

# Analysis of Driving Conditions and Preferred Media on Diversion

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**Abstract**—Studies on the distribution of traffic demands have been proceeding by providing traffic information for reducing greenhouse gases and reinforcing the road's competitiveness in the transport section, however, since it is preferentially required the extensive studies on the driver's behavior changing routes and its influence factors, this study has been developed a discriminant model for changing routes considering driving conditions including traffic conditions of roads and driver's preferences for information media. It is divided into three groups depending on driving conditions in group classification with the CART analysis, which is statistically meaningful. And the extent that driving conditions and preferred media affect a route change is examined through a discriminant analysis, and it is developed a discriminant model equation to predict a route change. As a result of building the discriminant model equation, it is shown that driving conditions affect a route change much more, the entire discriminant hit ratio is derived as 64.2%, and this discriminant equation shows high discriminant ability more than a certain degree.

**Keywords**—CART analysis, Diversion, Discriminant model, Driving conditions, and preferred media

## I. INTRODUCTION

### A. Backgrounds and Purposes

INTERESTS in the greenhouse gas reduction and the environmental friendly green growth are increasing as the global warming problems are aggravated. It is more and more interested in how to efficiently use the existing roads in order to reduce greenhouse gases and reinforce road's competitiveness in the transport section, and studies on the distribution of traffic demands by providing traffic information are in progress as a practical method for them.

However, driver's decision making to change routes is not a problem whether or not the information is simply provided, but may be varied depending on driving conditions or preferred media when it is provided. In other words, driver's responses for route changes may be varied depending on the driving conditions such as weather situations and traveling distances etc. and the individual driver's preferred property for media to provide information even though the same information is provided. In particular, even though a result of driver's decision making to change routes is represented as a simple result whether to drive the existing route or change the route, the process to actually determine it is carried out through a diverse, complex and step-by-step process such as examining various environmental conditions, considering the worst situation, and ranking priority in accordance with the preferred property for each person. Therefore, it is needed a study on such a decision

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making process to change routes, if sufficient studies are not accomplished, drivers may respond differently each other for the same traffic information, furthermore, it is important that the fact they may respond inconsistently from operator's intention is not overlooked.

### B. Scope of Work and Methods

In terms of the importance for such a decision making to change routes, this study would develop a discriminant model to change routes considering the driving conditions including traffic situations on the road and the driver's preferred property for information media. For an analysis, it is investigated whether or not to change routes followed by traffic situation on the road and preferred media by carrying out a survey for drivers using expressways. To efficiently collect and classify data to be examined, the tree analysis method for decision making is used, and they are re-classified according to driving conditions representing statistically meaningful collective differences for whether or not to change routes. In addition, the extent that driving conditions and preferred media affect a route change is examined through a discriminant analysis, and a discriminant model equation is developed to predict a route change.

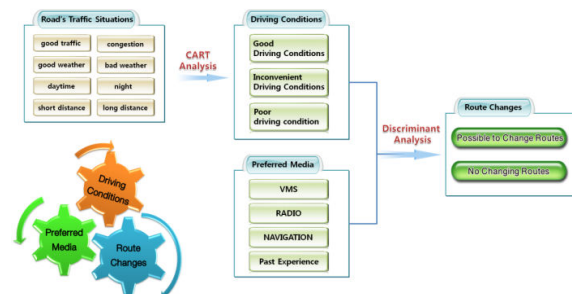


Fig. 1 Research Method

## II. BACKGROUNDS

### A. Literature Review

Studies related to providing the traffic information are divided into information provision, strategies to provide information, evaluations of information provision effects, system configurations to provide information, and recently studies on the driver's response behavior followed by providing information are primarily carried out.

Khattak (1993) presented a result that driver's decision making was affected in the order of their past experiences (63%), direct observation (21%), and traffic information (16%) in his study on the driver's selection for actions [1]. And H. R. Kim et al. (2004) identified that there were traveler's property, travelling property, route property, information content, their

past experiences etc. for factors affecting driver's decision making to change routes, and it was affected by inherent property of media, form of information, and delivered content etc. when drivers made a decision to change routes after receiving information from media [3].

