ANALYSIS OF DRIVERS' ROUTE CHOICE BEHAVIOR USING CAR NAVIGATION SYSTEM (CNS)

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Abstract: The Car Navigation System (CNS) of Advanced Traveler Information Systems (ATIS) provides drivers with the shortest routes using route traffic information. The purpose of this study is to analyze drivers' route choice behavior when the CNS provides the route information. While CNS provides the drivers with the lowest cost route from origin to destination, it has been reported that drivers do not always make use of this information as provided. This paper reports the analysis, which shows that the drivers' route choice behavior is different in terms of drivers' socioeconomic characteristics, trip purposes and a way of using the CNS, etc. In addition, route choice behavior is analyzed in terms of non-drivers' point of views such as types of roads, the level of congestion and the reliability of route traffic information.

1. INTRODUCTION

The Car Navigation System (CNS) of Advanced Traveler Information Systems (ATIS) is a car navigation device using real time route traffic information and electronic map, in which a CD-Rom is installed in the car to reveal the current road navigation status and the shortest routes connecting origin and destination. As the CNS is introduced, the importance of the traffic information, which induces the driver to choose or change the route in order to drive the shortest path, is highlighted. However, several studies have been conducted regarding when the shortest path information is given to the drivers, how drivers react and choose the route - for the application of the CNS.

In this regard, the purpose of this study is to analyze the drivers' route choice behavior when the CNS provides route traffic information. In order to analyze the drivers' route choice behavior, 558 drivers of various types of automobiles such as passenger vehicles, taxis, and trucks, were randomly selected and interviewed from a large, densely populated city in 1988.

First, in this study we've analyzed the differences in the route choice behavior in terms of trip purposes when the CNS provides an unfamiliar route to the drivers before they travel. Second, we've analyzed the differences in using the CNS in the following two circumstances – before the driver travels and when the route provided by the CNS is congested. Third, we've analyzed the difference in the route choice behavior in terms of the drivers' socioeconomic characteristics and their trip purposes. Fourth, we've analyzed the difference in the route choice behavior in terms of drivers' socioeconomic characteristics when the CNS selected route is congested.

2. REVIEW OF PRIOR RESEARCH

In general, the drivers' route choice behavior depends on traffic factors, such as travel distance, time, degree of traffic congestion, demographic characteristics, the driver's psychological, physical, biological characteristics, and past driving experience, etc. (Doo-Won Cha and Peom Park, 1998)

Seung-Ra Moon (1998) established a travel pattern data through surveys using the Probit Model and analyzed the driver's route-changing behavior in terms of traffic information provided by the radio to understand the complex factors affecting the drivers' route-changing behavior. As a result, the drivers' socioeconomic characteristics, travel time, and the number of recognizable routes were revealed as notable. Also, this analysis showed that the more the driver recognizes the routes and the more he likes to find new routes, the higher his/her tendency is to change routes using traffic information. In terms of trip purposes, work related trips rather than other commuting showed higher tendency of changing routes.

Jun-Hwan Hwang (1995), using the Logit Model, analyzed whether there is a difference in the number of changes in routes and starting time in terms of drivers' socioeconomic characteristics, such as age, occupation, education, driving experience, etc., and traffic information characteristics, such as the level of accuracy and promptness of traffic information.

Khattak et al (1993) analyzed the effect of drivers' socioeconomic characteristics, road conditions, traffic conditions and accuracy of traffic information on the drivers' route changing behavior for Chicago automobile commuters. The results were as follows: first, drivers change routes more often during traffic congestion, second, drivers are more inclined to change routes on their way to work rather than on their return trip home, and third, if the drivers are not familiar with the routes provided by the traffic information system, they are less likely to switch their routes.

3. STUDY AREA AND CORRESPONDING DATA

The study area is densely populated with a population of approximately 10.1 million. The number of registered cars is about 2.1 million from which 738 samples of survey data was collected. Table 1 shows the number of registered cars and collected sample survey data by the type of car in the study area. The sample was randomly selected and the survey data

was collected by personal interview.

