ORDERED PROBIT MODEL OF THE SPEED SELECTION BEHAVIOR : RESULTS BASED ON A KOREAN MICRO DATA

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Abstract : Many studies on drivers' speed selection behavior have been reported in the last decade. Most previous studies have, however, concentrated on the relationship between drivers' speed selection and road/vehicle characteristics without considering other important factors such as personal characteristics and drivers' perception of speed limit. This paper analyzes Korean drivers' speed selection behavior by taking into account such factors as trip characteristics in addition to personal, vehicular, and attitudinal factors. Speed selection behavior is measured by a categorical measure over speed limit, and an ordered probit model is used to econometrically estimate the speed behavior equation.

1. INTRODUCTION

Mohring (1965), who estimated the value of time for travel has reported numerous studies in the literature on speed selection behavior since his pioneering work. Most previous studies of driver's speed selection behavior have, however, focused on the relationship between speed choice and speed limit, road characteristics, and vehicle types without considering personal characteristics and trip purpose. Also McFarland et al.(1987) investigate the value of travel time for drivers, vehicles, and passengers.

Recent studies by Jorgensen (1983, 1991), Jorgensen and Polak.(1993), Wasielewski (1984) and Rienstra and Rietveld (1996) include detailed variables for speed selection in analyzing driver behavior such as attitude for speed selection. Their studies are limited for practical use, however, because they use only limited variables for driver characteristics. They ignore vehicular characteristics such as safety features for vehicles. In general, speed selection behavior is determined by the combination of physical characteristics of roads, vehicles, and traffic conditions as well as trip purpose. For a given set of road and traffic conditions, speed selection behavior should be determined by the characteristics of vehicles and drivers, including trip purposes. Actually, we can easily infer the importance of those factors from different speed distributions on the same road segments at the same time. In order to analyze speed selection behavior comprehensively, we, therefore, should include various factors not only on traditional physical conditions of roads but also on vehicle and driver's characteristics.

Exceeding the speed limit is one of the most important factors in traffic accidents. This is well known, even though the recent experiences of speed limit increase in the USA show some significant reductions of traffic accidents. Traffic accidents are one of the most serious economic and social losses in modern society. Also, traffic accidents cause massive

traffic congestion in urban areas. Therefore, various factors such as physical characteristics of roads and drivers behavior should be investigated in order to set the optimal speed limits. The main purpose of this research is to study driver's speed selection behavior in Korea using various combinations of variables including vehicles and characteristics of roads and driver's and trip conditions. Target groups are restricted to automobile drivers during off-peak hours because the morning and afternoon peak hours in urban area have severe traffic congestion during which driver's desired speed can not be achieved.

This paper has five sections. The first and second section introduce speed selection behavior and literature review of speed selection models. Section three discusses our survey methodology and data collection method. Section four will summarize estimation results of ordered probit analysis for speed selection behavior and provides some international comparisons. Finally, concluding remarks and some suggestions for further studies follow.

2. SPEED SELECTION MODEL

After a careful review of the existing literature, we have decided that an economic model for speed selection behavior suggested by Jorgensen and Polak (1995) is suitable for our purpose. In their model, drivers are subjectively rational, risk neutral, and utility maximizing agents. We also assume that driver's speed selection is determined by trip time, safety consideration, expected speed limit, and speeding ticketing costs. Under these assumptions, the drivers choose their speeds to minimize total travel costs taking into consideration of the existing conditions described above.

To investigate the effect of speed selection behavior in Korea, ordered probit models were estimated. This model was selected because of its ability to analyze ordered categorical response data, that is, the response to select speed to maximize net benefits which is defined expected benefits minus expected related costs for given speed. The ordered logit model was also considered for estimation, however, in practice the two formulations give very similar results and therefore the ordered probit model, where the error term is normally distributed, was selected.