Y. H. Choi et al. (2007) identified in their study on the information media affecting driver's decision making to change routes that drivers depended on traffic information more than their own experiences as the congestion was more serious [6]. And I. P. Kim (2008) found a primary factor deciding a detour through a preference analysis, and identified that a strategy was needed to provide each traffic information for each traffic situation that was a core factor of route changes [4]. Meanwhile, Khattak et al. (2008) presented that media such as Internet, radio broadcasting, VMS, navigation etc. among information provision media affecting driver's behavior had affected the decision making of destinations, travelling means, route selections etc [2]. In particular, when comparing the existing study's result of Khattak (1993, 2008), it could be found that individual driver's experiences were regarded as important in the 1990s, but preference for information media has been increasing more than personal experiences since the high reliable traffic information is timely provided via various media due to development of information communication technologies from the 2000s. Nevertheless, a remarkable fact is that even now, there are drivers who select routes using the past experiences in spite of the information age, and it is not irrelevant to user experiences (Ux) becoming an issue recently. The Ux means overall experiences that users feel and think as they directly or indirectly use any system, product, and service. It is a valuable experience that users could know by participating, using, observing, and interacting in every whole perceivable aspect as well as satisfaction on functions or procedures simply. Referring to the results of Khattak (1993) and Y. H. Choi et al. (2007), it is seemed that the past experiences such as user's direct driving experiences and indirect travelling experiences by persons around them affect a route selection primarily in the traffic aspect.

Y. H. Choi et al. (2009) identified that there was a meaningful relationship between driver's detour behaviors and road's traffic situations through a correlation analysis between the bypass rate investigated actually and the road's traffic situation (traffic volumes on the main line, travelling speed, and travelling time), and derived a regression equation for the expressway's bypass rate by using it [7]. In addition, Y. H. Choi et al. (2010) analyzed how the use pattern of information media was varied according to traffic situations, and re-classified into passive use media, active use media, the past experiences based on the property for each medium to analyze variation of the bypass use rate for each information medium followed by each traffic situation [8]. They identified that while the use rate of a passive use medium was decreased as the traffic situation became worse, the bypass rate using an active use medium and the past experiences was increased. S. N. Son (2010) identified that a will to change routes and driver's perceived behavior control for a route change most significantly affected a decision whether or not to change routes [5].

### B. Problem statement

In spite of many studies related to traffic information like this, studies on the driver's decision making to change routes are insufficient. In particular, since it has been identified that driver's route changes depend on traffic situations and the traffic information media used for changing routes become different according to traffic situations, an analysis on the relationship between traffic situations, preferred media, and route changes is needed by integrating them. This study is a succeeding study of Y. H. Choi et al. (2009, 2010), which would comprehensively analyze driver's property to change routes considered fragmentarily such as traffic situations and route changes, traffic situations and properties to use traffic information media etc. according to the property of preferred media under driving conditions such as travelling distances including road's traffic situations and weather conditions etc.

### III. ANALYSIS METHODS

This study performed an analysis with the following process.

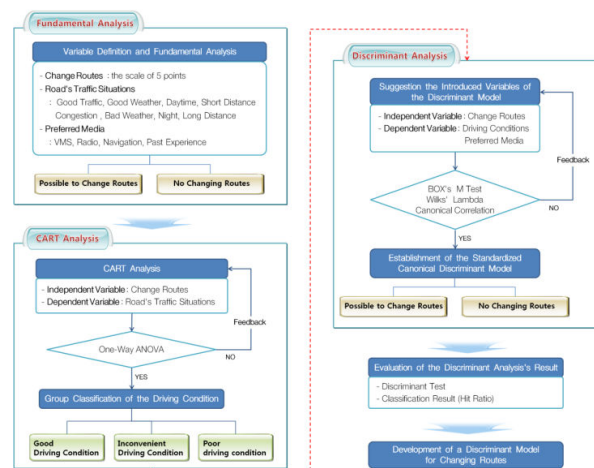


Fig. 2 Analysis Method

First, it is performed whether or not to change routes for variables to be used in this study, definitions of the classification for road's traffic conditions and preferred media, and a fundamental statistical analysis.