Table 1. The Number of Registered Cars and Collected Sample Survey Data

Type of Car	Registered Car		Sample Data	
	Number	%	Number	%
Auto	1,669,989	81.4	558	75.6
Taxi	74,761	3.6	90	12.2
Truck	307,154	15.0	90	12.2
Total	2,051,904	100.0	738	100.0

Survey instrument consists of 29 route choice related questions. Sample questions involved factors such as, the drivers' socioeconomic characteristics, trip purposes, the level of necessity of route information by the trip purposes, the type of road, congestion level, alternative route choice behavior under different levels of reliability of the route information etc.

4. ANALYSIS OF ROUTE CHOICE BEHAVIOR USING CNS

4.1 Route Choice Behavior and Trip Purposes

When the CNS provides unfamiliar routes to the drivers before they travel, we set up a hypothesis and verified the Chi-square to analyze the differences in route choice behavior in terms of trip purposes. In addition, the route choice behavior was classified into two cases, first choosing the routes using CNS and second choosing the routes using other traffic information sources.

In the analysis, we marked the item 1 when the drivers used the CNS to choose the routes and 0 when the drivers used other route traffic information sources. The probabilities of using CNS for commuting, shopping, and leisure were 0.75, 0.90, and 0.88, respectively. This result shows that drivers used CNS the most often for a shopping trip purpose. The Chi-square test results show that there is a difference in the route choice behavior in terms of trip purposes, but there are no differences in shopping and leisure trips.

Table 2. Basic Statistics of Route Choice Behavior by Trip Purposes

Trip Purpose	Mean	Variance
Commuting	0.75	0.19
Shopping	0.90	0.08
Leisure	0.88	0.10

Table 3. Chi-square Test Results of Route Choice Behavior by Trip Purposes

Trip purpose		χ^2	Remarks
Commuting	Shopping	50.54	Significantly Different
Commuting	Leisure	33.12	Significantly Different
Shopping	Leisure	2.12	No Difference

In this analysis, we can assume that drivers use CNS more often for shopping and leisure purposes than for commuting. This result could be explained by understanding that when the drivers are commuting, they already have information of various familiar routes connecting their home and work place. Therefore, drivers do not need new information and aren't likely to use the unfamiliar routes provided by the CNS.

Actually, when the drivers are unfamiliar with the routes to which the drivers are about to switch, it is likely that the drivers will avoid the route switch (Khattak, 1993). Meanwhile, it could be deduced that the drivers use the CNS more often for shopping and leisure trip purposes because drivers have less route information of shopping and leisure trips than commuting. In general, while work trips occur every day and their destinations are fixed, shopping and leisure trips are not frequent and their destinations are not fixed. Therefore, the route information provided by the CNS could be quite helpful in choosing the most efficient or shortest routes for shopping and leisure destinations.

4.2 Route Choice Behavior and the Use of the CNS

In this analysis, we've established a hypothesis and verified the Chi-square to analyze the difference in route choice behavior in terms of use of the CNS. The usage of the CNS is classified into two cases, where drivers use CNS before they travel or when the chosen routes are congested.

The analysis shows that 75% of drivers will use the routes provided by CNS before they travel. However, when the routes provided by CNS are congested, 54% of drivers will use the routes. Analyzing CNS usage, we found that the probability of using CNS before starting the car is 0.75 and the probability of choosing a congested route using CNS is 0.54.

Therefore, when drivers use CNS before they travel, they are more likely to use the traffic information provided by the CNS.

Table 4. Route Choice Behavior by the Uses of CNS

Distinction	Mean	Variance	χ^2	Remark
Before Starting	0.75	0.19	45.13	Difference
When selected Routes are Congested	0.54	0.25		

It has been found that when the routes chosen by CNS are congested, the drivers are more likely to use the familiar routes. Although the drivers chose routes using CNS before starting their travel, it is inferred that the reliability of the route information provided by CNS decreased, once those routes were found to be congested.

Also, it has been found that if the reliability of the route information is low, drivers are less likely to choose the routes using CNS. As a result, it is inferred that if the routes chosen by CNS are congested, then the drivers are less likely to use the CNS, because the route information provided is assumed to be less trustworthy.

4.3 Route Choice Behavior and the Drivers' Trip Purposes and Socioeconomic Characteristics

We've analyzed the differences in route choice behavior in terms of trip purposes such as commuting, shopping, leisure trips which are classified into drivers' socioeconomic characteristics and travel conditions. The drivers' socioeconomic characteristics are sex, age, income, and driving experience and travel conditions are travel distance, travel time, the reliability of the traffic information and the degree of route exchange. In addition, these factors are classified into several groups as shown in Table 5.

