교통정보시스템과 다양한 다이나믹 혼잡통행료의 결합시행에 대한 연구[1]

(Responses to Dynamic Road User Charges and Traffic Information)

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1. Introduction

There are various charging methods and a considerable amount of research about road user charges has been undertaken. However, previous studies concerning road user charges mainly considered cordon charges, or tolls. Recent technical development related to road user charges may make it possible, whereby charge levels are decided depending on the current road conditions. For these variable systems, various methods have been studied to determine the charging levels including time-based charges, distance-based charges, and delay-based charges. Researches about variable road user charges have been carried out, but most of them are focus on the acceptability. Some of them have investigated the effects of these variable road user charges on network conditions, which were based on assumption about drivers responses. They have done this without any consideration of the possibility that the behavioural response might depend on the nature of the charging regime. There is hardly any literature about detailed analysis about those charging particularly about drivers responses to them. There is also little literature about the value of time in terms of which was based on the drivers responses rather than assumed values. Therefore, this study investigate the effects of variable road user charges on drivers and estimate value of time in terms of variable road user charges.

Some authors tested the various variable road user charges to investigate which charging method are more effective. Smith *et al.* (1994) compared the network effects of four road-user charging systems in the Cambridge network (including toll, distance-based charge, time-based

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[1] **This paper is heavily based on Hye-Jin Cho's Ph.d thesis.**

charge, and delay-based charge). They concluded that delay-based charging reduces congestion substantially at comparatively low levels of charging and suggested delay-based charging would have the best effects in terms of relief of congestion. However, Bonsall *et al.* (1998) asked drivers the most acceptable option of charges among fixed charges, distance-based charges, time-based charges and delay time-based charges. They found that the fixed charges were the most preferable and people were hostile to unpredictable charges. This study investigates what kind of variable road user charges is the best option to reduce congestion by changing drivers behaviour.

Certain types of road user charges, such as time-based charges and delay-based charges have been criticized because of their difficulty in predicting accurate charges. Providing information is necessary for implementing these types of road user charges and can solve the problem of the unpredictable charges for time-based charges and delay-based charges (Cho, 1997). Even though Emmerink *et al.* (1995) mentioned providing charge information, there was hardly any literature about detailed and practical information about charges and the effect of charge information on drivers route choice. Therefore, this study investigates the practical application of the charge information, and the design of charge information. This study also explores alternative ways of presenting charge information for different charging regimes and the effect of providing charge information on route choice.

The extent to which responses to traffic information vary also depends on the characteristics of traffic information. The value of delay time indicates the extent to which drivers perceive delay time and in particular, the delay threshold is the point at which drivers change their behaviour. Estimating value of delay time help to understand drivers behaviour in response to delay information and to predict their response to delays stated on VMS signs. Therefore, this study investigate the extent to which the amount of delay information affect drivers route choice and the way in which drivers evaluate the value of information concerning delay time in detail.

Drivers responses to traffic information were found to vary depending on drivers individual factors. This study investigates the effects of drivers individual factors on their response to information, particularly that responses segmented by their sex, age and income levels and explores drivers response to traffic information and charge information.

The survey is conducted in Leeds and Seoul. The purposes of the Seoul survey are to investigate drivers responses to traffic information and road user charging regimes in Seoul and to investigate whether cultural difference influence drivers responses by comparing the results between Leeds and Seoul.

There are four objectives of this study. First, this study explore drivers responses to different types of variable road user charges and their sensitivity to these road user charges. Secondly, this study explores alternative ways of presenting charge information for different charging regimes and the effect of providing charge information on route choice. Thirdly, this study investigates the extent to which the amount of delay information affect drivers route choice and the way in which drivers evaluate the value of information concerning delay time. Finally, this study investigates the extent to which socio-economic characteristics influence drivers responses to road user charge and to the information. The effect of cultural difference on reposes to road user charges and traffic information is also explored.

