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DEVELOPMENT OF COGNITION CHARACTER MODEL FOR ROAD SAFETY FACILITY

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Abstract: This study, we got down to this experiment by a sensibility ergonomics approach with images felt by drivers driving vertical alignment sections in order to know how much roads safety facilities affect the drivers' feeling when they are driving potentially high accidents of vertical alignment. By driving the vertical alignment sections represented by the driving simulator and 3D graphics, image search step has made experiment participant overcoming difficulties of field experiment which could be burdened to participants in terms of safety. This paper, based on image materials, used Quantification Ⅱ Theory and analyzed factors of safety effect and researched the degree of effects of road safety facility to safety by modeling it by Quantification Ⅰ Theory that is used generally for statistical interpretation of cognition data.

Key Words: Driving Simulator, Quantification Theory, Cognition Character Model

1. INTRODUCTION

1.1 Background

Automobiles have been essential instruments for our daily life along with increasing life standard and consciousness of the people since the 1980s continuous economic development. An explosive traffic mentioned above has made turned a recent purpose of enhancing roving into a viewpoint of road construction aimed at traffic safety. Particularly, traffic accidents among comprehensive matters derived from automobiles caused property damage as well as human one, resulting in a new social matter along with environment issue in a modern society. The causes for car accidents are largely categorized into three parts of human sources, cars and road environment aspects and among them, geometrical structure of roads corresponded to roads-environmental cause has been made by a standardized plan guideline through a number of experiments. This geometrical structure plan structure has been made to provide safety enhancement and smooth covering ability of car drivers but the poor topography of Korea could not meet such a standard, which makes safety worse. It appears that especially reactions of drivers are different from the intentions of roads plan guideline at vertical alignment than plane alignment generally, so there could be much more potential of accidents. It is generally thought that setting of road safety facility on high potential of accidents sites could reduce a great deal of danger of accidents. However, we have seen little researches of setting effects of safety facility on the roads currently, especially the relevancy between road-environmental factors such as safety facilities and human source ones. Although the effectiveness of road safety facility could be verified through objective numerical data like car accident report, the effects could not be all perfect because of the collection of accidents report and the limitation of pure measurement.

For this, we got down to this experiment by a sensibility ergonomics approach with images felt by drivers driving vertical alignment sections in order to know how much road safety facilities affect the safety drivers feel when they are driving potentially high accidents of vertical alignment. By driving the vertical alignment sections represented by vehicle simulation and 3D graphics, image search step has made experiment participant overcoming difficulties of field experiment which could be burdened to participants in terms of safety. This study, based on image materials, used Quantification Ⅱ Theory and analyzed factors of safety effect and researched the degree of effects of roads safety facility to safety by modeling it by Quantification Ⅰ Theory that is used generally for statistical interpretation of cognition data. In addition, we also studied what factors we should consider to guarantee safe and agreeable driving by examining relevancy between road safety facility and safety clearly with analysis of experiment data for driving simulator.

1.2 Contents and Purposes of the Study

In this study we represented the vertical alignment by driving simulator and 3D graphics and expressed factors that could express image factors into 2 pairs by causes of factors to receive the images about safety, acknowledgment and drives agreeableness felt before and after setting of road safety facility. In each item from very positive to negative replies of 5 steps, participants could reply their perception to this. Based on searched data, we executed modeling before and after road safety facility. Through this, we examine the relevancy between road safety facility and safety on the vertical alignment sections clearly and suggest what factors drivers should consider to guarantee their comfortable and pleasant driving.

2. OVERVIEW

2.1 The Study on the Relation between Speed and Accidents

Even if traffic experts have its own view point, they generally agreed that speed is the main cause for express highway traffic accidents. From the first start of the study by Solomon in 1864 to the one by Frank Navin in 2001, many studies have been executed to examine the causes for express highway traffic accidents. Until now, many studies show that it is more effective method to minimize the speed dispersion of cars to operate highway safely. As well, they examine the proposal through the existing case studies suggested on table 1.