Second, for the appropriate classification of road's traffic situations which is a core part of this study, the CART analysis method is used to investigate road's traffic situations representing statistical meaningful collective differences for route changes.

Third, a statistical verification is performed for the group classification of driving conditions by performing the one-way ANOVA for driving conditions classified by the CART analysis.

Fourth, a discriminant model is developed for driving conditions and preferred media affecting the route changes.

Fifth, the discriminant hit ratio is analyzed for the developed discriminant analysis model.

IV. DATA ANALYSIS

A. Fundamental Analysis

This study performed a survey for total 500 persons using metropolitan expressways. Among total 500 of respondents, males occupied 60% as 286, and females occupied 40% as 214. In the result of responses having multiple choices asking whether or not to change routes for 8 road's traffic situations and 4 preferred media, the analysis was performed by using 6,462 data that the preference for each medium was responded above 8 points. It was because drivers having a preference of 'above favor' for the preferred media in each road's traffic situation were considered to represent well the relationship between the road's traffic situations and the preferred media and the relationship between the preferred media and whether or not to change routes as drivers affected by the preferred media when changing routes.

The questions about whether or not to change routes would be responded whether or not to change routes for each question on the scale of 5 points from 'no changing routes at all' to 'always possible to change routes.' The analysis was performed by grouping the point between 1 to 3 into 'no changing routes' and the point between 4 to 5 into 'possible to change routes' among responses for questions of the 5-point scale. As a result of the frequency analysis for whether or not to change routes as a target variable, it was analyzed that the responses of the possible to change routes occupied 46.7%, and the responses of the no changing routes occupied 53.3%. Since the respondents responding as 'average (3 points)' who occupied 25% of the entire respondents are classified into the no changing routes, it is considered that a little conservative response result was come out.

Since the major purpose of decisions for whether or not to change routes that would be presented in this study is also to find the possibility to change routes by drivers who use the corresponding road when variables for preferred media of the drivers are entered for each road's traffic situation, this study would be approached in a little conservative aspect by using the result of above survey.

TABLE I  
ANALYZING THE FUNDAMENTAL DATA FOR WHETHER OR NOT TO CHANGE ROUTES

Type	No Changing Routes			Possible to Change Routes	
	1 (No Changing Routes At All)	2	3 (Average)	4	5 (Always Possible to Change Routes)
Frequency	828	999	1616	1806	1213
Percent (%)	12.8	15.5	25.0	27.9	18.8
	53.3%			46.7%	

B. Group Classification of the Road's Traffic Situations with the CART Analysis

The CART analysis method was used to classify the road's traffic situations considered as a major factor affecting driver's route changes, and the groups of road's traffic situations representing the statistical meaningful collective differences for whether or not to change routes were re-classified depending on driving conditions. In addition, a statistical verification between groups re-classified depending on driving conditions was performed with the one-way ANOVA for the groups classified by the CART analysis.

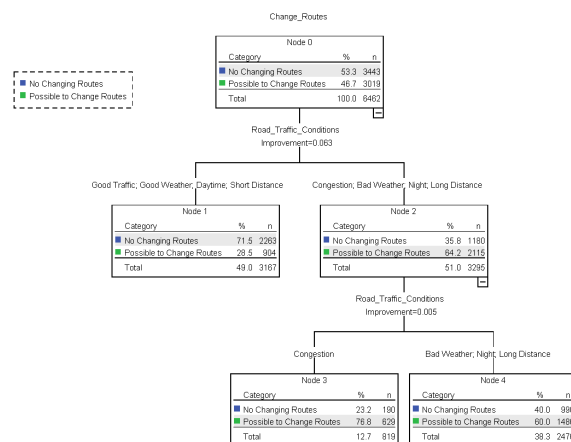


Fig. 3 Group Classification of the Road's Traffic Situations with the CART Analysis

