THE ANALYSIS OF DRIVERS' COMPLIANCE RATE IN CAR NAVIGATION SYSTEMS

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Abstract: The objective of this paper is to see how drivers react and comply with travel information given by traffic actuated car navigation systems. The traffic actuated car navigation systems can deliver real time traffic information and guide the way with both the turn-by-turn voice indication and the visual indication on the digital map. The systems have been applied to all the road networks in Korea but the traffic actuated car navigation systems are mainly applicable to the road networks in Seoul, which has 40 km diameter, including satellite cities. We have investigated to see how drivers comply with such real time information from peak time to non-peak time, from weekdays to weekend. We have obtained a log historical file in which we can analyze provided route, actual route chosen and compliance rate. It was indicated from the result that compliance rate is more likely to be high when trip distance is shorter and traffic congestion is lower. Visual Analysis based on GPS showed that 'route deviation' tend to happen around departure zone during weekdays, while it happen around arrival zone during weekend. 'Route deviation rate" accounted for from 6% to 22% during weekdays but from 5% to 13% on the weekend. This study will be the foundation on route choice reflecting real driver's behaviour by analyzing log historical data presented by SK Marketing and Company.

Key Words: Car Navigation Systems, Compliance Rate, Driver′s Behaviour, Log File for Route Choice.

1. INTRODUCTION

Car navigation system has been widely used by drivers. The market penetration of car navigation system will be expected to rise 46.8% by 2010. It makes drivers find the destination easily and save travel time. Ultimately, it leads to efficient use of roadways for all drivers.

In the past, early car navigation system just offered the shortest path to destination. But recently, it has begun to offer traffic actuated route information considering like traffic congestion, accidents and incidents. However, sometimes such information would be somewhat different from actual route choices made by car navigation users. It occurs reliability decrease of car navigation system drivers.

Ruiqi Ma and David B. Kaber (2007) gave wrong route information step by step (100%, 80%, 60%), and analyzed the reliability of drivers to route information. It is concluded although the accuracy of information falls in geometric, the reliability of drivers to route information falls exponentially. This result means that the reliability of drivers shows a steeper decline than the accuracy of information. In other words, if the level of route information accuracy can't be maintained highly, drivers will disuse car navigation system. To maintain the rate of market penetration of car navigation drivers and for efficient traffic management, the research focused on how drivers react and comply with travel information given by traffic actuated car navigation systems is needed.

This research paper is to make the comparative analysis on provided route by car navigation and actual route selected by drivers, using log historical data presented by SK Tmap Drive. From the log historical data, we analyzed compliance rate and classified it according to days, time period and trip distance. Also, the visual analysis based on GPS data shows the location of route deviation and route deviation rate. From these results, we can rationally infer real driver's behaviours and contribute to development of actuated car navigation system.

2. LITERATURE REVIEW

Several studied have been made route information advice by car navigation. But, in past, most studies assumed full compliance of drivers, that is, all drivers follow route advice of system. Some premised fixed compliance rate (Mammar et al., 1996) others systematically varied on network performance (Srinvasan and Krishnamurthy, 2003).

But, the interest in providing advice is compliance rate; how many drivers follow the received information?

Yin and Yang (2009) tried to increase realism of driver's compliance model. They defined the compliance rate as the probability of the actual time of complied drivers being less than that of non-complied drivers. The results show that the quality of information affects compliance rate. But the congestion has little relationship with the compliance. In this research, we may think that actual response or reaction of driver to advice is very complicated than previous studies.

Although studies have been made on compliance rate, most of them have only conducted SP surveys or constructed imaginary networks to support their opinion. This approach definitely has a limitation, because the number of resources is not enough to reflect overall driver's behaviour. But, recently GPS data started to be used as resources of driver's route choice. We have reviewed literatures using GPS data for analyzing.

Wolf, Guensler, and Bachman (2001) derived trip purpose of drivers from trip speeds and contextual land-use information. It indicates that GPS data can replace traditional diary data entirely. While traditional diary data is used to expect tip start and end time roughly, GPS data can record accurate start and end times of trips and activity locations. Studies also demonstrate that mixture of GPS data and traditional diary data is effective to research driver behaviour.