2 Methodology & Data Collection

2.1 Methodology

2.1.1 Traffic Information Systems and Road User Charges

The traffic information was provided via VMS and related to the expected delay time. Three types of variable road user charges were applied: fixed charges; time-based charges; and delay time-based charges. With total time-based charges, the charge is directly proportion to the travel time spent in the charged area and with delay time-based charges, vehicles are charged directly in proportion to delay they experience within the charged area. For fixed charges, it was assumed that with the fixed charge, each vehicle is charged a fixed amount which might in practice be the same every day or might be designed to reflect traffic conditions in some previous time period, in which case, therefore the drivers might need information on the value of the charge.

2.1.2 Presentation of Charge Information

There are two possible ways of presenting variable charge information in practice. The first is to give a charge rate formula. This could be assisted in this task if they were given information about expected traffic conditions. When the formula is simple most drivers should find it easy to calculate the resulting charge. However, it is anticipated that some drivers would find it difficult. An alternative to the formula approach would be to provide estimates of the charges payable. In this case, it is assumed that the estimate would be based on the current traffic conditions observed by the central control centre. Such estimates would not be precise but could be quite reliable and would certainly ease the burden on the individual drivers. It may therefore be an attractive option for a real-time road user charging in the future. Since total travel time on any journey is generally more predictable than the amount of delay time, it is likely that estimates of charges payable would be more accurate for travel time charges than for delay time-based charges.

2.2 Experimental Design & Survey Method

The Stated Preference(SP) surveys were conducted to collect data. This study tested the SP survey design through three pilot surveys and simulations. The surveys were conducted in Leeds and Seoul. The issues to explore in this survey are:

- Route choice faced with traffic information
- Route choice faced with traffic information and fixed charges
- Route choice faced with traffic information and time-based charges
- Route choice faced with traffic information and delay-time based charges

2.3 Data Collection

The survey was conducted in April and May, 1997. The questionnaires were distributed personally to drivers commuting between 7:00 am and 9:00 am at the several car parks in Leeds. Total 281questionnaires were returned giving a response rate of 41.4% containing a total of 2626 SP choice observations.

3. Qualitative Analysis

The qualitative and attitudinal results are analysed using tabulations. Response to road user charges were analysed and the results were that if a road user charges were introduced to Leeds, drivers would consider paying relatively modest charges but that they would be very sensitive to higher charges. Changing departure time earlier was the most likely means of avoiding the higher charge levels. The responses to the charges depended on the sex, age and income of the respondents. Responses to road user charges revealed that though generally people do think the road user charges are unacceptable some drivers in Leeds are ready to pay a charge. This indicates that drivers have been changing their attitude to road user charges because they realized the problem due to worsening congestion. This may be explained by the fact that drivers in Leeds already perceived the additional cost caused by congestion. The estimated perceived additional cost caused by the congestion was 9.9 pence per mile in Leeds. These estimated additional cost may contribute to estimation of perceived congestion cost and also may be useful to deciding the charge levels for the road user charges.

4 Analysis

4.1 Model Estimation

The SP results are analysed by using logit models. Seven models are estimated to find out the best fitting model for the results and the finally selected model was the non-linear model. This model included the free flow travel time, the square term of normal delay, the square term of extra delay, and three charging regimes variables. The normal delay is the usually expected delay in drivers' journeys as a part of normal travel time. The extra delay is an additional delay over and above normal delay and is given as traffic information on VMS. These separate delay parameters allow investigation of the separate effect of each type of delay on route choice. The normal delay parameter and extra delay parameter, *exdelay* are based on the square of delay time in order to allow for any non-linearity in the relationship between delay and travel time. The charges for time-based charge and for delay-based charges were given with ranges. Four models were estimated in order to investigate the effect of the ranges of the charges. According to the results all models were based on the median value of charges. The utility functions of the final model follow. The model estimates are shown in Table 1.

