Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 1833 - 1843, 2005

MODELING EN-ROUTE DIVERSION BEHAVIOR UNDER ON-SITE TRAFFIC INFORMATION

Hye Ran KIM
Researcher
Graduate School of Engineering
Seoul National University
San 56-1, Sillim-dong, Gwanak-gu, Seoul, 151-742, Korea
Fax: +82-2-889-0032
E-mail: holyegg@korea.com

Kyung Soo CHON
Professor
Graduate School of Engineering
Seoul National University
San 56-1, Sillim-dong, Gwanak-gu, Seoul, 151-742, Korea
Fax: +82-2-889-0032
E-mail: chonks@snu.ac.kr

Abstract: Real-time traffic information is considered as system which can alleviate traffic congestion. Effective information will help drivers make efficient travel decisions, and improve network performance. To make efficient strategy of providing information, the analyzer should quantify the reduced congestion by the traffic information. Many other route diversion models considered only media-information as information sources and ignored the influence of on-site information such as visible delay or average speed, which in practice affects drivers' route diversion decision. In those models, the influence of on-site information could be disguised to the influence of media information, and the effectiveness of media information would be over-estimated. The proposed model including the influence of on-site information will contribute to estimate accurately the influence of information on drivers' route diversion decision and network performance.

Key Words: route diversion, stated preference, visible queue, Variable Message System, radio

1. INTRODUCTION

Providing real-time traffic information makes drivers recognize network unbalance and gives them chances to divert route. These procedures could alleviate congestions and improve the network performance. But providing information does not always guarantee congestion diminished. Bonsall (1992) emphasized that the way in which drivers' route choice is influenced by ATIS is important in terms of evaluating the ATIS' impact on network performance and environmental conditions.

Many researchers attempt to quantify the influence of real-time traffic information on drivers' en-route diversion behaviors and network performances. If drivers' route diversion behaviors are modeled properly, simulation tools using the model could be used to estimate the effectiveness of information system on network performances.

Many en-route diversion models considered only media-information as information sources in en-route diversion modeling and ignored the influence of on-site information such as visible delays or perceived average speeds, which affects drivers' route diversion decision in practice. In those models the influence of on-site information is not identified, so the influence of media information on drivers' diversion tendency will not be estimated properly. Moreover almost models don't consider the differences of various types of the information phrases, forms and sources in modeling.

The aim of this paper is to evaluate and clarify the effect of the real-time information on drivers' route diversion behavior. Not only media information but also on-site information is considered. Variable message system (VMS) and radio traffic information are considered as media information and visible delay is considered as on-site information.

Influencing factors on driver's route diversion decision are classified five components; driver's characteristics, trip characteristics, route attributes, traffic information and priori experience. Among them driver's characteristics, Trip Characteristics and priori experience are excluded from the view of practical-use because they are hardly controlled by analyzer.