In estimating the speed selection behavior of Korean driver model, we have take into account the fact that our speed measure is an ordered with three categories (0=observe speed limit, 1=speeding over 0-10Km/hour, 2=speeding 11-20Km/hour). The ordered probit model analyzed the effect of various factors on the propensity to select speed behavior decisions. It uses the following form:

$$y^* = \beta' x + \varepsilon \qquad \cdots\cdots(1)$$

Where y* is the propensity to use a particular type of information, β is the vector of estimated parameters and x is a vector of independent variables and ε is the usual error term which is normally distributed with zero mean and unit variance). Also, cumulative distribution denoted by $\Phi(\bullet)$ and density function denoted by $\phi(\bullet)$. As mentioned before, The dependent variables are the actual observed speed which is measured on a three-point scale ranging from below or observed speed limit(coded as 0) to speed over 10-20Km/hour (coded as 2). An individual falls in category n if $\mu_{n-1}<y^*<\mu_n$ and μ_n are thresholds where n=0,1,2.
With the normal distribution, we have the following probabilities:

$$\begin{aligned} \Pr ob[y=0] &= 1-\Phi(-\beta' x), \\ \Pr ob[y=1] &= \Phi(\mu-\beta' x)-\Phi(-\beta' x), \\ \Pr ob[y=2] &= 1-\Phi(\mu-\beta' x). \end{aligned} \qquad \cdots\cdots(2)$$

For the three probabilities, the marginal effects of changes in the regressors are;

$$\begin{aligned} \frac{\partial \Pr ob[y=0]}{\partial x} &= -\phi(\beta' x)\beta, \\ \frac{\partial \Pr ob[y=1]}{\partial x} &= [\phi(-\beta' x)-\phi(\mu-\beta' x)]\beta, \\ \frac{\partial \Pr ob[y=2]}{\partial x} &= \phi(\mu-\beta' x)\beta. \end{aligned} \qquad \cdots\cdots(3)$$

Computation of marginal effect is particularly meaningful for the ordered probit model where the effect of variables x on the intermediate categories is ambiguous if only the parameter estimates are available.

3. DATA COLLECTION METHOD

3.1 Data Collection

For our model, we need two types of data sets, namely, speed data that are measured in the survey segment of road, and the characteristics of drivers, roads, vehicles, and trip purposes.

Speed can be measured by using video cameras and detectors. In order to obtain personal data for drivers, however, drivers must be stopped and interviewed in the middle of road. In some other studies, police assistance is required in order to conduct field interviews and license matching program. In our study, however, we have ruled out the police assistance, because driver's speed selection behavior can be significantly modified when police appear. At the same time, license-matching method can not describe the exact driver and passenger. The vehicle registrations only show the owner of the vehicle.

In order to avoid such difficulties, we have selected four lanes of each direction of a 1.2Km restricted access road section in the city of Ansan. Ansan has approximately half million population and is one of the first planned major industrial cities in Korea. In the surveyed section of road, two speed limit(70Km/hour) traffic signs were installed. During the survey period, no police were present or visible for speeding control. Below [Figure 1] shows the survey section of the road.

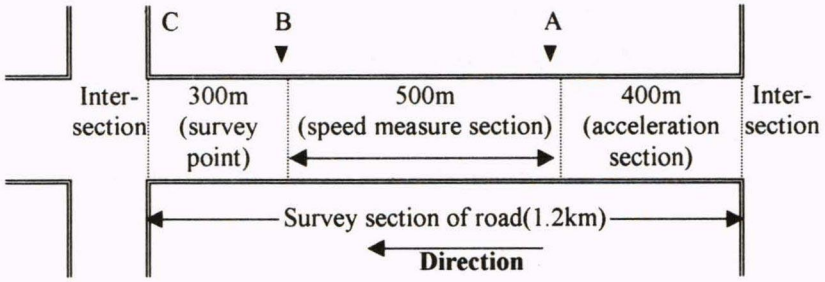

Figure 1. Description of Road Section

The speed of vehicles was measured between point A and point B. At point A, vehicle license plates were recorded in order to make sure that the same vehicle is surveyed at the point B. Then, field interviews were conducted at the point C, where vehicles are stopped at red traffic signal for approximately 100 seconds long.

The field survey consist of 18 questions, among which four questions are recorded by interviewers about license number, sex, occupancy, and seat belts. The remaining 14 questions for the characteristics of drivers, vehicles and trip purposes are collected from the interviews with drivers. The survey was conducted from June to August in 1997 where four different distinct characteristics of roads. The weather in all those days was sunny. Survey time was selected from 10:30 AM to 5:00 PM in order to collect various trip purposes. A total of 2,889 vehicle speed observations and 769 field interviews were collected. After a careful review of vehicle speed data and field data, 581 observations were selected for our analysis in speed selection behavior. Below [Figure 2] shows the usable observation selection procedure.