$$\begin{aligned} U_{route1} &= \alpha * fttime_1 + \beta_1 * ndelay_1^2 + \beta_2 * exdelay_1^2 \; (+\beta_3 * htraffic) \\ &\quad + \gamma_1 * fcharge + \gamma_2 * ttcharge + \gamma_3 * dtcharge \\ U_{route2} &= \alpha * fttime_2 + \beta_1 * ndelay_2^2 + \beta_2 * exdelay_2^2 \end{aligned} \tag{1}$$

Where

fttime	**In-vehicle free-flow travel time(minutes)**
ndelay^2	**normal delay(minutes^2)**
exdelay^2	**extra delay reported on VMS(minutes^2)**
htraffic	**dummy variable for the heavy traffic situation at the decision point :**
	1 if local traffic is slow moving htraffic, 0 otherwise
fcharge	**fixed charge(pence)**
ttcharge	**total time-based charge(pence) : the mid point of range**
dtcharge	**delay time-based charge(pence) : the mid point of range**

Table 1 Model estimates results

	Coefficient	T-ratio
fttime(min)	-0.103	-11.6
ndelay²(min)	-0.017	-8.8
exdelay²(min)	-0.007	-6.3
fcharge(pence)	-0.027	-14.8
ttcharge(pence)	-0.022	-13.4
dtcharge(pence)	-0.024	-14.5
Number of observation	2626	
Final Likelihood	-1500.781	
Rho-Squared w.r.t. zero	0.176	

The parameter, *fttime* for free-flow travel time indicates that drivers' are less likely to choose the route as travel time increases. This parameter explains the strong preference on route 1. The estimates for normal delay minutes, $ndelay^2$ and extra delay, $exdelay^2$ suggest that when the normal delay or extra delay increases, their preference of that route decreases.

A number of research has found that drivers are more likely to divert when the length of delay reported on their usual route increase (Huchingson and Dudek 1979; Mannering 1989; Mahmassani *et al.* 1990; Khattak *et al.* 1991; Khattak *et al.* 1993a and 1993b; Bonsall and Merrall 1995).

The value of normal delay and extra delay time are estimated from the estimated results of the model in **Table 1.** The value of normal delay and extra delay are expressed in units of normal travel time. The values of normal delay time and extra delay time are also illustrated in **Figure 1** which also explains the way drivers value delay time, compared with the free-flow travel time. The total delay means the sum of normal delay and extra delay. The area between total delay curve and normal delay curve represents the extra delay. The curve of the value of normal delay and extra delay are non-linear and concave. This indicates that the value of normal delay time and extra delay time in terms of free travel time increase at an increasing rate as delay time increases. Therefore, drivers thus value delay time more highly and became increasingly sensitive to delay time as it increases.