Doherty and Papinski (2004) showed how GPS data can be used to record a person's activity-travel data. Unlike previous studies, this study dealt with dynamic scheduling model. GPS data and diary information offered contextual information to detect spontaneous activities. It began to use decision-making process comparing planned route with observed activity-trip patterns.

Li, Guensler, and Ogle (2005) investigated 182 subjects over a 10-day period and recorded traveler's route information. With this route information, they concluded that those who have more flexible schedule have a character of having more routes to work. Simultaneously, it seems that those who hesitated frequently during their commute also have multiple routes.

Doherty and Papinski (2007) compared information on the planned and observed route choices for the home-to-work commute using a geographic information system (GIS) and geographical positioning system (GPS). GIS recorded the planned rout information with the route planning sequence and GPS observed the actual route of drivers. It said that short-trips are easier to deviate from the planned route and the survey proved that minimizing

travel time is the first consideration to choose their route. But only thirty-one individuals participated in this study for 2 days, this number of participants could be insufficient to conclude their opinion and apply to real world.

But, in spite of those GPS investigation, there has been no studies tried to reflect sufficient data to reflect overall driver's behaviours and geographical character. The character of driver compliance would be different depends on drivers or locations. To consider all, the more number of data and more detailed information including the location of route change, the trace of cars are required. SP survey, imaginary networks and GPS investigation conducted until now can't satisfy those conditions. But, log historical data includes 557,780 requests of drivers on December, 2009 and information of route like the trace of cars, the location of route deviation and so on.

In this study, we will analysis compliance rate of drivers and classify if according to many conditions and compare previous studies like; do short trips show high deviation rate?

3. METHODOLOGY

3.1. Data

This paper analyzed the traveller's behaviour using log historical data presented by SK Tmap Drive. Fig 1 shows the information processing when drivers deviate from the route in SK Marketing and Company. For those processing, the log historical data is accumulated.

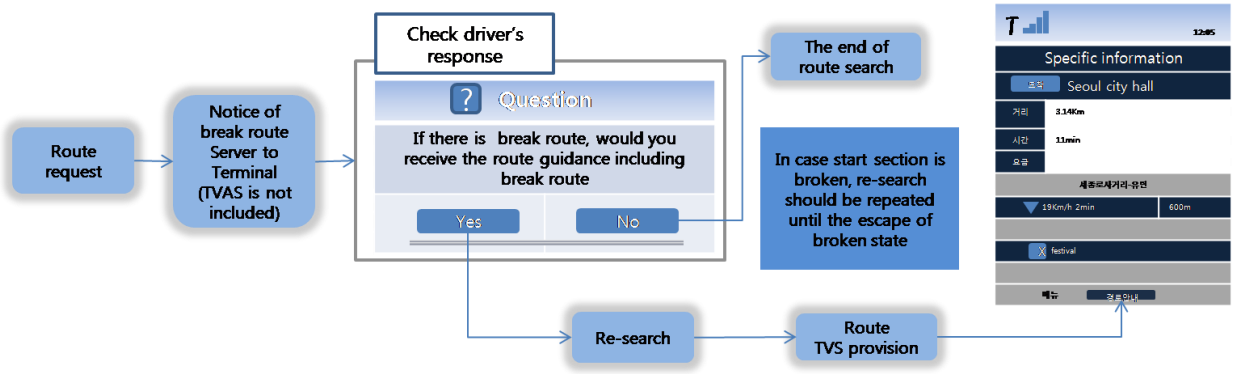

Fig. 1. The Process of information in route changes

Log historical data makes it possible to compare 'navigation recommending route' with 'drivers selecting route' in the Fig2. And, such data gives an easy access to detect the location of route deviation. This provides the novel approach to improve route information.

Classification	ID	Destination	Route distance (m)	Rout time forecasting based on real traffic situation(sec)	Rout time forecasting based on real traffic situation and traffic pattern (sec)
Suggested route information	91392874	Gochuk-dong in Kuro district, Seoul	29706	3455	3151
Real route information	91392874	Gochuk-dong in Kuro district, Seoul	26856	3112	3042

Fig2 Log Historical data

The range of time on log historical data is 9th December 2009 and 13th December 2009. Each includes 12,147 and 13,985 requests of route information from drivers respectively. Totally, the sum of request is 26,143 requests and spatial rage of log historical data is Ant the rage of space on log historical data is Seoul Metropolitan areas.