Table 1. Main Contents of the Existing Studies

Researcher	Study Contents	Results
Solomon (1964)	definition of the relation with accidents according to the speed dispersion	in case higher or lower than average speed, causing for high danger of accidents
Australia Study	using right before accident and average speed (using MSMAC)	more than average speed 60km/h, danger increases exponentially
Saskatchewan Rural Highways	average speed of vehicle, speed variance, alignment regression analysis between accident rates	decrease in average speed by 1km/h → decrease in injury accident by 7%
U.K. Experience	analysis for affects by average and speed difference to accident frequency	average speed 1km/h dropped → accident frequency 2.6% dropped
Nordic Road Experience	analyzed speed limit to (110km/h→90km/h)	injuries accident 27% dropped death accident 21% dropped
Frank Navin(2001)	prediction development of accident cases and death tolls	minimized accidents by reducing variance of driving speed

2.2 The Study on the Relation between Vertical Alignment and Accident Danger

The vertical features affect the driving speed. Trucks and buses are affected by the gradient of an uphill road where their speeds decline surely, and if there is a steep vertical gradient in a long downhill road and speedy heavy vehicles brake, they have more longer stopping distance than on the level ground due to the low speed decrease. So the possibilities of accidents could be much larger as the traffic rises unequally due to the increase in vertical gradient, resulting in increased mobility. According to the study by Bitzl quoted in Pucher, it has demonstrated that the relation between vertical gradient and accident rate in two-lane roads of rural areas in Germany is in proportion. The study on the highway of Germany shows that accidents on the vertical gradient of about 6% to 8% have four times on the one of 2% below. Krebs and Kloeckner analyzed reports of accidents occurring on the two lane rural roads of Germany and showed that the accident rate was insignificant to 6% vertical gradient but from more than 6% of vertical gradient the accident rate sharply increased. Thai is to say, vertical gradient less than 5% didn't affect the accident rate remarkably. In a recent study in the US, in case of that the traffic is the same both uphill and downhill roads, the accident rate on the downhill road are higher on the uphill roads.

2.3 The Study on Perception Reaction of Driver

The studies on visual information of drivers are feeling while driving include the study of visual density and speed through driving test, improvements and guide-eye auxiliary arrangement by understanding and quantifying driver's visual behavior on the curve section. And there are other studies including the study on a measure of perception for road images while driving based on the existing study “the behavior of human depends on image", and the studies on streetscape plan and design through SD method and perception analysis of psychological evaluation of physical components of streetscape. And Hassan and Easa, using an animation similar to the real roads, researched the study on driver's perception reaction with road geometric changes. Due to impossible experiment for real situations, advanced countries have executed driving simulator that has safety for drivers, study flexibleness and cost-saving effects using virtual reality to represent real driving situations. In Korea, researchers are studying on driver's reaction analysis and sudden acceleration incidents through driving simulator, driving feature analysis of drunk-drivers and factors analysis of the speed of driving environment using driving simulator.

3. FUNDAMENTAL THEORY

3.1 Human Sensibility Ergonomics

Virtual reality-type human sensibility ergonomics means new words, an integrated technology of virtual reality and Kansei Enginrrting, or Human Sensibility Ergonomics. The largest difference between sensibility ergonomics and the existing technology system lies in "emotional satisfaction' and "physical convenience." That is, sensibility ergonomics appeared after researchers profoundly realized that the extreme pursuit of physical convenience all could not give emotional satisfaction to people. The essence of sensibility ergonomics is a basic material to evaluate human's pleasantness, measure human senses such as visual, auditory, olfactory, gustatory and tactile sense, and is also thought to be a technology to measure under what conditions human beings feel "value", "freshness", "difference". Sensibility ergonomics systematically means “a technology to translate and realize the images from people into practical and physical design components”, a system for translation of word-expressed images for practically expressing design.

3.2 Quantification Ⅰ Theory

The quantification theory divides the number of items related to the situations into some categories for prediction of the occurrence of external standard Y. The quantification Ⅰ theory is an analysis method to utilize discrete data as a method to execute factors analysis of item.category, or to predict characteristics yield of the purpose based on explanation characteristics X_j, when explanation features $(X_1, X_2, \cdots, X_m)$ that are evaluated. This method could be corresponded to double regression analysis when X_j takes continuous values. For changing this into formula, if we assume an independent variable y_i of road image variable i is safety and explanation variable (factor) is road image characteristics drivers feel x_{jki},

The linear relationship is $y_i = \sum \sum a_{jk} x_{jki} + \varepsilon_i$ (1)

3.3 Quantification Ⅱ Theory

Discriminant analysis largely includes discriminant function to use quantitative data like interval or proportion scale as explanation variables and quantification Ⅱ type to use qualitative data like ordinal scaling or name scaling as explanation variables. Here, quantification Ⅱ theory is a method to discriminate external standard or analyze prediction. Certain classification items $G_1, G_2, \cdots, G_T$ are determined, each element having descriptor volume of involvement in that classification item $X_1, X_2, \cdots, X_m$. We observe descriptor group from each element and predict what item each element belongs to with high probability using their descriptor volume. Generally, such analysis problem is data-analyzed in the discriminant analysis. The commonly used scale for discriminant standard is correlation ratio or hit ratio and so forth.