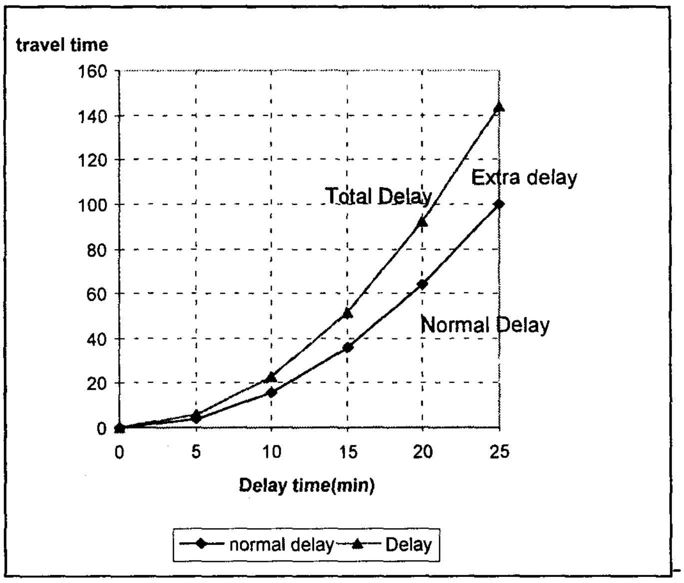

Figure 1 Value of normal delay and extra delay

For example, 5 minutes of normal delay is equivalent to only 4 minutes of travel time and 5 minutes of extra delay is 1.75 minutes of travel time. However, the value of normal delay and extra delay time increase rapidly as delay time increases. So 20 minutes of normal delay is 64 minutes of normal travel time which is the 3.2 time of travel time. 20 minutes of extra delay is 28 minutes of travel time. Wardman *et al.*(1997) also found that additional delays on the VMS were valued more highly than normally expected travel time due to the uncertainty, stress, frustration and the worse driving conditions involved. The non-linear curve of the value of delay time have also been found by earlier studies. Huchingson and Dudek (1979) found that the relation between length of delay and diversion could be plotted as a S-shaped curve, in which few drivers were willing to divert in response to minor delays and most drivers were willing to divert as a result of long delay between 30 and 60 minutes delay. Wardman *et al.* (1997) reported that the unit value of expected delay time increases as the amount of delay time increases, at least between 5 and 30 minutes in their study, which indicates that motorists became increasingly sensitive to delay time as it increased. However, Khattak *et al.* (1993a and b) reported that willingness to divert increased with length of delay but at a decreasing rate which meant the convex curve for the value of delay function.

The value of delay time is lower than travel time until normal delay becomes 10 minutes and the extra delay time become 15 minutes. The value of 5 minutes delay time is less than value of normal journey time, while the value of time increases rapidly as the amount of delay increases. It seems that there is a kind of threshold for delay time. Drivers did not value delay time differently from the journey time up to a certain amount of delay time. However, as delay time increases over the certain level, drivers become to value delay time greater than travel time and this trend become greater. The point at which the values begin to diverge may be termed 'delay threshold' for drivers. Estimates from the results in this paper and from one of the pilot survey results suggest that the delay threshold is 10 minute for the normal delay time and 15 minutes for the extra delay time on VMS. Khattak *et al*(1993b) also investigated the delay thresholds by length of expected delay in the model and reported that drivers are significantly more likely to divert if the expected delay is at least 20 minutes and larger delay time increased the probability of diversion.

Among three charging parameters, *fcharge* is bigger than other charging parameters, shown in **Table 1**. Three parameters for charging regimes are significant. In order to find out whether three different charging regimes are significantly different, t-statistics tests for the relevant difference between estimated coefficients were conducted. The t-static for the difference between two coefficients estimates (α_1, and α_2) is calculated as (Wardman *et al.* 1997)

$$t = \frac{\beta_1 - \beta_2}{\sqrt{Var(\beta_1) + Var(\beta_2) - 2Cov(\beta_1, \beta_2)}} \qquad \textbf{(2)}$$

The variance of relative attribute valuations can also be calculated by converting the correlation coefficient for the parameters given by ALOGIT into a covariance as follows (Palmer, 1995)

$$Cov(\beta_i, \beta_j) = \rho_{(\beta_i, \beta_j)} \cdot \sqrt{[Var(\beta_i)\, Var(\beta_j)]} \quad (3)$$

where

β_i	**is the parameter estimate for attribute i (i= 1,2)**
$Var(\beta_i)$	**is the variance of** β_i
$Cov(\beta_i, \beta_j)$	**is the covariance between parameter estimate** β_i **and** β_j
$\rho_{(\beta_i, \beta_j)}$	**is the correlation coefficient for parameter estimate** β_i **and** β_j

The t-statistics show that *fcharge* coefficient estimate for the fixed charge is statistically significantly different from the other charge coefficient estimates, *ttcharge* for the time-based charge and *dtcharge* for the delay-based charge at the usual 5% level of significance. This suggests that a fixed charge has significantly more influence on route choice than do time-based charges or delay-based charges. The *ttcharge* and *dtcharge* coefficient estimates have similar values and are not statistically and significantly different from each other.