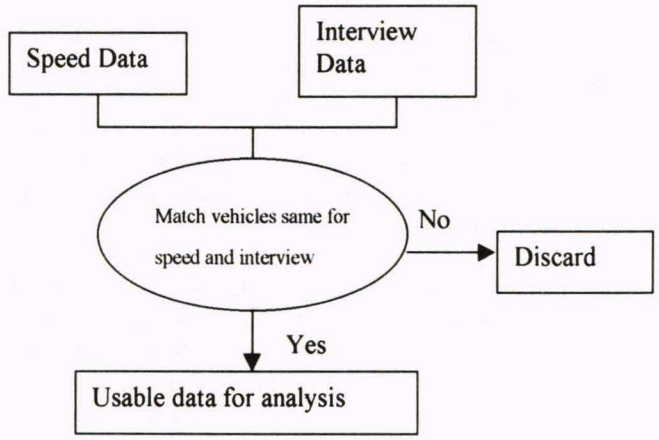

Figure 2. The usable data selection procedure

3.2 Descriptive Statistics

As indicated earlier, data sets for driver's speed behavior consist of four major components: The first component shows personal characteristics of drivers such as age, sex,

driving experiences, monthly income, and the past experiences of accidents. The second component includes vehicle and safety characteristics such as the nature of insurance (full, partial and no insurance), horsepower, seat belt, airbag, anti-lock brake, power steering and automatic transmission. The third component records trip characteristics such as trip purpose, urgency of trip and accompanying passenger. Table 1 shows the summary of survey of speed selection behavior data.

Table 1. Summary of survey

Sample Attributes			Frequency(%)
Personal Characteristics	Sex	Male	91.8
		Female	8.2
	Age	18-29	17.6
		30-39	48.2
		40-49	24.0
		50-59	7.9
		60 plus	2.3
	Driving Experience	Below 5 years	39.7
		5 ~ 10 year	38.4
		over 10 years	21.9
	Education	Middle school	5.9
		High school	43.5
		University	50.6
	Monthly income	Up to 200 M. won	58.2
		200 ~ 350 M. won	33.5
		350 M. won plus	8.3
Vehicle And Safety Features	Seat belt	No	78.0
		Yes	22.0
	Ownership	Own	80.4
		Company owned	16.1
		Others	3.5
	Horse-power	Up to 1500cc	15.4
		1500-2000cc	53.2
		2000cc plus	31.4
	Safety features	0	17.0
		1	46.7
		2 plus	36.3
Trip Characteristics	Trip distances	Up to 20km/day	9.2
		20 km ~ 49km/day	23.5
		50 km ~ 100km/day	30.6
		100 K	36.7
	Trip frequency	Up to 15/month	52.0
		15 ~ 30/month	26.0
		30/month plus	22.0
	Occupancy	1 person	67.7
		2 person	25.4
		3 person plus	6.9
	Trip purpose	Business	89.0
		Non-business	11.0
Driver's Perceptions of Enforcement	Expectation of Enforcement	Yes	75.2
		No	24.8
	Expectation of Penalty	Up to 10 points	25.9
		11-20 points	58.0
		20 points plus	16.1
	Desired Speed limit	Up to70km/h	17.7
		71km/h ~ 85km/h	64.1
		86km/h ~ 100km/h	5.9
		100km/h plus	12.3

4. ESTIMATION RESULTS

The model specifications explored the effects of following various factors on speed selection behavior of Korean drivers:

A personal characteristic effects on speed selection behavior.
Vehicle and safety characteristics of speed.
Trip characteristics.
Perceived likelihood for speeding.

Table 2 shows estimation results for speed selection behavior of Korean drivers. They also display the marginal effects of changing variables from personal characteristics to perceived likelihood of enforcement and penalties for speeding. Dependent variable variables are speed selection behavior, which is categorized for three levels. A positive sign for the estimated parameter indicated propensity to speeding. The signs of the parameters β are intuitively reasonable and their magnitudes are plausible.