4. DRIVING SIMULATOR EXPERIMENT AND IMAGE SURVEY

4.1 Outline of Driving Simulator

Driving simulator could evaluate various electronic control system performance, drivers' acceptance and user friendliness including various and repetitive driving situations and emergency along with Driver-in-the-Loop Simulator in the experiment room instead of real driving outdoor. The success of driving simulator depends on how much closely drivers feel about the changes of vehicle characteristics and driving conditions. Initial simulator used quite different screen from real driving situations or didn't give dynamic feeling of vehicles to drivers, but the recent simulator could not be distinguished between real driving and simulator. Figure 1 is a vehicle system used in this study and is equipped with 3 channel screen system which provides wide range of 150×40 degree for drivers and also secures a high sense of the real situation by doing feedback of a kind of vehicle’s dynamics to drivers with electronic motion system.

Figure 1. Driving Simulator and Experiment Situation

4.2 Construction of Experiment Environment

To identify road images drivers actually drive and feel according to the establishment of road safety facility, we constructed data base of multiple alignment section with 3D graphics as shown at Figure 2 and did experiment. After the completion of the experiment, we carried out an image survey to participants.

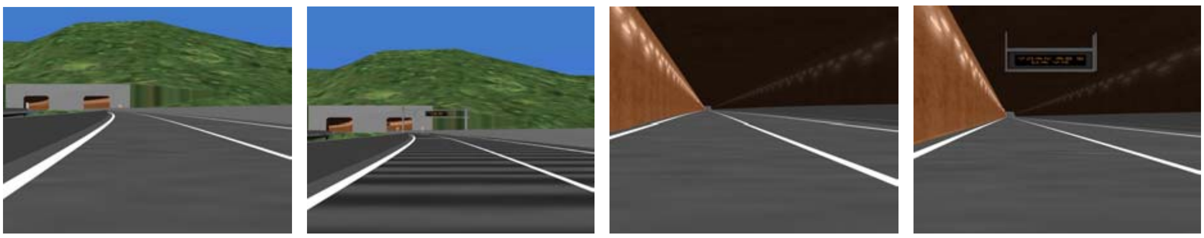

Figure 2. 3D Graphics Construction Situation

And to receive factors of pleasantness, perception and safety of roads drivers feel, we expressed items that could express image factors to two-pairs by factors. We executed a survey where respondents did express their degree of perception from 5scales of very positive reply to not at all one about each item. In this study, driving-experienced drivers were instructed to sit to be able to see the forward where driver's location was set for driver's vision. From this we executed survey road images felt by drivers seeing 3D graphics screen according to road safety facility establishment. And we built up road situation of real multiple alignment sections using 3D graphics and did experiment about driver's perception characteristics to safety facility through driving simulator. The kinds of road safety facility and each design element of experiment environment constructed in this study are as the same as Table 2.

Table 2. Experiment Environment by Scenarios

Scenario	Design Speed	Road Length	Number of Lanes	Vertical Slope	Road Safety Facility
A	80km/h	5.0km	Both four-lane	4~6%	non-existence
B					existence

Kinds of Road Safety Facility Established in Scenarios			
Non-Slip System	Vehicle Enforcement System	Variable Message Sign	Speed Limit

5. SURVEY ANALYSIS AND EXAMINATION

5.1 Individual Attribute and Simple Analysis

This study put in effect with people who are driving vehicles with their driver's licenses as of Jan. 2004. The sample size of personal behavior and its patterns of participants are as the same as Figure 3. The study showed that most respondents who have experiences of express highway driving have one or two driving on average per month, as Figure 3 shows.