Table 2 Differences between coefficients

β_1	β_2	t-test	$\beta_1 - \beta_2$
fcharge	***Ttcharge***	**-3.075**	**-0.00404**
fcharge	***Dtcharge***	**1.418**	**0.00168**
ttcharge	***Dtcharge***	**-1.979**	**-0.00246**

The values of time in terms of different charging regimes are estimated based on the model estimate results, as shown in **Table 1**. The values of time are: 3.9 pence per minute in terms of fixed charging; 4.5 pence per minute in terms of total time-based charging; and 4.3 pence per minute in terms of delay time-based charging. This result shows that the value of time in terms of the fixed charge is smaller than those of total time-based charge and delay time-based charge and indicates that certainty of charge decreases the value of time. This is presumably due to the fact that total time based charge and delay time are uncertain due to the uncertainty of travel time and delay time. The value of time in terms of road user charges are less valued than would be implied by normal values of time.

4.2 Segmentation

In order to investigate the extent to which responses are influenced by socio-economic characteristics of respondents, segmentations are made according to the sex , age and income levels of the respondents. The detailed results are shown elsewhere(Cho, 1998). Male drivers are more likely to change their route than female as increases on the route. Males are more sensitive to the increases of normal delay time, extra delay time and free-flow travel time on their route choice. Females are also less influenced on route choice by the increase of charges than males regardless of different charging regimes. This may be explained due to female risk-averse attitude and due to the different positions of female drivers in the labour market. Among three charge parameters, the fixed charge has the strongest effects on route choice regardless of sex. The young drivers under 35 years are more sensitive to free flow travel time, extra delay time, and any types of charges. These results may be explained by the risk attitude, because the young are less risk-averse than the old. The lower level of income they have, the more sensitive to the free flow travel time. The drivers who have the higher level of income are more sensitive to the normal delay than others. Those who have lower level of income, they are more sensitive to extra delay information on VMS. The higher level of income they have, the less they are sensitive to the amount and types of charges.

4.3 Correction of the repeated measurement problem

The repeated measurement problems in logit models were corrected by applying the Jackknife method and Kocurs method(Cho and Kim, 1999) to deal with the "repeated measurement problem" which is caused by allowing several observations from each respondent and inflates the significance of explanatory variables. The Jackknife method was implemented using a program '**JACKKNIFE**'. The following formula is used to combine these partial estimates to get the Jackknife estimates. The eleven Jackknife models were estimated with 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 99 of sub-samples.

$$\theta_{*Jack} = r\theta_0 - (r-1)\overline{\theta} = \theta_0 + (r-1)(\theta_0 - \overline{\theta}) \quad (4)$$

where

$$\overline{\theta} = \frac{1}{r}\sum_{j=1}^{r} \theta_{j} \quad (5)$$

θ_{*Jack}	:	**the final Jackknife estimate**
θ_{-j}	:	**the *j*th partial Jackknife estimate**
θ_0	:	**the uncorrected estimate**
$\overline{\theta}$	:	**the mean of partial Jackknife estimates**
r	:	**the number of sub-samples**

The Jackknife variance estimator (σ^2_{JACK}) is ;

$$\sigma^2_{JACK}(\theta) = \frac{n-1}{n}\sum_{i=1}^{n}\left(\theta_{-j} - \overline{\theta}\right)^2, \quad (6)$$

The model estimate results of Jackknife method and Kocur's method were compared with those of the uncorrected estimates in order to test whether there was repeated measurement problem or not and the extent to which this problem affected the model estimates. The standard errors between the uncorrected model estimates and Jackknife estimates were also compared.