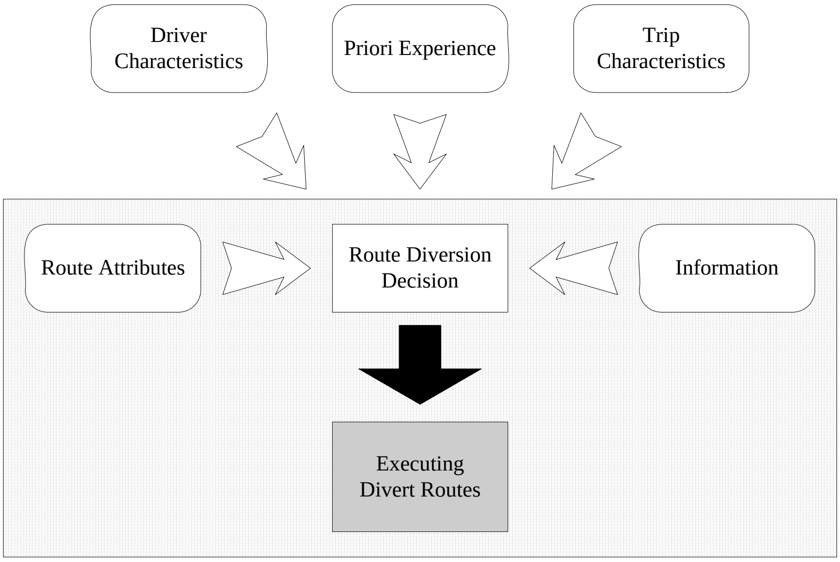

Figure 1. Scope of the Study

2. INFLUENCING FACTORS

2.1 Route Attributes

Travel time of route is conventionally regarded major factors to be considered by driver in route choice decision. Many researchers have found that drivers with longer travel time on current route were more likely to divert as a result of traffic information (Khattak et al., 1993; Emmerink et al., 1996). Emmerink et al. (1996) pointed that this tendency was probably the result of their increased number of opportunity to take alternative routes.

Delay time and length of route are also dealt with important influencing factors. Previous studies, reviewed by Wardman et al. (1997), have found that delay time was valued more highly than free flow time and the relative weight have been calculated from previous works, e.g. 1.43 from Wardman (1991), 1.39 from Oscar Faber TPA (1992), 1.7 for commuters and 14.0 for other journey purposes from Hensher et al. (1990).

Ben-Akiva and Bergman (1984) regarded travel length, number of stops, number of signal intersections, scenic view, travel time and length on access-limited roads, safety, CBD and quality of the congestion roads as route attributes which affect driver's route choice. Bonsall

(1992) considered congestion, toll, safety, route familiarity and scenic view in route choice modeling. Bonsall (1992) reported that road type or hierarchy of road was an important influence on drivers' route choice.

2.2 Traffic Information

2.2.1 Media Traffic information

The influence of traffic information on route diversion depends on the type of information, the reliability of information source, the way information presented and the contents of information.

Bonsall and Palmer (1998) indicated that information about accidents, delays and congestion, when displayed on VMS, can have a great influence on route choice behavior and the effects are very dependent upon the phrasing of the message.

Khattak et al. (1993) reported that descriptive information (i.e. information without advice) was likely to have more impact on route choice than prescriptive information, but drivers were more willing to divert in response to a combination of prescriptive and descriptive traffic information either of them separately. And Wardman et al. (1997) showed that if the cause of delay were displayed, the propensity to divert routes would be increased.

Descriptive information is divided into qualitative information and quantitative information. Wardman et al. (1997) showed that when drivers received qualitative and un-quantified delay information, they valued "long delay" as between 35 and 47 minutes and "delay likely" as between 10 and 31 minutes depending on the cause of delay. Hato et al. (1999) reported that quantified travel time signs need higher ability to process than graphical maps, message signs or radio traffic reports.

Emmerink (1996) and Lotan (1997) reported that the propensity to divert routes would be increased when information was obtained more than two sources, however, if the messages from the different information sources were conflict, the reliability of information will be decreased.

2.2.2 On-site Traffic Information

Khattak (1993) reported that the driver who have ever diverted routes replied that the information sources on which driver made diversion decision based are traffic information 16%, direct observation 21% and priori experience 63%.

The influence of observation on route diversion may be different with and without other information given. Wardman et al. (1997) shows that visible queues were found to have a significant effect on route choice, particularly for more experienced drivers and those who stated that VMS signs are unreliable.

Al-Deek and Khattak (1998) studied travel time reducing effects of Advanced Traveler Information Systems (ATIS). They used a composite model that combines a traveler behavior model of route diversion and a queuing model. Using a microscopic traffic assignment and simulation technique it assigned travelers to shortest travel time route. Two routes with one origin-destination pair are assumed, and the incident is occurred at one of the routes. Incident-occurred route suffers capacity decreasing.