3.2 Algorithm for searching optimal route.

The process of route searching of SK Tmap Drive is based on A* Algorithm. A* Algorithm is one of graph/tree-searching algorithm, which searches lowest cost route from the origin node to destination. This algorithm was described by Peter Heart, Niles and Berthlam Label, in 1968 for the first time. With appropriate Heuristic-based algorithm, it is rendered optimal. Thus, this is called as A * Algorithm.

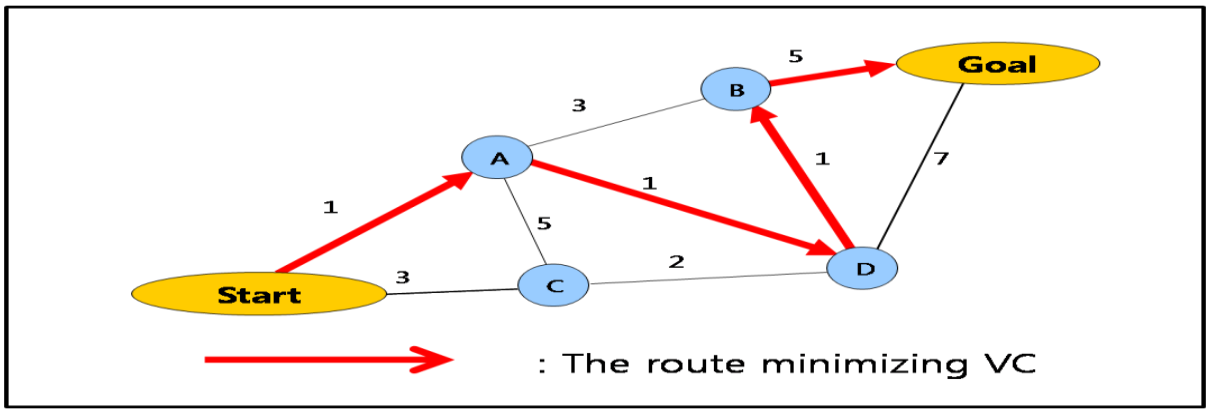

Fig. 3. the illustration of A * algorithm

As the Fig 3, the optimal route is generated searching for the route minimizing VC (Virtual Cost). The basic procedure of making LC (Link Cost) is to utilize travel time of link. To estimate VC appropriately, LC is needed and some values needed to be added like road

grade factor, geographical structure (Server factor) and direction (Logic factor). The formula of VC is as follows

$$\mathrm{VC} = \mathrm{LC\ (the\ lengh\ of\ link)} \times \mathrm{Road\ grade\ Factor} + \mathrm{Server\ Factor} + \mathrm{Logic\ Factor} \qquad (1)$$

To detail VC algorithm, case study was examined. On the next figure 5, this shows how VC is calculated. In Seoul, Namsan tunnel is operated toll-charged way. In this case, there are two ways drivers can select. To pass Namsan tunnel by paying the toll fee or detour Namsan tunnel without paying. VC is the efficient way to provide decision to drivers which route is the best way for drivers. Link cost is calculated dividing link length by travel speed. Travel speed is provided based on actuated traffic information. Road grade weight, total trip length weight, entrance/exit weight and optimum cost weight are determined by SK M&C's algorithm.

Fig. 4. VC comparison between two selection of driver

Table3.The Comparison of VC according to the selection of Namsan Tunnel

Type	Pass Namsan Tunnel		Detour Namsan Tunnel	
The road type	Tunnel	Local Road	Tunnel	Local Road
Link Length (m)	1600	500		4010
Travel Speed(km/h)	28	9	30	9
Link Cost	205	200		1604
Road Grade Weight	1.4	1.55	1.4	1.55
Total Trip Length Weight	252		481.2	
Entrance/Exit Weight	60		-	
Optimum Cost Weight	840		-	
VC	1,750		2967.4	

3.3 Methods

Based on Log historical data, compliance rate and route deviation can be analyzed and classified according to days, time period and route distance. Route deviation is the ratio of travelled distance to straight-line distance. This index shows how much driver prefer shortest distance or optimized distance fitted for them.