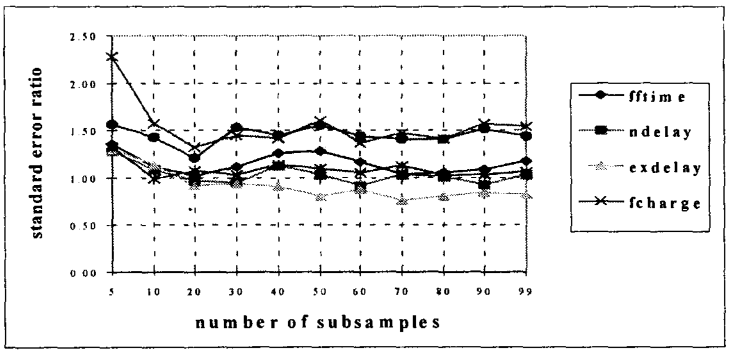

Figure 2 Comparison of standard error ratio

The results reveal that the t-ratios of Kocur's are much lower than those of the uncorrected method and Jackknife estimates, indicating that Kocur's method underestimates the significance of the coefficients. Jackknife method produced the almost same coefficients as those of the uncorrected model but the lower t-ratios. These results indicate that the coefficients of the uncorrected method are accurate but that their significance are somewhat overestimated. This result is consistent with Cirillo *et al.* (1996).

Therefore, I conclude from this finding that the repeated measurement problem does exist in my data, but that it does not affect the model estimation results significantly in this study. The uncorrected model estimates are good enough to predict the route choice behaviour despite repeated observations.

4.4 Results

Results based on the model estimates are summarised as follows. Drivers were less likely to choose a route characterised by recurrent delays and as the length of delay reported on their usual route increased. When the normal delay or extra delay increases, their preference of that route decreases. Although they were affected by the amount of the length of extra delay time stated on VMS, the effect on route choice of extra delay time on VMS was less than that of normal delay time. The reason might be because of the perceived unreliability of VMS information.

The values of normal delay and extra delay time on VMS were estimated, expressed in units of normal free-flow travel time. The value of normal delay time and extra delay time in terms of free travel time increase at an increasing rate as delay time increases. Therefore, drivers thus value delay time more highly and became increasingly sensitive to delay time as it increases. The threshold of delay information was also found at which point the values of delay time began to diverge for drivers.

Among three different types of charges, the fixed charges had a stronger effect on drivers route choice than did the others. The reason is that drivers tended to underestimate the uncertain charge of the total time-based charge and delay time-based charge. The values of time in terms of different charging regimes were estimated. This result shows that the value of time in terms of the fixed charge is smaller than those of total time-based charge and delay time-based charge and indicates that certainty of charge decreases the value of time. This is presumably due to the fact that total time based charge and delay time are uncertain due to the uncertainty of travel time and delay time. The value of time in terms of road user charges are less valued than would be implied by normal values of time.

5. Seoul Survey Results

5.1 Survey & Qualitative Results

In order to validate the method and findings from the Leeds survey, the methodology was replicated in Seoul in March 1998. Although the overall design of the Seoul survey was the same as those of the main survey, there were several changes to reflect the difference of travel pattern and traffic conditions between Leeds and Seoul. The SP design was slightly changed considering the average journey time for the commuters in the morning, the average journey distance for commuting trip, and their value of time. The charge levels were also converted into the Korean currency, Won.

The Seoul survey was conducted in March 1998. The interviewers visited several companies located in Seoul city centre and handed out the questionnaires to car commuters personally. They collected the questionnaires a week later. A total of 150 questionnaires were distributed and collected, containing a total of 1276 valid SP observations.

Respondents were asked about their experience of using different types of traffic information systems and their perception about the usefulness of these systems. VMS and radio traffic information were considered. About 66 % of respondents have had experience with VMS, of whom 87% thought it was useful. Approximately 87% of respondents had listened to radio traffic messages and 80% of them said it was useful. These results indicate that drivers in Seoul were familiar with traffic information systems and considered them useful.