1) Route Choice Behavior and Sex

The analysis shows that there are differences in the number of male and female drivers using CNS for each trip purpose such as commuting, shopping, and leisure. We have found that while male drivers use the CNS more than female drivers for commuting and shopping trips, female drivers use the CNS more than male drivers for leisure trips. However, the Chi-square test results show that there are no significant differences in the number of male and female drivers using the CNS for each trip purpose.

Table 5. Classification of the Drivers' Socioeconomic Characteristics

Drivers' Socioeconomic Characteristics	Grouping
Sex	Male, Female
Age	Under 30, 30 ~ 39, 40 ~ 49, 50 and over
Income	Under 2 million won/month, 2 million ~ 4 million won/month, More than 4 million/month
Driving Experience	Less than 4 years, 4 ~ 10 years, More than 10 years
Commuting Distance	Less than 10km, 10 ~ 20 km, More than 20 km
Commuting Time	Less than 30 minutes, 30 ~60 minutes, More than 1 hour
Degree of Information Necessity	Necessary, Unnecessary, In Between
Degree of Information Reliability	Reliable, Unreliable, In Between
Usual Route-changing Behavior	Change, Not Change

2) Route Choice Behavior and Age

The analysis shows that there are some differences in route choice behavior between age groups. While the 40 years-old driver group shows the highest probability -0.8- of using the routes provided by CNS for commuting, the 20 years-old driver group shows the lowest probability of 0.69. However, there are no significant differences between other age groups. In cases of shopping and leisure trips, drivers in the 40s show the highest probability of using the routes provided by CNS with 0.93, 0.91, respectively, but there are no significant differences between other age groups.

Therefore, in terms of age, there is a difference in the route choice behavior of commuting, but no difference in the behavior of shopping or leisure trips. We found that the older the driver, the more likely it is that they would use the routes provided by CNS. Drivers in the 40s tend to use the CNS the most, and drivers over 50s have similar route choice behavior with those in the 30s. In this regard, we can infer that this is because the older drivers have more driving experience, thus have more confidence in new routes, and have more auto trips than younger drivers, thus feel more need for traffic information.

Table 6. Information Necessity and Age

Traffic Information Necessity	Less than 30 year-old		30 ~ 39		40~49		Over 50	
	Number of Drivers	%	Number of Drivers	%	Number of Drivers	%	Number of Drivers	%
Necessary	91	72.22	132	76.74	108	76.60	82	68.91
Unnecessary	4	3.17	13	7.56	7	4.96	3	0.54
In between	31	24.60	27	45.70	26	18.44	34	28.57

3) Route Choice Behavior and Income

The analysis shows that there are slight differences in the probability of using the CNS between income levels. We have found that drivers with a monthly income of 4 million Won show the highest probability - 0.76 - of using the CNS for commuting trips. However, the Chi-square test results show that there are no significant differences in CNS use between income levels for commuting trip purposes.

In case of shopping trips, drivers with a monthly income of 4 million won have the highest probability - 0.92 - of using the CNS, but there is no significant difference in using the CNS between income levels for shopping trip purposes.

In case of leisure trip purposes, there is a difference in the probability of using the CNS between income levels. Table 7 shows that the higher the drivers' income is, the more the driver is likely to use the CNS. In the table, 75.86% of drivers with the monthly income of 4 million or more said that they need traffic information. This is higher than the 71.13 % for those with the monthly income of less than 2 million Won. Therefore, we infer that drivers with higher income use routes provided by CNS because they need more traffic information.

Table 7. Information Necessity and Income (1Dollar = 1,200Won)

Traffic Information Necessity	Less than 2 Million Won a Month		2 Million ~ 4 Million a Month		More than 4 Million a Month	
	Number Of Drivers	Percent (%)	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)
Necessary	101	71.13	244	75.08	66	75.86
Unnecessary	8	5.63	13	4.00	5	5.75
In between	33	23.24	68	20.92	16	18.39

4) Route Choice Behavior and Driving Experience

In case of commuting trips, while the probability of using the CNS for drivers with less than four-years driving experience is 0.67, those for drivers with four to ten and more than ten years driving experiences are 0.78 and 0.76, respectively. Although Chi-square test results show the differences in route choice behavior in terms of driving experiences, there is no difference between drivers with four to ten and more than 10 years driving experience.