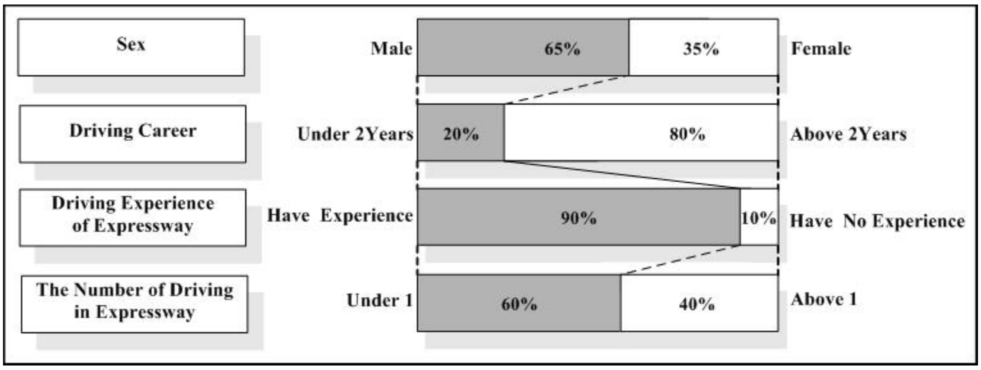

Figure 3. Composition Ratio for Individual Attribute

5.2 Outline of Road Image Survey

To draw the images drivers feel while driving, it is much more than anything to abstract image items which could speak human's feelings to the maximum. In this study, we enough considered a kind of representation related to factors of special cognition or degrees of cognitions along with road images related factors survey. We abstracted cognitive factors about road image used in this study through such course as Figure 4.

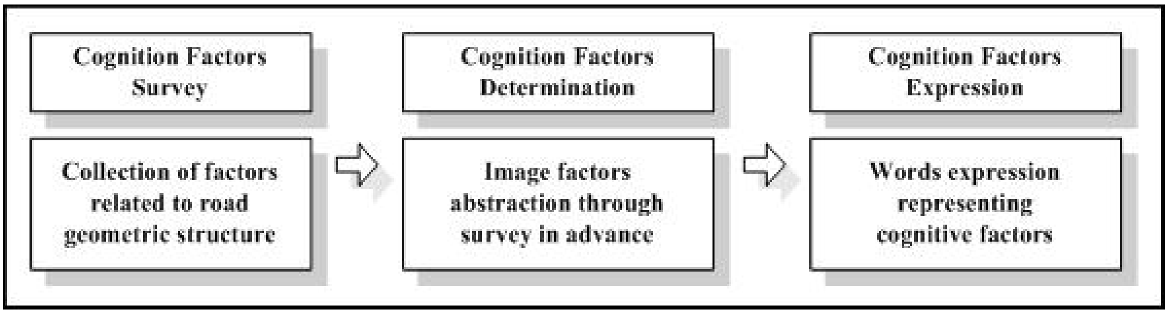

Figure 4. Abstraction Course of Cognitive Factors

Participants were scheduled to drive randomly each scenario regardless of the order of the experiment in the image survey using vehicle simulator experiment. To receive replies from the images drivers feel about road geometric structure, we expressed items which could express cognitive factors by three in the aspects of cognitive factors such as Figure 5. Participants could select and answer how much they recognize about each item among five steps, and through this we surveyed the images they feel in the three-dimensional combined alignments.

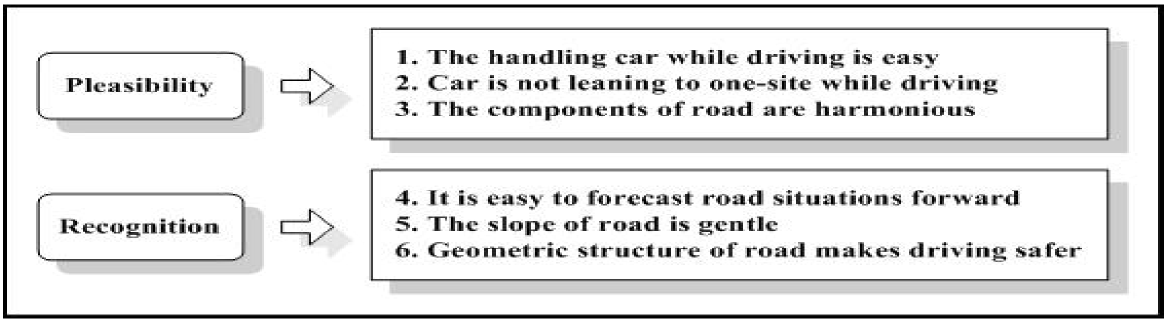

Figure 5. Cognitive Factors of Vertical Alignment Sections

5.3 Analysis of Road Image Survey

For confidence analysis of road image research, we calculated the confidence through Chronbach's Alpha coefficient. We could see 0.8276 before road safety facility establishment, 0.8576 after the establishment so that they were relatively high in confidence. Thinking road safety facility could affect a lot images drivers feel during driving, we analyzed differences in images felt by drivers before and after the establishment.