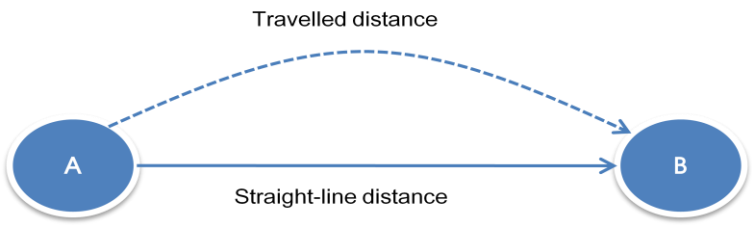

Fig. 5. VC the illustration of route deviation

The detailed classification criteria of route distance are placed as follows: Route distance was defined as follows: short distance as of 0-10km, middle distance as of 10-30km and long distance as of more than 30km. Compliance rate and route deviation will characterize drivers' behaviour on the basis of route distance, day and time period. Survey was also

conducted to analyze and supplement the weakness of existing car navigation system whose result will help to rise compliance rate for specific cases.

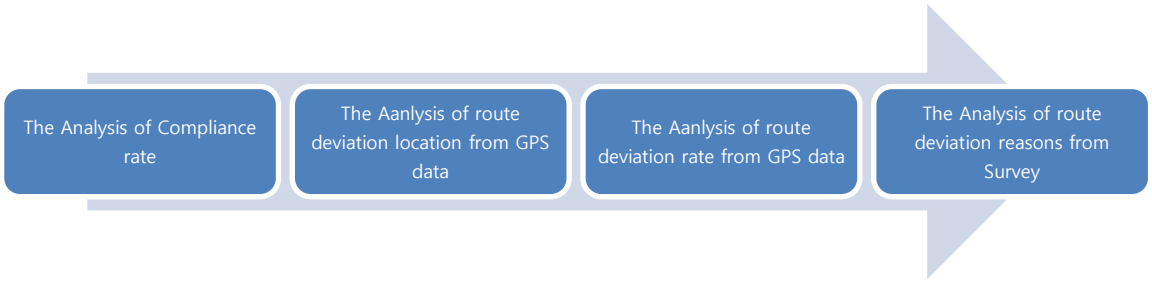

Fig. 5. the method in this study

4. RESULTS

4.1 Compliance rate

From the log historical data, the compliance rate was analyzed according to time period (peak on weekday, non-peak on weekday and weekend) and trip distance (0~10km, 10~30km, over 30km) In contrast to previous researches and studies, the result of this study shows that compliance rate is more likely to be high when trip distance is shorter. Previous researches and studies reported that route choice is influenced by previous knowledge of driver. As the drivers of short trips have more local knowledge, they tend to deviate frequently more than drivers of long trips. But, Log historical data demonstrates the sharply-contrasting results. That's because long trip commuters from satellite cities to Seoul are more influenced by geographical conditions like access zone of main road, the Han River Bridge more than in-Seoul commuters. Compliance rate rendered higher in non-peak hours compared to peak-hours. The reasons are estimated for difference between route purpose and traffic volume. In peak-hours, trip purpose of most drivers is for commute and traffic congestion and signals makes them sensitive to their route choice. By contrast, in non-peak hours, trip purpose is varied and relatively less influenced by traffic sign and volume, compared to peak-hours. Table1 summarizes compliance rate in various situations.

Table. 1 Compliance rate according to trip distance, time period

.	Average	0~10km	10~30km	Over 30km
Weekly Peak	68%	76%	65%	65%
Weekly non-peak	73%	79%	68%	70%
Weekend	69%	75%	65%	68%

4.2 Route deviation location

Route deviation location was analyzed and classified according to time period (peak on weekday, non-peak on weekday and weekend) and trip distance (0~10km, 10~30km, over 30km) through visual analysis based on GPS. Table 2 shows the result of route deviation location on the basis of a variety of situations.