First, as a result of the CART analysis based on whether or not to bypass, they were classified into 'node 1' (smooth traffic, good weather, day, short distance) and 'node 2' (poor driving conditions, bad weather, night, long distance) as the Fig. 3. The result of the statistical significance test for the classification between groups represented the p-value for the t-test as 0.000, so it could be said that the difference between two groups was significant for 95% level of the reliability. The result of the t-test analysis for the 'node 3' (poor driving conditions) and the 'node 4' (bad weather, night, long distance) for the node 2 also represented the p-value for the t-test as 0.000, so it could be said that the difference between two groups was significant for 95% level of the reliability.

TABLE II  
RESULT OF THE STATISTICAL SIGNIFICANCE TEST FOR THE CLASSIFICATION BETWEEN GROUPS

Parent Node	Child Node	N	Mean	Std. deviation	Levene's Test of Equality of Error Variances		t-test	
					F	p-value	t-value	p-value
Node 0	Node 1	3167	1.71	0.452	155.615	0.000	30.731	0.000
	Node 2	3295	1.36	0.480				

Node 2	Node 3	81 9	1.23	0.423	468.556	0.000	-8.764	0.000
	Node 4	24 76	1.40	0.490				

Based on the groups classified by the CART analysis, the road's traffic situations were re-classified into three groups of driving conditions to perform the post analysis.

- Group A (good driving conditions): good traffic, good weather, daytime, short distance
- Group B (inconvenient driving conditions): bad weather, night, long distance
- Group C (poor driving conditions): congestion

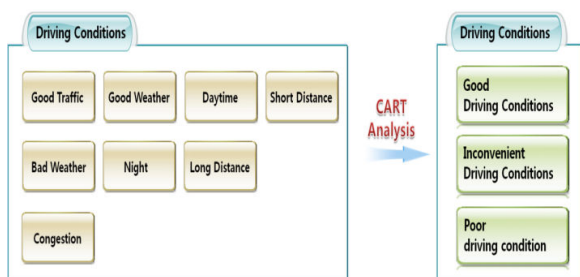


Fig. 4 Group Classification of the Driving Condition

The result of the one-way ANOVA and the post analysis to verify the difference between three groups classified by the driving condition represented the p-value as 0.000, and the difference between groups depending on the driving condition was the same as the CART analysis, so it had been proved that the group classification with the CART analysis was statistically appropriate.

TABLE III  
RESULTS OF THE ONE-WAY ANOVA FOR EACH DRIVING CONDITION

Driving Condition	Mean	Std. deviation	Levene's Test of Equality of Error Variances		One-Way ANOVA		Post Hoc Tests
			F-value	Sig.	F-value	Sig.	
Good Diving Conditions (a)	2.71	1.167	139.251	0.000	2337.863	0.000	a≠b ≠c (Scheffe Test)
Inconvenient Diving Conditions (b)	3.65	1.168					
Poor Driving Conditions (c)	4.12	0.910					

V. DEVELOPMENT OF A DISCRIMINANT MODEL

A. Outline

The "1" of nominal scale was assigned to drivers changing routes, and the "0" of nominal scale was assigned to drivers not changing routes depending on whether or not to change routes for drivers using their own preferred media for each driving

condition. The analysis with the stepwise method was performed to understand variables affecting the route changes significantly, and the Wilks' method was used as the criteria to select variables.