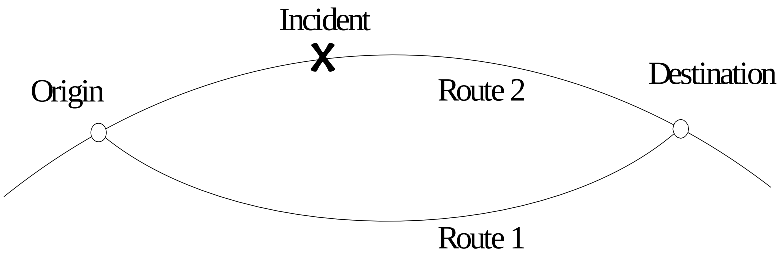

Fig 2. Al-Deek and Khattak (1998)

The benefits of ATIS under incident conditions are expected to be marginal when there is more information available to travelers through their own observation or radio.

Table 2. Results; Al-Deek and Khattak (1998)

Unit: minutes

Scenarios	ATIS market penetration	Travel time	ATIS benefit
Queue Observable	All ATIS (100%)	45.34	4.37
	All unequipped (0%)	49.71	
Queue Unobservable	All ATIS (100%)	43.74	0.12
	All unequipped (0%)	43.76	

3. MODEL SPECIFICATION

3.1 Model Structure

Binary Logit Model is used to model drivers' route diversion behavior.

The dependent variable of binary logit model means whether driver divert route or not. (1-divert; 0-do not divert) Thus, negative parameter means that increase of the variable make decrease route diversion probability.

$$U_{in} = \boldsymbol{\beta}\mathbf{X}_{in} + \boldsymbol{\gamma}\mathbf{D}_{in} + \varepsilon_n \tag{1}$$

where,

n = individual driver

i = route alternative

$\mathbf{X}_{in}$ = route attribute variable vector

$\mathbf{D}_{in}$ = information dummy variable vector

$\boldsymbol{\beta}, \boldsymbol{\gamma}$ = parameter vector

ε_n = disturbance term

3.2 Influencing Variables

3.2.1 Route Attribute Variables

- Travel Time: Travel Time is traditionally regarded as most important factor in driver's route choice behavior or in traffic assignment. It also seems to be important factor in driver's route diversion behavior. In this paper perception travel time of individual driver is considered Travel Time.

- Delay Time: Driver often prefer longer length route with little delay time than shorter length route with considerable delay time. Delay Time is calculated by subtracting Free flow Travel Time from Total Travel Time. Free flow Travel Time is calculated by dividing length of the route by free flow speed, which is assumed 60km/h in highway and 80km/h in freeway.

- Number of Signalized Intersections: Number of Signalized Intersections sometimes is considered as uncertainty term of travel time prediction.

- Number of Turns: Driver feels comfort in simple route than in complex route, because complex route needs harder cognitive process to driver unless the route is very familiar. Driver along the route with large number of turns sometimes has to change lanes more frequently, and turning movement needs more attention than going straight. So Number of Turns is considered as an instrumental variable of the complexity of route.

- Length of the Route: Length of the Route also is representative factor in driver's route choice behavior. It has the advantage of easily observable in comparison with Travel Time.

- Freeway Section Ratio: Driver recognizes freeway and general highway differently. It is based on the accessibility and geometric properties. Freeway section has no intersections so that average speed is higher than general highway with intersections. But when congestion is generated in freeway section by car accident or other reasons, it is hardly dissolved than general highway with intersections because accessibility to the freeway is limited.

- Informed Section Ratio: Most traffic information is not offered fully what driver wants. Usually information about only part of driver's route is offered, and the detail level is limited. If given information explains only small part of driver's route, the information is regarded limited usage. Thus Informed Section Ratio to route may affect driver's route diversion behavior.

3.2.2 Information Dummy Variables

- Information Sources: Variable message system (VMS) and radio are considered as media information. Visible queue is considered as on-site traffic information. In Seoul metropolitan area, VMS displays travel time and traffic condition of specific highway section by letters. Radio information gives qualitative information mainly description.

4. DATA COLLECTION

Data collection is conducted in two stages. First stage is to survey driver's route-choice behavior, and second stage is to survey driver's route-diversion behavior.