The table 2 Frequency of route deviation per time and distance

	Total		**0~10KM**		**10~30KM**		**Over 30KM**	
Hours	Route Deviation Zone	Deviation Figure (per km)	Route Deviation Zone	Deviation Figure (per km)	Route Deviation Zone	Deviation Figure (per km)	Route Deviation Zone	Deviation Figure (per km)
weekly Peak Hours	Departure 51	***5.1***	Departure 4	0.4	Departure 34	***3.4***	Departure 13	1.3
	Middle 106	1.325	Middle 17	0.2125	Middle 64	0.8	Middle 25	0.3125
	Arrival 30	3	Arrival 5	0.5	Arrival 19	1.9	Arrival 6	0.6
weekly Non-Peak Hours	Departure 57	***5.7***	Departure 14	1.4	Departure 21	***2.1***	Departure 18	1.8
	Middle 103	1.2875	Middle 43	0.5375	Middle 42	0.525	Middle 18	0.225
	Arrival 33	3.3	Arrival 4	0.4	Arrival 17	1.7	Arrival 12	1.2
Weekend	Departure 15	1.5	Departure 3	0.3	Departure 5	0.5	Departure 7	0.7
	Middle 62	0.775	Middle 21	0.2625	Middle 31	0.3875	Middle 10	0.125
	Arrival 21	***2.1***	Arrival 3	0.3	Arrival 12	***1.2***	Arrival 6	0.6

Route deviation near the departure zone is defined that drivers deviate from the route within 10% of total route distance from the departure zone. End route deviation is defined that

drivers deviate from the route within 10% of total distance from the arrival zone. Route deviation happened more frequently around departure zone on the weekdays. Fig 5 show the reason of route deviation, most drivers who deviate near departure zone, have a tendency selecting different access point of main road from the access point provided by car navigation. Conversely, on the weekend, the result was opposite. Route deviation happened around arrival zone. The drivers for travel or leisure have little knowledge around arrival zone. The analytic result was founded on travelling or leisure-targeting drivers who had a lack of information of arrival zone. The visual analysis based on GPS showed they miss the exit of expressway, or find wrong destination around landmark.

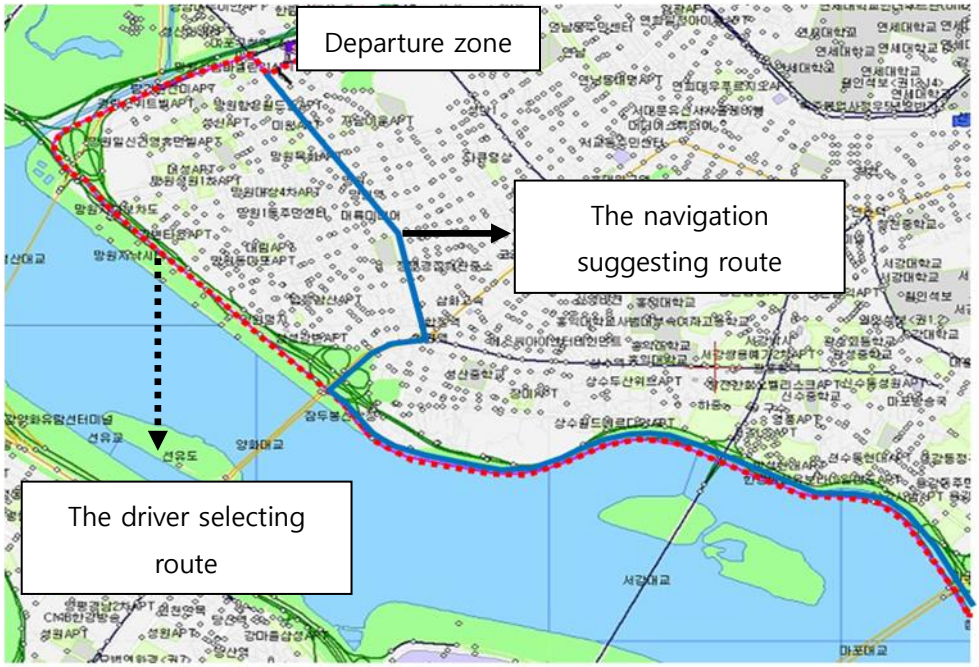

Fig. 6. The route deviation near departure zone; the problem of main road access

4.3 Route deviation Rate

Route deviation rate is defined the ratio of distance of driver selecting route to navigation suggesting route. This index indicates how much drivers detour the route provided by car navigation system.

$$\text{Route deviation rate} = \frac{\text{The distance of drivers selecting route}}{\text{The distance of navigation suggesting route}} \quad (2)$$

The following results were obtained. On weekdays, the drivers have a tendency to deviate from the route provided by car navigation system more than drivers on the weekend. The deviation rate of drivers on the weekday rages from 6% to 22%, while the drivers on the weekday rage from 5% to 13%. The cause of these results is due to the change of traffic condition. In peak time, most drivers are sensitive to traffic congestion, signals while in non-peak time. Also, these results reveal that route deviation in departure zone influences the overall route from origin to destination, meanwhile, the route deviation in arrival zone have a small effect on whole trip distance.