Table 2. Ordered probit model of speed selection behavior of Korean drivers

Variables		β	t-statistics	Marginal effects		
				(y=0)	(y=1)	(y=2)
Constant		-1.8477*	0.6590	0.4412	-0.0995	-0.3416
Sex dummy(mail=1, female=0)		0.5055	0.3965	-0.1207	0.0272	0.0935
Driving	5 ~ 10 years	0.8442*	0.2430	-0.2016	0.0455	0.1561
	10 years plus	1.2523*	0.3300	-0.2990	0.0675	0.2315
Monthly income	200 ~ 350M won	0.2057	0.2702	-0.0491	0.0111	0.0380
	300M. won plus	0.2585	0.3610	-0.0617	0.0139	0.0478
Horse-power	1500cc ~ 2000cc	0.0405	0.2300	-0.0097	0.0022	0.0075
	2000cc plus	-0.5179*	0.2584	0.1237	-0.0279	-0.0958
Safety Features	2 ~ 3	-0.0227	0.2134	0.0054	-0.0012	-0.0042
	4 plus	-0.8112**	0.4160	0.1937	-0.0437	-0.1500
Occupancy	2 person	0.2919	0.2175	-0.0697	0.0157	0.0540
	3 person plus	0.1569	0.3426	-0.0375	0.0085	0.0290
Age	35 ~ 44	-0.0998	0.2168	0.0238	-0.0054	-0.0185
	45 ~ 64	0.1855	0.2939	-0.0443	0.0100	0.0343
Education	High school	0.1164	0.4422	-0.0278	0.0063	0.0215
	University	-0.0201	0.4412	0.0048	-0.0011	-0.0037
Ownership of car		-0.0432	0.2392	0.0103	-0.0023	-0.0080
Trip Distances	20 ~ 100km/day	0.7035*	0.3407	-0.1680	0.0379	0.1301
	100km/day plus	0.6826**	0.3797	-0.1630	0.0368	0.1262
Frequency	15 ~ 30/month	-0.2594	0.2020	0.0619	-0.0140	-0.0480
	30/month plus	-0.3340	0.2633	0.0797	-0.0180	-0.0618
Expectation of enforcement		0.6634*	0.2041	-0.1584	0.0357	0.1226
Desired speed limit		0.4770*	0.1166	-0.1139	0.0257	0.0882
μ_1 (Threshold)		1.5570	0.1118			
Summary statistics						
Log likelihood at 0		-526.07				
Log likelihood at convergence		-491.91				
Rho squared		0.0649				
Number of observations		485				

4.1 Personal characteristics of speed

In our sample, male drivers account for about 90%. In order to make sure that our sample represents national average, we compared our values with national averages. Nationwide, female drivers account for almost 23%, which are much higher than the 10% of female drivers in our sample. Since the number of female driver licenses are generally much greater than actual drivers in road, it is reasonable to assume that the sex distribution in our sample does not significantly deviate from the national average.

Other things being equal, male drivers drive faster than female drivers do. This result implies that female drivers generally show greater responsibility for the care and welfare of other family members and/or passengers than male driver does. In terms of driving experiences, drivers with 10 years and more driving experiences drive faster than any other categories. This behavior also confirmed by marginal effects such as 0.0675 and 0.2315 which is clearly higher than 0.0455 and 0.1516 respectively. Regarding to educational level, drivers with higher education tends to drive carefully than drivers with less education, which is confirmed by marginal effects.

4.2 Vehicle and safety characteristics of speed

Among four variables, horsepower of vehicles and an index (airbag, ABS, power steering and automatic transmission are indexed according to their existence so that the index ranges from 0 to 4) of safety features are statistically strongly significant for speed. As unexpected, vehicle with a greater horsepower tends to travel faster. Also, other things being equal, the less safety features there are, the higher the speed is. This unexpected speeding behavior can be explained that higher value of human life has more safety features and more horse-powered vehicles. Obviously, the more horse-powered vehicle has the higher safety features such as ABS and airbag. This results are quite important policy implication such that the less safe vehicles tends to the higher speeding behavior which has the higher severe traffic accidents.

4.3 Trip characteristics

Regarding the trip characteristic variables, trip distance is statistically significant factors for speed selection behavior. The longer trip distances the higher speed. Even though statistically not significant, trip frequency of the road indicated that drivers with the more use of the road so the familiar of the road characteristics tends to drive carefully than drivers with less knowledgeable of the road. This trends also increase the probability of traffic accidents.