In case of shopping trips, while the probability of using CNS for drivers with less than four years driving experience is 0.86, drivers with four to ten years driving experiences have scored 0.93. Chi-square test results show the differences in route choice behavior between less than four years and four to ten years driving experience groups. However, there are no significant differences between the rest of the driving experience groups.

Leisure trip cases show that there is a difference in route choice behavior between driving experiences. Drivers with four to ten years driving experience show the highest probability of using the CNS.

In Table 8, 74.85% of drivers with more than ten years driving experience have replied that they need traffic information, compared to 72.41% of drivers with less than four years driving experience. In this regard, it is analyzed that drivers with more driving experience use the routes provided by CNS because they need more traffic information. We infer this is so because drivers with more driving experience are less nervous about new routes and they make trips more frequently, increasing their need for more traffic information.

Table 8. Information Necessity and Driving Experience

Traffic Information Necessity	Less than 4 years		4 ~10 years		More than 10 years	
	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)
Necessary	105	72.41	180	74.38	128	74.85
Unnecessary	8	5.52	8	3.31	11	6.43
In between	32	22.07	54	22.31	32	18.71

5) Route Choice Behavior and Commuting Distance

The analysis shows that while the probability of using the CNS is 0.71 for trips with less than 10Km of commuting distance, the probability of using the CNS is 0.79 for those trips with a commuting distance of 20Km or higher. However, there is no significant difference in the route choice behavior regarding commuting distance.

6) Route Choice Behavior and Commuting Time

Drivers with longer commuting time tend to use the routes provided by CNS more often. As shown in Table 9, while 75.7% of drivers with one-hour or longer commuting time reply that they need traffic information, 71.24% of drivers with less than 30 minutes of commuting time reply that they need traffic information. It is inferred that drivers with longer commuting time tend to use the routes provided by CNS because they need to save travel time.

Table 9. Traffic Information Necessity and Commuting Time

Traffic Information Necessity	Less than 30 minutes		30 to 60 minutes		More than 1hour	
	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)
Necessary	166	71.24	166	76.85	81	75.70
Unnecessary	12	5.15	9	4.17	6	5.61
In between	55	23.61	41	18.98	20	18.69

7) Route Choice Behavior and the Reliability of Route Traffic Information

The Chi-square results show that there is a difference in the route choice behavior in terms of the degree of information reliability for leisure trips, but there are no differences in commuting and shopping trips. Moreover, it is analyzed that drivers who have higher reliability of route traffic information are more likely to use the routes provided by CNS. As shown in Table 10, while 79.55% of drivers who rely on route traffic information need the information, and 73.17% of drivers who don't rely on information need traffic information. Therefore, it is analyzed that drivers who have higher reliability of route traffic information use the CNS more than drivers who have lower reliability of information.

Table 10. Traffic Information Necessity and Reliability of Route Traffic Information

Traffic Information Necessity	Reliable		Unreliable		In between	
	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)
Necessary	245	79.55	30	73.17	138	66.03
Unnecessary	19	6.17	1	2.44	7	3.35
In between	44	14.29	10	24.39	64	30.62

8) Route Choice Behavior Using the CNS and Drivers' Usual Travel Patterns

It is analyzed that the drivers' route choice behavior of commuting using the CNS is affected by the drivers' usual travel patterns such as whether or not the drivers usually

switch routes. However, the drivers' usual travel patterns have no effect on route choice behavior for shopping and leisure trips. Additionally, it is analyzed that drivers who usually change routes tend to use the routes provided by the CNS more often.

As shown in Table 11, while 76.78 % of drivers who have a higher tendency of changing routes need traffic information, 72.33 % of drivers who don't usually change routes need traffic information. Therefore, it is analyzed that drivers who usually change route use the routes provided by CNS because they need traffic information in order to change routes. We infer this is true because drivers who usually change routes need more route traffic information in order to save travel time by choosing the shortest routes.