Table 3. Confidence Analysis Result of Road Image Survey

Type	Number of Item	Chronbach's Alpha
Before Road Safety Facility Establishment	6	0.8276
After Road Safety Facility Establishment	6	0.8576

We used Wilcoxou Test and saw all was significant within 5% of significant level. Table 4 is the analysis result of image difference by road safety facility establishment.

Table 4. Analysis of Road Image Difference According to Setting up Road Safety Facility

Road Image Item	Z -Value	Level of Significance	Road Image Item	Z -Value	Level of Significance
1	2.360	0.018	4	2.351	0.019
2	2.559	0.010	5	2.439	0.015
3	2.137	0.033	6	4.018	0.000

Note) the number of the image items is the one of 6 sentences which was selected final image items

6. MODEL DEVELOPMENT

6.1 Affect Factor Analysis by Quantification Ⅱ Theory

After expressing external standard and explanatory variance with dummy variable, quantification Ⅱ theory optimizes the correlation between linear combination of dummy variables of external standard and linear combination of dummy variables of explanatory variance, so this theory provides quantification values to qualitative range and predicts or discriminates external standard by explanatory variance. Quantification Ⅱ theory could be explained by the two approaches of canonical correlation analysis and canonical discriminate analysis. In this study we adopted 5 image factors as explanatory variables to discern and examine factors related to safety drivers feel and its effect degree during driving vertical alignment sections. And we did analysis by canonical correlation analysis of quantification Ⅱ theory by making "driving is safe by road geometric structure" external standard. Table 5 and Table 6 were the result which analyzed effect factors to safety drivers feel before and after road safety facility establishment on vertical alignment sections.

In quantification Ⅱ theory, we use partial correlation and quantification range as a standard for the importance of explanatory factor. Quantification range is a difference between maximum and minimum quantification values and meaning the possibility of that difference in the factor and also an indicator to see the importance (contribution) of each explanatory variance. Partial correlation is the partial correlation after replaced by quantitative variance from qualitative variance using quantification result.

The first axis of quantification of external standard, before road safety facility establishment, shows that 'no', 'common', 'good' and 'very good' are directed in (-), while 'not at all' is directed in (+). Among them, 'not at all item (2.319)' related to low safety locate in (+) and 'no' item (-0.150) is relatively close to 0. The item of "road composition elements are harmonious" is the largest relating factor in consideration of quantification range, it showed that participants with 'not at all (2.703)' item had a tendency to think safety is low while their driving. The second axis of quantification of external standard is comprised of 'good'(-1.534) and 'very good'(4.112) items related to high safety (-1.534). That is to say, it distinguishes 'good' and 'very good' related to high safety. The factor related to this is the item of "the slope of road is gentle" and participants with 'very good (4.263)' thought 'safety was very high.' Multiple variance statistics has been proven significantly because of P value of test statistic of Wilks' Lambda and Pillai's trace nearing 0. In addition, canonical correlation coefficient was very high and 0.820(second axis: 0.814) square of canonical correlation coefficient was significant and was 0.672(second axis: 0.662). After road safety facility establishment, the first axis of external standard was comprised of 'not at all', 'no' and 'common' directed in (+)

while 'good' and 'very good' located in (-). Among them, the items of 'not at all'(2.540), 'not'(0.672) and 'common'(0.472) related to low safety located in (+).The highest relating factor was the item 'road composition elements are harmonious'(2.174) and participants with such a thought had a tendency to think safety was very low. The second axis of quantification is composed by 'good'(1.138) and 'very good'(-1.207) related to high safety. The highest relating factor was the item "road composition elements were harmonious" participants with 'very good'(-0.380) thought safety was very high. Multiple variance statistics appeared significantly due to the P value of test statistic of Wilks'Lambda and Pillai's trace nearing 0. As well, canonical correlation was very high with 0.848(second axis: 0.792) and square of canonical correlation coefficient was 0.720(second axis: 627). After we compared and analyzed the model by quantificationⅡtheory before and after road safety facility establishment, safety of drivers feel while driving vertical alignment sections was "it was easy to forecast the situation forward"(first axis importance: 1.567, second axis importance: 4.108), "the slope of road is gentle"(first axis importance: 2.087, second axis importance: 4.624), "road composition elements are harmonious"(first axis importance: 3.177, second axis importance: 2.545), showing higher importance relatively before and after road safety facility establishment. We could judge factors related to perception in the safety drivers feel during driving vertical alignment sections affect a lot of the safety feelings.

