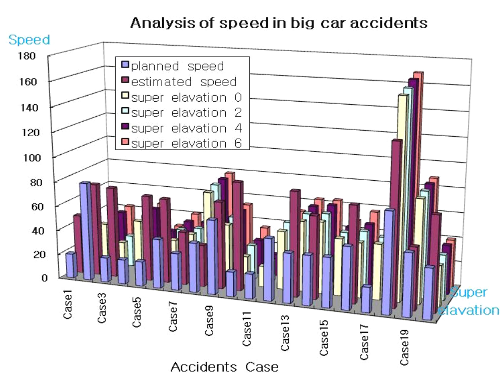
Representative 4 types of experiment vehicles related to superelevation and changes in the center of gravity among key factors in car accidents extracted from cross-analysis and frequency analysis on 112 fatal accidents which occurred from January 2000 to December 2007 were simulated for 20 cases, using PC-Crash 8.0, and the results are shown as 〈Figure 5〉 below.

As you can see from the result above, the estimated speed for fatal accident in real is shown much greater than planned speed & ultimate speed limit. However, when there is high steering without trace such as skid mark which can be the base of speed calculation, it is not able to suggest the estimated speed.

〈Figure 4〉 Road condition and vehicles after the accident

When we did cross-analysis & sensibility analysis, we found out that the element which was the main factor in fatal accidents was influenced by the provision of superelevation, and so did the severity level of the accident. That is the reason why we subjected 20 car accidents cases which are relevant to road departure & rollover at 112 crash point cases of the fatal accidents for the computer simulation.

Because a risk & severity of accident is high at the worst condition in road environment, we did 720 times simulation tests on the assumption that wheeling was on wet roads(coefficient of friction 0.5~0.7) and maximum riding capacity



〈Figure 5〉 Analysis of speed in fatal

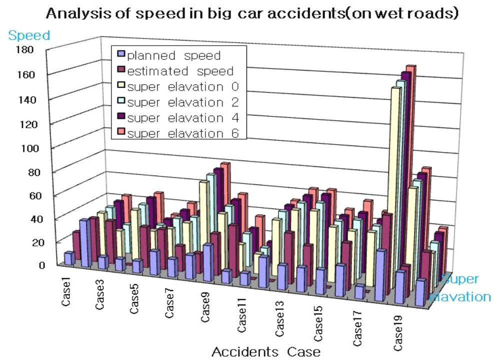
〈Table 2〉 severity model for fatal accidents

		B estimated value	Standard error	Wald	Degree of freedom	PAR P-value	95% confidence interval	
							Lowest limit	Highest limit
Limit value	〔severity of injuries=1〕	2.669	2.523	1.119	1	0.29	-2.276	7.614
	〔severity of injuries=2〕	3.918	2.542	2.376	1	0.123	-1.064	8.9
position	radius of curvature(m)	-0.001	0.001	2.164	1	0.141	-0.002	0
	vertical slope(%)	9.47	6.162	2.362	1	0.124	-2.606	21.547
	Cross slope(%)	0.072	16.63	0	1	0.997	-32.522	32.665
	superelevations(%)	0.72	9.624	0.006	1	0.94	-18.144	19.584
	Lane road(round)	-0.101	0.111	0.834	1	0.361	-0.318	0.116
	〔types of road=1〕	2.097	0.755	7.726	1	0.005	0.618	3.576
	〔types of road=2〕	1.692	0.759	4.967	1	0.026	0.204	3.18
	〔types of road=3〕	5.619	6529.761	0	1	0.999	-12792.5	12803.716
	〔types of road=4〕	0(a)	.	.	0	.	.	.
	〔accident vehicle=1〕	0.053	1.287	0.002	1	0.967	-2.47	2.575
	〔accident vehicle=2〕	-1.245	1.395	0.796	1	0.372	-3.98	1.49
	〔accident vehicle=3〕	-1.864	1.322	1.988	1	0.159	-4.454	0.727
	〔accident vehicle=4〕	0.457	1.379	0.11	1	0.74	-2.246	3.16
	〔accident vehicle=5〕	6.892	3692.233	0	1	0.999	-7229.75	7243.537
	〔accident vehicle=6〕	5.64	6529.761	0	1	0.999	-12792.5	12803.737
	〔accident vehicle=7〕	0(a)	.	.	0	.	.	.
	〔road surfacing=1〕	9.989	1.466	46.397	1	0	7.115	12.863
	〔road surfacing=2〕	9.403	1.613	33.962	1	0	6.24	12.565
	〔road surfacing=3〕	15.33	6529.762	0	1	0.998	-12782.8	12813.428
	〔road surfacing=4〕	0(a)	.	.	0	.	.	.
	〔center=1〕	1.288	1.064	1.464	1	0.226	-0.798	3.374
	〔center=2〕	-0.426	0.989	0.185	1	0.667	-2.364	1.513
	〔center=3〕	0.385	1.04	0.137	1	0.712	-1.654	2.423
	〔center=4〕	4.765	6529.761	0	1	0.999	-12793.3	12802.862
	〔center=5〕	0(a)	.	.	0	.	.	.
	〔types of crash=1〕	2.356	1.03	5.235	1	0.022	0.338	4.375
	〔types of crash=2〕	0.977	0.769	1.614	1	0.204	-0.531	2.485
	〔types of crash=3〕	0(a)	.	.	0	.	.	.
	〔other factor=1〕	-7.382	0.75	96.759	1	0	-8.853	-5.911
	〔other factor=2〕	-7.717	0.674	130.945	1	0	-9.038	-6.395
	〔other factor=3〕	-8.202	0	.	1	.	-8.202	-8.202
	〔other factor=4〕	0(a)	.	.	0	.	.	.