4.1 Route-Choice Behavior Survey

For commuting drivers who live and work in Seoul metropolitan region, revealed preference survey was conducted. The purpose of this survey is to gather commuting routes and their attributes data. This survey result is used to find who is suitable for driver's route diversion behavior survey.

- Driver's socio-economic characteristics
- Origin and destination
- Primary commuting route
- Frequently congestion section
- Secondary commuting route (driver can divert this route when congestion generated in the 'frequently congestion section')
- Perceived travel time of each routes

Of the 400 questionnaires, which were distributed, 340 questionnaires were returned. Among them some drivers were excluded in the route-diversion behavior survey because the congestion region is too short or two routes (primary and second) are separated from the beginning.

4.2 Route-Diversion Behavior Survey

The survey of driver's route-diversion behavior was conducted for 134 respondents with tailored SP scenarios by e-mail. SP scenarios are designed by 1/2 fractional design method (Louviere, 2000) using on-site traffic information (visible queue) and media traffic information (VMS, radio) as two main attributes.

Of the 134 questionnaires that were distributed, 70 questionnaires were returned giving a response rate of 52.2%.

Table 3. SP scenarios

	Type I Survey		Type II Survey	
	On-site info.	Media info.	On-site info.	Media info.
1	Queue	None	Queue	None
2	Queue	VMS, congestion	Queue	VMS, accident & congestion
3	Queue	VMS, no delay	Queue	VMS, delay
4	Queue	Radio, accident	Queue	VMS, no delay
5	Queue	Radio, delay	Queue	Radio, congestion
6	None	VMS, accident & congestion	None	VMS, congestion
7	None	VMS, delay	None	Radio, accident
8	None	Radio, congestion	None	Radio, delay

Age distribution of respondents ranges from 24 to 47. Percentage of respondents over 40 is rate; it seems to be caused the survey is not simple for them and conducted by e-mail based.

Table 4. Characteristics of respondents

Sex	Male: 65 (92.8%), Female: 5 (7.2%)
Average Age	30.5
Average Driving Experience (year)	6 years and 4 months

Choice alternatives of route diversion model are defined from the diverging point to destination of each route.

Table 5. Route attributes of two alternatives

	Primary Route	Secondary Route
Travel Time (min)	28.3	33.5
Number of Signalized Intersections	8.9	10.4
Number of Turns	3.1	4.0
Length of the Route (km)	11.1	11.6
Freeway Section Ratio (%)	25.3	16.5
Delay Time (min)	18.1	22.6
Informed Section Ratio (%)	46.0	-

5. MODEL ESTIMATION

The combination of Travel Time, Number of Turns, Freeway Section Ratio, and Informed Section Ratio is revealed statistically significant, and the signs of parameters don't violate priori expectations.

Travel Time variable is revealed most significant among the route attribute variables. The probability to divert routes from primary route to secondary route tend to increase when the difference between Travel Times of the primary route and the secondary route. It is also applied to Freeway Section Ratio, Informed Section Ratio and Number of Turns variables.

The driver seems to prefer the route which is shorter travel time, shorter freeway section ratio and smaller number of turns, when one consider whether divert routes or not. When received traffic information covers larger portion of the route, uncertainty in prediction travel time of the route become smaller, the reliability of the information become higher, and the propensity for driver to divert routes gets stronger.

The positive sign of Freeway Section Ratio means driver tends to avoid freeway when congestion is identified. On the contrary, it is widely understood that driver generally prefer freeway to highway in route-choice behavior. This discrepancy is originated by the geometric condition of the freeway. Entry and exit of freeway are limited, which makes driver not to escape easily from the congested situation generated in freeway. Limited accessibility of the route gives advantages in the point of route choice, conversely, gives disadvantages in the point of route diversion. Thus the preference of route is changeable with driver's decision subjects, in that point, utilizing route-choice model instead of route-diversion model in Microsimulator is unreasonable.