TABLE IV  
SUMMARIZING THE INTRODUCED VARIABLES OF THE DISCRIMINANT MODEL

Dependent Variable	Independent Variable	
Whether or Not to Change Routes	Driving Conditions (a)	Good Diving Conditions (a1)
		Inconvenient Diving Conditions (a2)
		Poor Driving Conditions (a3)
	Preferred Media (b)	VMS (b1)
		Radio (b2)
		Navigation (b3)
		Past Experience (b4)

B. Consideration of the Discriminant Analysis's Result

The discriminant analysis is established under the assumption that it has a multi-variate normal distribution and the covariance of each group is identical. The homogeneity test result of the covariance matrix analyzed through the Box test for groups represented the significance probability of the Box test as 0.139, and it was selected the null hypothesis that their covariance are identical, so it could be defined that the covariance matrixes of two groups are identical.

TABLE V  
BOX'S TEST RESULTS

Box's M		122.830
F	Approx.	1.831
	df 1	3
	df 2	1.647E10
	Sig.	0.139

As a result of the discriminant analysis, a discriminant function was derived, and it was analyzed that both the driving conditions and the preferred media had the statistically significant effects. Even though this analysis represented the canonical correlation coefficient as 0.310, the eigenvalue as 0.107, the Wilks' lambda value as 0.904, which the discriminant were not very high, but the significant probability of the chi-square test was  $0.000 < \alpha = 0.05$ , which represented that it was statistically significant. Examining the Wilks' lambda for road's traffic situations and preferred media and the value converting it into the F statistics also in the analysis on the discriminant factors, since the significant probability of the F statistics was less than 0.05, it could be said that the average difference of the discriminant score between groups was significant.

TABLE VI  
SUMMARY OF CANONICAL DISCRIMINANT FUNCTIONS

Eigenvalues	Eigenvalues	% of Variance	Cumulative %	Canonical Correlation
	0.107	100.0	100.0	0.310
Wilks' Lambda	Wilks' Lambda	Chi-square	df	Sig.
	0.904	653.970	2	0.000
Test of Equality of Group Means	Type	Wilks' Lambda	F	Sig.
	Driving Conditions	0.909	649.788	0.000
	Preferred Media	0.999	8.727	0.003

The size of coefficient's absolute value in a discriminant equation represents the relative importance between variables, and it could be found that the driving conditions have more effects than the preferred media when it was examined the result analyzing the coefficients of the standardized canonical discriminant function for these discriminant factors.

TABLE VII  
STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

Variable	Function	
	Standardized Canonical Discriminant Function Coefficients	Canonical Discriminant Function Coefficients
Driving Conditions	1.002	1.132
Preferred Media	- 0.239	- 0.216
(Constant)	-	- 1.635

C. Establishment of the Standardized Canonical Discriminant Model

The discriminant model equation was defined for whether or not to change routes by using the coefficients of the canonical discriminant function (non-standardized canonical discriminant function).

$$z = -1.635 + 1.132 \times XF_i - 0.216 \times XM_j \quad (1)$$

Here,  $z$  : Whether or Not to Change Routes

$XF_i$  : Driving Conditions ( $i$  : 1=Good Driving Conditions,

2=Inconvenient Driving Conditions, 3=Poor Driving Conditions)

$XM_j$  : Preferred Media ( $j$  : 1=VMS, 2=Radio, 3=Navigation, 4=Past Experience)

If the discriminant score found by the above discriminant equation is larger than the classification standard, it is classified into the group 1 (possible to change routes), or if it is smaller, it is classified into the group 2 (no changing routes.) The average discriminant score of the group 1 is 0.349, and the average

discriminant score of the group 2 is -0.306, which the standard of classification is calculated as the average of the cutting point of these two groups.

$$Centroid = \frac{\sum_{i=1}^m n_i C_i}{\sum_{i=1}^m n_i} = \frac{n_1 C_1 + n_2 C_2}{n_1 + n_2} \quad (2)$$

Here,  $n_i$  : Sample Size of Group  $i$

$C_i$  : Centroid of Group  $i$

The standard of classification is derived as the 0 of cutting point according to the above equation. Therefore, the case of having a larger value than the 0 by the discriminant model is classified into the group 1 (possible to change routes,) or if the value is less than the 0, it is classified into the group 2 (no changing routes).