Table 5. Analysis Result for Affection Causes before Road Safety Facility by QuantificationⅡTheory

Items	Categories	First axis			Second axis		
		Quantification Value	Range	partial correlation	Quantification Value	Range	partial correlation
External Standard Geometric structure of road makes driving safer	not at all	2.319	4.136	-	0.552	5.647	-
	no	-0.150			0.101		
	common	-0.440			-0.437		
	good	-0.458			-1.534		
	very good	-1.817			4.112		
It is easy to forecast road situations forward	not at all	1.247	1.567	0.329	-3.059	4.108	0.593
	no	-0.319			-0.292		
	common	0.168			-0.080		
	good	-0.047			1.049		
	very good	-0.228			0.855		
Car is not leaning to one-side while driving	not at all	-0.315	0.794	0.380	0.442	1.233	0.397
	no	0.386			0.038		
	common	-0.394			0.273		
	good	0.182			-0.790		
	very good	-0.407			-0.174		
The handling car while driving is easy	not at all	4.436	0.796	0.210	0.082	2.869	0.543
	no	-0.090			1.349		
	common	0.104			-0.348		
	good	0.232			-0.548		
	very good	-0.564			-1.519		
The slope of road is gentle	not at all	-1.412	2.087	0.447	1.695	4.624	0.697
	no	0.382			-0.262		
	common	0.142			-0.361		
	good	-0.333			-0.292		
	very good	-1.705			4.263		
The components of road are harmonious	not at all	2.703	3.177	0.509	1.111	2.545	0.550
	no	-0.122			-1.434		
	common	-0.475			0.361		
	good	-0.377			0.045		
	very good	0.607			0.283		
Canonical Correlation(Square Canonical Correlation)Analysis		0.820(0.672)			0.814		
Wilks'Lambda		0.032(Significant Probability : 0.002)					
Pillai's trace		2.261 (Significant Probability : 0.001)					

Table 6. Analysis Result for Affection Causes After Road Safety Facility by Quantification Ⅱ Theory

Items	Categories	First axis			Second axis		
		Quantification Value	Range	Partial Correlation	Quantification Value	Range	Partial Correlation
External Standard Geometric structure of road makes driving safer	not at all	2.540	3.526		-1.375	2.513	-
	no	0.672			0.893		
	common	0.472			0.009		
	good	-0.108			1.138		
	very good	-0.986			-1.207		
It is easy to forecast road situations forward	not at all	0.019	2.192	0.526	0.135	1.402	0.637
	no	1.052			-0.213		
	common	0.044			0.269		
	good	-0.264			0.094		
	very good	-1.140			-1.133		
Car is not leaning to one-side while driving	not at all	-0.557	0.897	0.287	0.141	0.767	0.341
	no	0.339			0.493		
	common	-0.001			-0.045		
	good	0.158			-0.273		
	very good	-0.345			0.296		
The handling car while driving is easy	not at all	0.680	1.462	0.512	0.352	0.688	0.424
	no	0.794			0.041		
	common	0.140			-0.254		
	good	-0.666			-0.053		
	very good	-0.076			0.434		
The slope of road is gentle	not at all	-0.707	0.827	0.166	-1.296	1.802	0.393
	no	0.120			0.506		
	common	-0.021			-0.022		
	good	0.115			-0.168		
	very good	-0.267			-0.703		
The components of road are harmonious	not at all	2.174	2.780	0.534	4.021	4.758	0.418
	no	-0.028			-0.176		
	common	-0.606			-0.737		
	good	0.399			0.552		
	very good	-0.190			-0.380		
Canonical Correlation(Square Canonical Correlation)Analysis		0.848(0.720)			0.814		
Wilks'Lambda		0.044(Significant Probability : 0.014)					
Pillai's trace		2.032 (Significant Probability : 0.023)					

6.2 Safety Change Predictive Model by Quantification Ⅰ Theory

Quantification Ⅰ theory, because of no using original code values, is to find linear combination of dummy variable with only 0 and 1 explanatory variance which has lots of correlation with external standard.