Table 6. Model Estimation Results

Variables	Parameter	T-statistics
Travel Time	0.0964	(6.01)
Delay Time	-	-
Freeway Section Ratio	0.0045	(1.29)
Informed Section Ratio	0.0063	(1.37)
Number of Signalized Intersections	-	-
Number of Turns	0.0892	(2.06)
Length of the Route	-	-
Queue	0.7514	(4.02)
VMS, accident	1.6608	(4.11)
VMS, congestion	0.4514	(1.29)
VMS, delay	-1.5672	(-4.34)
VMS, no delay	-2.5803	(-5.79)
Radio, accident	2.5216	(5.22)
Radio, congestion	0.5611	(1.61)
Radio, delay	0.0517	(0.15)
Number of observations	560	
L(0)	-384.02	
L($\hat{\beta}$)	-276.43	
ρ^2	0.2802	
$\bar{\rho}^2$	0.2489	

The propensity to divert routes by radio information is revealed larger than by VMS information with same information contents. However it does not mean driver relies on radio information more. Practically VMS is located in front of frequently congested point having large traffic flow where congestion level is very high with little variability, so just ‘delay’ information may be regarded as confirmation that the traffic condition is NOT BAD compare to average condition (parameter of VMS-delay variable is estimated negative sign). Thus driver’s reaction is revealed less sensitive on VMS information.

The ‘accident’ information is most effective in driver’s route-diversion; the effectiveness of ‘congestion’ and ‘delay’ information is decreased in sequence. ‘No delay’ information works for driver not to divert routes even there is visible queue.

Parameter of ‘Queue’ is estimated 0.7814, which is between the parameter of ‘accident’ and ‘delay’. It shows that visible queue affect driver’s decision more strongly than ‘delay’ information, and it is too powerful to be ignored.

Relative value of estimated information parameters to Travel Time parameter is calculated in Table 7. It means that increasing travel time such minutes to primary route is indifference each information.

Table 7. Relative Values of Estimated Parameters

Queue	VMS				Radio		
	Accident	Congestion	Delay	No Delay	Accident	Congestion	Delay
7.8	17.2	4.7	-16.3	-26.8	25.2	5.8	0.5

Wardman et al. (1997) analyzed the effect of VMS information with same approach. The result is summarized and compared with above result in Table 8.

Table 8. Comparison the effects of VMS information

Results		Wardman et al.(1997)	
Accident	20.99	Long Delays: Accident	47.44
Congestion	7.92	Long Delays: None	38.37
Delay	-14.90	Delays Likely: None	13.70
No Delay	-26.26	All Clear	-9.9

The reason why the estimation results reported in Table 8 are different is explained by the underlying assumption of data survey used in model estimation process. The data used in Wardman et al. (1997) is surveyed on the assumption of Saturday afternoon trip on given highway network, otherwise in this study data is surveyed on driver's own commuting route and commuting trip. It raises two different properties.

First, the trip purposes are different. In Wardman et al. (1997) the trip purpose is not identified but usually shopping or recreation purpose trips occupy large portion of travel in Saturday afternoon trip. Otherwise in this study the trip purpose is commuting. Generally lateness penalty of driver is greater on commuting trip than on shopping or recreation trip, which is related to driver's propensity not to face a risk that might be brought by diverting routes.

Second, average congestion levels are different. In Wardman et al. (1997) data is surveyed on the assumption of non-peak period; otherwise in this study data is surveyed on the assumption of morning peak period. Usually driver experience heavier congestion in peak period, so stronger stimulus or pressure could be necessary to divert routes in peak period.

6. CONCLUSION

Commuter's route diversion behavior is modeled with real-time traffic information including by binary logit structure. Not only media information but also on-site information is included in modeling. Variable message system and radio traffic information are considered as media information and visible delay is considered as on-site information. Choice models including route attribute variables and information dummy variables were estimated. In this paper, 560 commuters' responses to the real-time information were observed over 8 SP questions. SP survey was accomplished with individually tailored scenarios for actual commuting O-D.