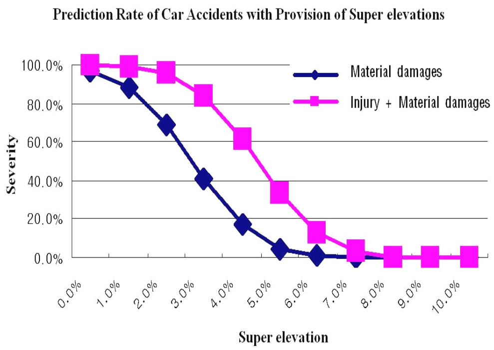
a seed tree overlaps at present and is set as 0.

(set the weight for 65kg per a passenger) as giving variety to superelevation & center of gravity. The analysis of simulation result is shown in 〈Figure 5〉 & 〈Figure 6〉. If a superelevation is provided, approximately 85% of actual car accidents will be prevented. Since it is not easy to improve horizontal and vertical alignments on the roads in cities, it is essential to provide superelevation having a great effect with a small amount of costs on a road where fatal accident occurred. In particular, as described in the guidelines, it is necessary to enhance the exceptional regulations for the city roads as proposed in this study.

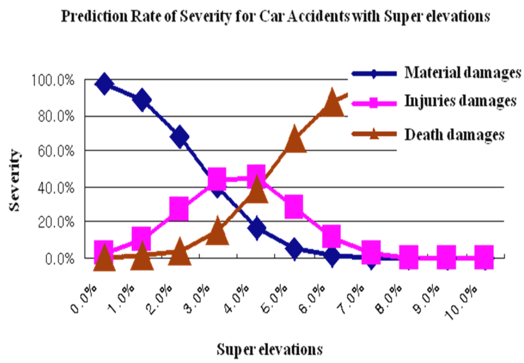
The researchers who recognized serious fatal accidents which occurred on sharp-curve roads due to omission of superelevation applied the damage severity models by the spots where 112 serious fatal accidents already occurred since 2000 to analyze the ratio of lowered severity



〈Figure 6〉 Analysis of speed in fatal accidents(wet)



〈Figure 7〉 Prediction Rate of Car Accidents with Provision of Superelevation



〈Figure 8〉 Prediction Rate of Severity for Car Accidents with Superelevation

〈Table 3〉 Verification Result for Goodness of fit on Model

Model	-2 log-likelihood	MFI Chi-square	Degree of Freedom	MFI Significance Probability
intersept	130.462			
Final	91.384	39.078	26	0.048

〈Table 4〉 Pseudo R^2

Cox & Snell	0.308
Nagelkerke	0.433
McFadden	0.296

when a superelevation is provided, and the result is shown in the following.〈Figure 7〉

〈Figure 7〉 shows that road deviation accidents reduces with the increased level of superelevation to result in significantly reduced vehicle damage and injuries and most of such damages will be reduced if approximately 6% of a superelevation is applied. Also, 〈Figure 8〉 shows that, when the superelevation increases, material damages reduce, but injuries reach the highest percentage at 4% of superelevation and death accidents increase. However, this is a model estimated when 100% of accidents occurred. If a superelevation is provided, car accidents significantly reduce. However, if a car accident occurs in such a situation, it may be caused by excessive vehicle speed or sharply-curved roads to lead to a death accident. It does not mean that death accidents increase simply when a superelevation increases.

As shown in 〈Table 3〉 & 〈Table 4〉, We used Cox, price of Snell R^2 and revised Nagelkerke R^2 to verify the model with R^2 in this study. And we found out that the price represented explanation of model well as the price was 0.296~0.433.