In the research, we constructed a model for safety drivers feel while driving vertical alignment sections using quantification Ⅰ theory. We constructed two models of safety model (A) before road safety facility establishment and safety model (B) after road safety facility establishment and compared and examined safety difference before and after safety facility establishment. We set “driving is safe in terms of road geometric structure” as an external standard, and executed model with explanatory variance of 5 image variables. The result was as the same as Table 7, Table 8. In case of model (A), factors to determine safety showed "good" and "very good" in most variables. "The slope of road was gentle"(range: 2.201, partial correlation: 0.531), the largest range of quantification, could be the most important explanatory variable in determining safety during driving multiple alignment sections. In case of model (B), high safety-determining factors showed "good" and "very good" in most variables. Besides, “road composition elements are harmonious (range: 2.120, partial correlation: 0.468)” has been shown to be the most important contribution of explanatory variables while driving vertical alignment sections. On the other hand, among surveyed and collected image data, we collected the same reply results before and after road safety facility establishment and analyzed safety prediction about model (A) and model (B). The results showed model (A) indicated average safety of 2.42 before safety facility establishment and model (B) indicated average safety of 3.16 after establishment. And we examined whether there was different safety prediction results between model(A) and model(B) and significant level was 0.045 so that we could see difference in prediction results between (A) and (B) within 0.05. It could be estimated that safety facility might induce safe from drivers while driving vertical alignment sections.

Table 7. Safety Predictive Model(A) by Quantification Ⅰ Theory
Before Road Safety Facility Establishment

Items	Categories	Quantification Value	Range	Partial Correlation
It is easy to forecast road situations forward	not at all	-1.445	1.801	0.409
	no	0.356		
	common	-0.182		
	good	0.070		
	very good	0.064		
Car is not leaning to one-side while driving	not at all	0.134	0.686	0.362
	no	-0.326		
	common	0.360		
	good	0.108		
	very good	-0.324		
The handling car while driving is easy	not at all	-0.669	1.707	0.376
	no	0.250		
	common	-0.011		
	good	-0.315		
	very good	1.038		
The slope of road is gentle	not at all	0.195	2.201	0.531
	no	-0.347		
	common	-0.071		
	good	0.514		
	very good	1.854		
The components of road are harmonious	not at all	-0.515	0.852	0.359
	no	-0.437		
	common	0.230		
	good	0.337		
	very good	-0.439		
Constant	2.500			
R-Square		0.599		
F-Value		2.170		
P-Value		0.027		

Table 7. Safety Predictive Model(A) by Quantification Ⅰ Theory
After Road Safety Facility Establishment

Items	Categories	Quantification Value	Range	Partial Correlation
It is easy to forecast road situations forward	not at all	-0.364	1.764	0.411
	no	-0.691		
	common	-0.100		
	good	0.194		
	very good	1.074		
Car is not leaning to one-side while driving	not at all	0.665	1.223	0.335
	no	-0.558		
	common	-0.027		
	good	-0.191		
	very good	0.430		
The handling car while driving is easy	not at all	-0.697	1.708	0.525
	no	-0.959		
	common	-0.119		
	good	0.749		
	very good	0.099		
The slope of road is gentle	not at all	0.948	1.275	0.205
	no	-0.327		
	common	0.062		
	good	-0.021		
	very good	0.332		
The components of road are harmonious	not at all	-1.478	2.120	0.468
	no	-0.178		
	common	0.642		
	good	-0.302		
	very good	0.313		
Constant	3.485			
R-Square		0.702		
F-Value		3.410		
P-Value		0.001		

7. SAFETY EXAMINATION BY EXPERIMENT DATA

This paper evaluated the safety analyzing driving speed data before and after road safety facility and compared this with the degree of safety drivers felt. In other words, we compared the driver's safety with a model derived from questions about images and analysis results of driving speed data of participants through driving simulator after driving vertical alignment sections. Through this, we tried to examine closely the changing degree of safety after establishing safety facility on road. Lamm from Germany proposed three safety criterions on route alignment like Table 8 for evaluation of safety valuation on route alignment. The Safety

Criterion Ⅰ is to evaluate safety level as the difference between running time and design one each section to examine the consistency of the design. Safety Criterion Ⅱ is to evaluate safety level by examining the consistency of each running time of the section. And Safety CriterionⅢ is to evaluate safety level difference between horizontal friction coefficient required when real driving and horizontal friction coefficient assumed for dynamic consistency of running.