The results show that on-site information has significant influence on drivers' decision to divert routes and the on-site information has effect on drivers' decision to the extents of the accident information through VMS. The drivers' compliance rate by radio traffic information is revealed larger than by the VMS information. The accident information has the greatest influence on the drivers' en-route diversion decision, and 'No Delay' and 'Delays Likely' information through VMS tend to decrease drivers' diversion utility. Among route attribute variables the route travel times, the ratio of freeway length to total length, the ratio of congestion section to total length, and number of turns are statistically significant.

The proposed model can be used to evaluate and analyze the influence traffic information strategies, and to design efficient traveler information system.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to **Engineering Research Institute SNU** by which they are supported, for giving them the opportunity to carry out this paper.

REFERENCES

Al-Deek, H., Khattak, A. and Thananjeyan, P. (1998) A Combined Traveler behavior and System Performance Model with Advanced Traveler Information Systems, **Transportation Research Part A, Vol.32, No. 7**, 479-493.

Ben-Akiva, M. and Lerman, S.R. (1987) **Discrete Choice Analysis**. MIT Press.

Ben-Akiva, M. et al. (1984) Modelling Inter Urban Route Choice Behavior, **9th International Symposium on Transportation and Traffic Theory**, 1984.

Bonsall, P. (1992) The Influence of Route Guidance Advice on Route Choice in Urban Networks, **Transportation, Vol. 19**, 51-73.

Bonsall, P. and Palmer, I. (1998) VMS signs-the importance of phrasing the message. In R. Emmerink, and P. Nijkamp (eds.), Behavioural and Network Impacts of Driver Information Systems, John Wiley, London

Bonsall, P. (2000) Information Systems and Other Intelligent Transport System Innovations. In Hensher, D. and Button, K. (eds.), **Handbook of Transport Modelling**. Pergamon.

Chatterjee, K., Hounsell, N., Firmin, P. and Bonsall, P. (2002) Driver Response to Variable Message Sign Information, **Transportation Research Part C, Vol. 10, No. 2**, 149-169.

Cho, H. (1998) Route Choice Responses to Variable Road User Charges and Traffic Information, Ph.D. Dissertation, University of Leeds.

Econometric Software (1994) **LIMDEP**. Econometric Software Inc., New York and Sydney.

Emmerink, R., Nijkamp, P., Rietveld, Pl and Ommeren, J. (1996) Variable Message Signs and Radio Traffic Information: An Integrated Empirical Analysis of drivers' Route Choice Behaviour, **Transportation Research Part A., Vol. 30**, No. 2, 135-153.

Hall, R. (1993) Non-Recurrent Congestion: How Big is the Problem? Are Traveler Information Systems the Solution?, **Transportation Research Part C, Vol, 1, No. 1**, 89-103.

Hato, E., Taniguchi, M., Sugie, Y., Kuwahara, M. and Morita, H. (1999) Incorporating and Information Acquisition Processing into a Route Choice Model with Multiple Information Sources, **Transportation Research Part C, Vol. 7**, 109-129.

Hensher, D. et al. (1990), Estimating Automobile Utilization with Panel Data: An

Investigation of Alternative Assumptions for the Initial Conditions and Error Covariances, **Transportation Research Part A, Vol. 24, No. 6**, 417-426.

Khattak, A., Schofer, J. and Koppelman, F. (1993) Commuters' Enroute Diversion and Return Decisions: Analysis and Implications for Advanced Traveler Information System, **Transportation Research Part A, Vol. 27A, No. 2**, 101-111.

Lotan, T. (1997) Effects of familiarity on Route Choice Behavior in the Presence of Information, **Transportation Research Part C, Vol. 5, No. 3-4**, 225-243.

Louviere, J.J., Hensher, D.A and Swait, J.D (2000) **Stated Choice Methods; Analysis and Applications**. Cambridge University Press, United Kingdom.

Wardman, M. (1991) Stated preference Methods and Travel Demand Forecasting: An Examination of the Scale Factor Problems, **Transportation Research Part A, Vol. 25, No. 2-3**, 79-89.

Wardman, M., Bonsall, P.W. and Shires, J.D. (1997) Driver Response to Variable Message Signs: A Stated preference Investigation, **Transportation Research Part C, Vol. 5, No. 6**, 389-504.