As for -2LL(-2 log-likelihood) price which is used as standard of judgment for goodness of fit on constructed model, if we apply only to initial constant term, the price 130.262would change to 91.384 after applying. This means that the goodness of model is improved over 30%. While it can figures out the improvement for goodness of fit on model, it is hard to verify significance of model. To investigate it, we examined a verification result for MF and the significance probability showed up 0.048 in fine condition. Chi-square divided by the degree of freedom gives 1.503 and it means it's very in significance; the price of chi-square is 39.078, degree of freedom is 26.

By applying the OPM(Ordered Probit Model) to the scene of accident, we can compare and estimate the severity levels of damage for car accidents between the spot which big car accidents occurred & spot which general car accidents occurred.

4. Cost · Effectiveness

Evaluation on investment in a certain project must determine whether project goals are suitable and whether they are achieved efficiently and effectively. The present study selects sites where big traffic accidents took place in '03 followed by completion of installing super-elevations and median strips as part of upgrade projects in '04, and analyzes the effectiveness before and after the upgrade projects by estimating average amount of damages from the accidents that happened in '05~'07. The analysis here results in finding the effects of upgrade projects amount to 89.0% as below.

Also, a simple comparison between the loss cost from large traffic accidents in '03 and the cost spent on installing super-elevations in '04 returns about threefold effects of the upgrade projects. Differently put, the finding implicates that if super-elevations had been installed at the expense of 1/3 of the amount of damage from big traffic accidents, the big traffic accidents could have been prevented in advance, let alone casualties.

1) Cost · effectiveness analysis

$$= \left(1 - \frac{\text{Loss cost from average accidents in '05~'07}}{\text{Loss cost from Fatal traffic accidents in '03}}\right) \times 100$$

$$= \left(1 - \frac{153,545,940}{1,399,131,196}\right) \times 100$$

$$= 89.03(\%)$$

2) Simple cost analysis

$$= \frac{\text{Loss cost from Fatal traffic accidents in '03}}{\text{Cost for installing super-elevations in '04}}$$

$$= \frac{\text{1,399-million Won}}{\text{460-million Won}}$$

$$= 3.04 \text{ times}$$

※ Cost from average accidents in '05~'07

= {(Vehicle cost × number of cars) + (Property cost × number of cases)} + {(death × number of people) + (injury × number of people)}

= {(1,100,000 × 1.33) + (1,193,000 × 1.33)} + {(419,440,000 × 0.33) + (5,185,000 × 2.33)}

= 153,545,940(Won)

Ⅲ. Conclusion

1. Study Findings

In this study, we specified the relationship between fatal accidents and geometrical structure of a road by means of various cross-analysis and frequency analysis, using 112 crash point cases of the accidents since 2000, and built up a fatal accident severity model on the basis of the result.

We then came to the following conclusion with analysis of investment effect in business of road safety & 720 times computer simulations for improving driving safety.

First, the result of cross-analysis and frequency analysis on the place where car accidents occurred showed 43.7% on the curved roads, 60.7% on the vertical slope roads, 57.2% on the roads of a radius of curvature 0 to 24m, 83.9% on the roads with superelevation of 0.1 to 2.0% and 49.1% on the one-way 2-lane roads; and passenger vehicles(33.0%), trucks(20.5%)

and buses(14.3%) in order of frequency. It was analyzed that the superelevation had the most effect on the fatal accidents.

Second, with the OPM(Ordered Probit Model), we developed a severity model for fatal accidents by which the damages can be predicted on various road conditions. Contribution was made to predict dangerous roads in advance and to take measures on the basis of the developed model.

Third, as a result computer simulation, it was analyzed that, when a superelevation is provided on a spot where a fatal accident already occurred, the effect of improvement was found that fatal accidents do not occur again on spots more than 85%. With the analysis result, it is considered that it is necessary to enhance the regulations for providing exceptional superelevation in the Rule for Road Structure and Facility Standard(description and guidelines).

2. Future Challenges

So, from now on by sharing the data base (DB) of fatal accidents with government and other research institutions, it is needed to devise various measures for reducing car accidents. And there is a need of improve a reliability in severity model of car accidents by including and applying geometrical structure of a road(vertical slope roads, roads of a radius of curvature, sight distance etc) to the model. Through this study, we will suggest a severity model for fatal accidents, a validity for provision of superelevation through simulation, verification of driving safety, cost analysis considering the amount of damage by car accidents and a need of effectiveness analysis through applying & analyzing construction cost for provision of superelevation. And we look forward to contribute to create optimum roads & transportation environment with reasonable and systematic decision at decision-making process of investment business for road & traffic safety.

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