Table 8. Safety Criterion on Road

Safety Criterion	GOOD	FAIR	POOR
	Design Levels		
Ⅰ	$\lvert V85i - Vd \rvert \le 10km/h$	$10km/h < \lvert V85i - Vd \rvert \le 20km/h$	$20km/h < \lvert V85i - Vd \rvert$
Ⅱ	$\lvert V85i - V85i{+}1 \rvert \le 10km/h$	$10km/h < \lvert V85i - V85i+1 \rvert \le 20km/h$	$20km/h < \lvert V85i - V85i+1 \rvert$
Ⅲ	$+0.01 \le \lvert fR - fRA \rvert$	$-0.04 \le \lvert fR - fRA \rvert < +0.01$	$\lvert fR - fRA \rvert < -0.04$

Vd : design speed (km/h), $V85i$: 85% expectation speed (km/h) in I section
$V85i+1$: 85% expectation speed (km/h) in i+1 section
fR : Presumed horizontal frictional force, fRA: required horizontal frictional force

We used driving speed consistency analysis method among route alignment safety criterions proposed by Lamm for safety evaluation of running speed data. Table 9 shows the result that evaluated the safety within each section analyzing speed difference among sections based on Lamm's running speed consistency analysis method about 16 sections divided by the spot where vertical gradient changed.

Table 9. Safety Evaluation Result by Speed Data

Section		Before Road Safety Facility Establishment		After Road Safety Facility Establishment	
		Analyzed Value	Safety	Analyzed Value	Safety
1	2	8.1	GOOD	12.0	FAIR
2	3	-5.4	GOOD	0.0	GOOD
3	4	-7.2	GOOD	-6.0	GOOD
4	5	-1.0	GOOD	-4.6	GOOD
5	6	10.1	FAIR	-0.2	GOOD
6	7	13.7	FAIR	7.7	GOOD
7	8	-4.1	GOOD	-2.3	GOOD
8	9	-8.7	GOOD	-4.8	GOOD
9	10	-2.9	GOOD	-0.5	GOOD
10	11	9.3	GOOD	8.4	GOOD
11	12	0.0	GOOD	-4.5	GOOD
12	13	1.2	GOOD	0.8	GOOD
13	14	-0.1	GOOD	2.2	GOOD
14	15	-8.6	GOOD	-4.7	GOOD
15	16	12.0	FAIR	5.2	GOOD

You could see FAIR at the three sections before setting road safety facility by the result of Table 9 and FAIR at one section after setting road safety facility. In addition, the differences of speeds among sections became gradually smaller. From this, we could judge road safety facility affect the driving safety of drivers.

8. CONCLUSION

This study represented vertical alignment sections with driving simulator and 3D graphics to overcome the difficulties of field study which could be a burden to participants in terms of safety. The represented vertical alignment sections had the same participants drive before and after road safety devices. Based on the image data drivers felt after driving, we calculated each model before and after road safety facility and we could examine the safety changes of the model by the image data analyzing the safety changes before and after road safety facility through the running speed data, vehicle simulator experiment data.

Analyzing the safety-effect factors by the canonical correlation of quantification Ⅱ theory, it proved that regardless of the existence of road safety devices, poor images of most explanation variables were associated with poor images of the safety of external standard. Particularly items related to driver's perception such as "easy prediction of the road situation forward", "the gentle slope of road", "harmonious components of road" showed larger size of the range and partial correlation than items related to pleasantness such as "no leaning to one side while driving", "easy handling of vehicle while driving", which in turn puts a little bit an importance on the safety drivers feel. We built up a safety prediction model drivers are feeling while driving vertical alignment sections by the quantification Ⅰ theory. As a result, model (A) and model (B) before and after road safety facility showed 59.9% and 70.2% respectively in terms of predictability. And this seems to be significant statistically. We inspected closely what explanation variable was the most important contribution a great deal to the safety drivers felt, we came to know that in the case of model (A) "the slope of the road is gentle" and in the case of model (B) "the composition elements of road are harmonious".

On the other hand, we gathered the same result of replies before and after set of road safety devices from image data and analyzed the safety forecasts and as an analysis result higher safety forecast has been shown in the after set of road safety facility than before. The difference from safety forecast results has the significance in terms of statistics. Along with this, we analyzed the running speed data of vehicle simulator by the Lamm's running speed consistency evaluation and speed differences by sections are decreasing gradually after the set of road safety facility. This result is suited to the our judgment that road safety facility affect the safety drivers feel through such models and is concluded that we could induce safe driving while drivers are running on the sections of vertical alignment by setting up road safety facility.

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