TABLE VIII  
FUNCTIONS AT GROUP CENTROID

Changing Route	Function 1	
	Centroid	Cutting Point
Possible to Change Routes	0.349	0.0
No Changing Routes	- 0.306	

D. Establishment of the Discriminant Model for Changing Routes

Using a result of the Fisher's linear discriminant analysis, the linear discriminant function for each group could be derived to determine a bypass.

$$z(\text{possible to change route}) = -5.635 + 2.543 \times XF_i + 1.638 \times XM_j \quad (3)$$

$$z(\text{no changing route}) = -4.282 + 1.803 \times XF_i + 1.779 \times XM_j \quad (4)$$

Here,  $z$  : Whether or Not to Change Routes

$XF_i$  : Driving Conditions ( $i$  : 1=Good Driving Conditions, 2=Inconvenient Driving Conditions, 3=Poor Driving Conditions)

$XM_j$  : Preferred Media ( $j$  : 1=VMS, 2=Radio, 3=Navigation, 4=Past Experience)

TABLE IX  
CLASSIFICATION FUNCTION COEFFICIENTS

Type	Whether or Not to Change Routes	
	Possible to Change Routes	No Changing Routes
Driving Conditions	2.543	1.803
Preferred Media	1.638	1.779

(Constant)	- 5.365	- 4.282
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### E. Discriminant Test

Examining the result performing the discriminant for each group based on data used in the analysis in order to verify the discriminative strength of the discriminant model developed as the result of the discriminant analysis, total discriminant hit ratio is derived as 64.2%. The discriminant hit ratio of the group 1 (changing routes) is represented as 60.1%, and the group 2 (no changing routes) is represented as 67.9%. It could be said that the discriminant by this discriminant equation shows higher discriminative strength than a certain level.

TABLE X  
CLASSIFICATION RESULT

Type		Predicted Group Membership		Total
		Possible to Change Routes	No Changing Routes	
Count	Possible to Change Routes	1813	1206	3019
	No Changing Routes	1105	2338	3443
Ratio	Possible to Change Routes	60.1	39.9	100.0
	No Changing Routes	32.1	67.9	100.0

## VI. CONCLUSIONS

More efficient and effective strategies to provide the traffic information and control the traffic should be established in order to relieve the confusion and solve the congestion, since the study on the driver's behavior to change routes and the factors affecting it is preliminarily needed for the purpose, this study would develop the discriminant model to change routes considering the driving conditions including the road's traffic situations and the driver's preferred property for the information media.

To find the relationship between the preferred media for traffic information and the driving conditions affecting the driver's decision to change routes, the CART analysis method is used to re-classify the group of road's traffic situations, which represents the statistically significant collective differences for whether or not to change routes, depending on the driving conditions. In addition, it was examined the extent that the driving conditions and preferred media affect the route change through the discriminant analysis and it was developed the discriminant model equation to predict whether or not to change routes. Examining the result of building the discriminant model equation, it was represented that the driving conditions affected the route change much more, and it could be said that this discriminant equation showed higher discriminative strength than a certain level because the entire discriminant hit ratio was derived as 64.2%.

Even though this study divided the road's traffic situations into three groups of driving conditions to analyze them, it is needed to analyze for whether or not to change routes by

classifying the road's traffic situations in more detail in order to establish more efficient and effective strategies to provide the traffic information and control the traffic. In addition, even though this study carried out the survey for the preferred media and whether or not to change routes depending on the road's traffic situations, an additional study is required for whether the driver's responses and whether or not to change routes acquired routes survey are also identical to actual sites. It should be found the various causes of changing routes, the priority of each cause, and the correlation between them for drivers changing routes actually, it should check whether the results of the survey is identical to driver's actual behavior through the factor analysis, and it should perform the correlation analysis.

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