The table 3 route deviation rate of weekdays and weekend

	Average	Standard Deviation	Range
Weekdays	1.08	0.14	0.94~1.22
Weekend	1.04	0.09	0.95~1.13

4.4 Route Choice weigh

We could know that route deviation near departure zone occurs more frequently and have a strong impact on overall trip distance. Therefore, modifying values used in car navigation route choice system should be required. By modifying them, we could improve compliance rate of drivers. Modified values would be different following to the situations like time period, trip distance, the location of route deviation. We conducted survey to set the appropriate weigh of road grade, server factors and logic factors. The survey represented that road grade is most important factor to determine the route accounting for 48%. The following values are logic factor and server factor accounting for 27%, 25% respectively. In conclusion, to improve the compliance rate of drivers, road grade should be considered more important.

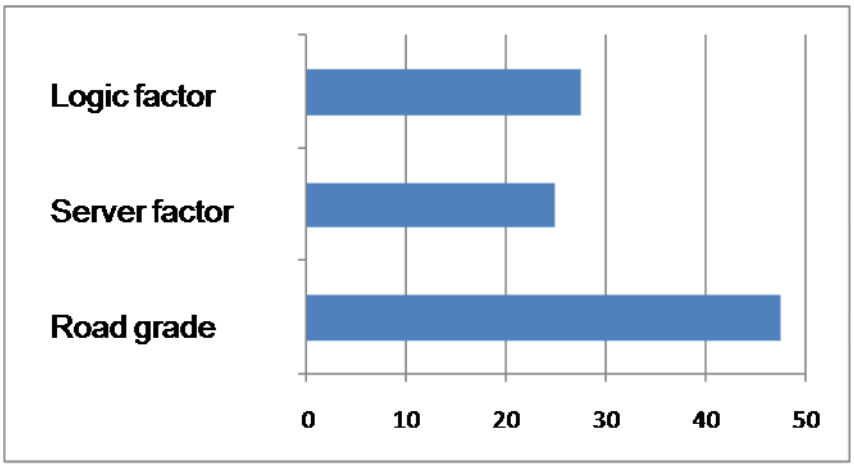

Fig. 7. The survey of values used in car navigation system.

5. SUMMARY AND CONCLUSIONS

The objective of this research paper is to see Compliance Rate of car navigation users., and find out ways to improve Route Information. Previous research and study focused on surveys, imaginary networks and small number of participants. But in this study, we use log historical data presented by SK marketing and company. From this data, we could get compliance rate, the location of route deviation and the route deviation rate. Compliance rate is in inverse portion to trip distance unlike previous researches. Previous research assumed that short trip drivers have more local knowledge. But in real, long trip drivers are influenced by geographical conditions like access like access zone of main road, the Han River Bridge, thin road. And also, time period also influences compliance rate. The more drivers are free of traffic intervention, the higher compliance rate is. Route deviation happened more frequently around departure zone on the weekdays. Drivers knew the local knowledge around departure zone and various routes to destination. Conversely, on the weekend, route deviation happened around arrival zone. The drivers have a tendency to deviate from the route provided by car navigation system on the weekdays more than drivers on the weekend. The deviation rate of drivers on the weekday rages from 6% to 22%, while the drivers on the weekday rage from 5% to 13%.The survey represented that road grade is most important factor to determine the route accounting for 48%. The following values are logic factor and

server factor accounting for 27%, 25% respectively. This paper will be foundation of route choice study reflecting travellers' with realistic log historical data. Further study on car navigation system automatically considering the character of travellers, time period, trip distance will be performed. Ultimately, it increases the level of route information and the credibility of drivers.

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