Table 11. Traffic Information Necessity and Usual Travel Patterns

Traffic Information Necessity	Doesn't Change Routes		Change Routes	
	Number of Drivers	Percent (%)	Number of Drivers	Percent (%)
Necessary	251	72.33	162	76.78
Unnecessary	16	4.61	11	5.21
In Between	80	23.05	38	18.01

In case of commuting, it is analyzed that when the CNS provides unfamiliar routes to the drivers before they travel, there are differences in the route choice behavior according to the drivers' age, driving experience, commuting time, and the usual route-changing patterns. Also, there are some differences in route choice behavior according to the drivers' usual route-changing patterns and degree of information necessity for shopping trips and drivers' income, driving experience, degree of information necessity, and degree of information reliability for leisure trips.

4.4 Route Choice Behavior and Congestion

In the analysis, when routes are congested, we set up a hypothesis and verified it using the Chi-square test results to analyze the route choice behavior in terms of drivers' socioeconomic characteristics. When the routes are congested, there were no differences in the route choice behavior in terms of the drivers' age, income, driving experience, travel distance, travel time, degree of information reliability, and the usual route-changing behavior. However, there were differences in route choice behavior in terms of the drivers' sex and degree of information necessity (see Table 12).

Table 12. Route Choice Behavior and the Drivers' Socioeconomic Characteristics

Drivers' Socioeconomic Characteristics	Characteristics of Drivers Choosing Routes Provided by CNS	
	Using CNS Before Starting	When the Route Chosen by CNS is Congested
Sex	Male	Female
Age	Older Age Group	No Difference
Income	Higher Income	No Difference
Driving experience	Longer Driving Experience	No Difference
Commuting distance	No Difference	No Difference
Commuting time	Longer Commuting Time	No Difference
Degree of Information Necessity	Needs Information	Needs Information
Degree of Information Reliability	Relies Information	No Difference
Usual Route Change Behavior	Usually Changes Route	No Difference

In addition, we have found that female drivers chose routes using the CNS more often than male drivers, because male drivers have a higher tendency to change routes for commuting and business trip purposes. Moreover, in the case of using CNS when the routes are congested, drivers chose the routes using CNS because they need more traffic information. It is inferred that drivers choose the routes according to the degree of traffic information necessity more than by the degree of traffic information reliability.

5. CONCLUSIONS AND FURTHER DIRECTIONS OF THE STUDY

5.1 Conclusion

This study analyzed the differences in route choice behavior in terms of trip purposes and the drivers' socioeconomic characteristics when the CNS provides the route traffic information. First, the probabilities of using the CNS for commuting, shopping and leisure trip purposes are 0.75, 0.90 and 0.88, respectively. However, there are no significant differences in using the CNS by trip purposes. Second, drivers are less likely to use the CNS when the routes provided by CNS are congested. Third, when the CNS provides route traffic information to the drivers, there are differences in the route choice behavior according to the drivers' socioeconomic characteristics.

The degree of information necessity has the highest effect on route choice behavior. Therefore, more drivers use the routes provided by CNS when drivers need route traffic information and rely on the information provided. When the reliability of route traffic information decreases, there are far less drivers who choose the routes provided by CNS. Considering the results, we need to increase the reliability of the route traffic information

provided by CNS and actively publicize ITS so that drivers may acknowledge the necessity of traffic information in order for ITS to operate effectively and widely.

Through this study, we can deduce the driver route choice behavior in terms of the trip purposes, drivers' socioeconomic characteristics, and how the driver reacts to the shortest path provided by CNS. We can also find the drivers' acceptability of ITS and predict the effect of CNS on the driver through the drivers' reaction.

Even though the network assignment model uses real-time traffic volume data, drivers cannot actually take routes assigned by the model because they don't have enough route traffic information and their route choice behaviors are quite different based on trip purposes and drivers' socioeconomic characteristics. Currently, ITS can be considered to provide enough route traffic information to drivers. In this regard, the network assignment model can be improved by considering the drivers' route choice behavior.

5.2 Further Directions of the Study

This study analyzes the route choice behavior of 558 drivers using survey data. Even though ATIS is not fully in practice, we assumed that the CNS was installed in each car. In this regard, this study cannot precisely determine the drivers' route choice behavior using the survey data.

Therefore, when ITS is in operation, we need to analyze the driver route choice behavior in terms of trip purposes and drivers' socioeconomic characteristics and compare that with this study. Moreover, a study needs to be conducted on the network assignment model with regard to CNS to accommodate the future ATIS environment.

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