4.4 Perceived likelihood for speeding

Among the perceived aspects of speeding such as likelihood of being caught for speeding, expected financial loss for speeding, and perceived speed limit for the section of road, perceived speed limit of road and likelihood of being caught for speeding are statistically a significant factor for speed selection behavior. Ironically, drivers with speeding have higher expectation to being caught. Despite that drivers with speeding already knows that

he/she is violating speeding law but he/she did not reduce speed which another factors for higher accident risks.

4.5 International Comparisons

The speed selection behavior of drivers is a combination of different variables as we mentioned above. Also, different cultural factors in different countries contribute the speed selection behavior. In order to compare our results with studies for other countries, we have selected research done by Wasielewski (1984) for the United States of America and Jorgensen and Polak (1993) for Norway.

In a study done in Michigan, Wasielewski (1984) used a simple index for the safety feature for speed selection behavior. In his study, two lanes of road of 800m length were observed for 20 days. The speed was obtained by video and then matched with two license plates. The characteristics of drivers were obtained from vehicle and driver registration information. The methodology used in his study is a general linear model by using speed as the dependent variable and other information for drivers as independent variables.

In a study done in Norway, Jorgensen and Polak(1993) developed an economic model for driving behavior between speed limit section and no speed limit section. The sample was collected in 2.8Km, 0.2Km and 0.7Km section of road adjacent to Oslo. Speed data were obtained on site and driver information was collected by field interviews for 2 days.

Table 3 shows the comparison between our study and Wasielewski (1984). It is difficult to make a direct comparison because of different sets of data used. However, variables for the past experiences of accidents and passengers show opposite results. The past experiences of accidents in the USA indicate that the more past experiences of accidents accompany a higher speed. Also, the number of passengers in vehicles has a negative impact to the speed selection.

Table 3. Comparison between USA and Korea

VARIABLES	U. S. A. (1984)	KOREA (1996)
Experiences of accidents	+	-
Number of passengers	-	+
Sample Size	2,632	581

Table 4 shows the comparison between our study and Jorgensen and Polak (1993) in Norway. Variables such as age, sex, experiences of drivers and trip urgency are similar aspects both Norwegian and this study. However, variables such as expectation of police and expected financial loss being caught for speed are opposite signs in Norway and our study.

Table 4. Comparison between Norway and Korea

VARIABLES	NORWAY (1993)	KOREA (1996)
Age	Not Significant	Not Significant
Sex	Not Significant	Not Significant
Experiences of Drivers	+	+
Trip Urgency	+	+
Expectation of Police	Not Significant	+
Expected financial loss being caught	-	Not Significant
Sample Size	508	581

5. CONCLUDING REMARKS

Unfortunately, Korea has one of the highest traffic accident rates among OECD countries. Korea recorded over 10,000 life losses each year for traffic accidents, which is 3-5 times higher than the USA and Japan in terms of vehicle registration . And speeding is the major factor for traffic accidents. In this study, we have estimated the speed selection behavior by using data collected for speed and 18 different variables including personal characteristics of drivers, vehicle and safety information, trip purpose, and perceived information about speeding in Korea.

We have estimated ordered probit model in order to capture different impacts on speed selection behavior. Results indicated that i) male drivers with higher income tend to drive faster, and experienced drivers drive more higher speed than others ii) vehicles with more horsepower and vehicles with safety feature go slower than vehicles with less safety features iii) trip distance and frequency user of the road are important factors for speed selection behavior, iv) perceived speed limit on road and expectation of being caught for speed are an important factor for driving behavior.

The result of this research has revealed that the speed selection behavior is a combination of different factors of personal, vehicle, safety, trip and drivers' perception. Some factors such as personal characteristics of drivers are not controllable for transportation policy purpose. Factors such as perceived impacts on drivers are certainly controllable, however, by using appropriate transportation policies. Especially, increases in awareness of speed limit and perceived financial loss of accidents are very important factors, which discouraging speeding. Drivers with more knowledge of the speed limit of road tend to observe the posted speed limit more strictly. In order to reduce speeding and accidents in urban area, more safety related traffic signs such as speed limit sign, fine for speeding, and police presence in road would be useful instruments.

Finally, as shown from the international comparisons, speed selection behavior is quite different from one country to another. Further studies are, therefore, needed for more conclusive evidences in speed selection behavior before an introduction of new measures for speeding policy such as an increase in speed limit.

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