The respondents were asked about their attitudes to road user charges. It was assumed that road user charging had been introduced for use of roads in Seoul city centre during morning peak hours. Three levels of charge were given: 1000 won, 1500 won and 2000 won[2]. About half of the respondents would consider travelling earlier regardless of charge levels. As the level of charges increased, they would also consider switching to public transport.

The respondents were asked to estimate their own petrol costs for hypothetical routes 1 and 2 in the SP experiments. The average estimates of petrol costs were 2274 won for route 1 and 3134 won for the route 2. This means that the estimate of petrol cost on route 1 was 227.4 won per km, while that on route 2 was 125 won per km. These results indicate that most drivers already perceive the additional cost caused by congestion. The perceived additional cost was 102.4 won per km (40 pence per km).

5.2 Model Esitmation and Analysis

The SP results were analysed using binary logit models to predict route choice as a function of information content, route attributes, types of road user charge, level of charges and socio-economic characteristics of the respondents. The Seoul survey data contained a total of 1350 SP choice observations, of which 1276 was available for the modelling.

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3 **£1.00 was equivalent to about 2,500 won at the time when the survey was undertaken.**

The utility functions of this model are:

$$U_{route1} = \alpha * fttime_1 + \beta_1 * exdelay_1^2 + \varphi_1 * pcost_1 + \gamma_1 * fcharge + \gamma_2 * ttcharge + \gamma_3 * dtcharge \quad (7)$$

$$U_{route2} = \alpha * fttime_2 + \beta_1 * exdelay_2^2 + \varphi_1 * pcost_2$$

where

fttime	**In-vehicle free-flow travel time(minutes)**
exdelay²	**extra delay reported on VMS(minutes²)**
pcost	**perceived petrol cost(won)**
fcharge	**fixed charge (won)**
ttcharge	**total time-based charge(won) : the mid point of range**
dtcharge	**delay time-based charge(won) : the mid point of range**

Table 3 Model estimates for the Seoul data

	Model	
	Coefficient	T-ratio
fttime(min)	-0.00989	-1.0
pcost(won)	-0.00015	-3.2
exdelay²(min)	-0.00301	-2.6
fcharge(won)	-0.00047	-6.2
ttcharge(won)	-0.00024	-3.4
dtcharge(won)	-0.00034	-4.2
Number of observation	1276	
Final Likelihood	-815.638	
Rho-Squared w.r.t. zero	0.078	

The model estimation results in Table 3 are acceptable; all parameters have intuitive signs, most of them are significant, and the rho-squared value is acceptable considering the small sample size and many variables.

The parameter, *fttime* for free-flow travel time indicates that drivers' are less likely to choose the route as travel time increases. The extra delay parameter, *exdelay²* suggest that they are also sensitive to the extra delay information on VMS signs as the extra delay increases. The parameter, *pcost*, indicates that preference for the route tend to decrease as the perceived petrol cost on the route increases.

All charge estimates, *fcharge, ttcharge* and *dtcharge* indicate that if a charge is introduced on a route, drivers are less likely to choose the route. Among three kinds of the road user charges, drivers are more sensitive to the fixed charge than total time-based charge and delay time-based charge. This is consistent with the results from the main Leeds survey, discussed in section 4. T-statistics for the relevant difference between estimated coefficients were conducted and results are shown in **Table 4.**

Table 4 Differences between coefficients in the Seoul model

β_1	β_2	t-test	$\beta_1 - \beta_2$
fcharge	*Ttcharge*	-3.544*	0.000237
fcharge	*Dtcharge*	-1.852***	0.000335
ttcharge	*Dtcharge*	1.488	0.000337

***significant for a 1% level of significance ***significant for a 10% level of significance**

The values of time in terms of different charging regimes are estimated based on the model estimate results. The values of time are: 21 won (0.8 pence) per minute in terms of the fixed charging; 41.2 won (1.6 pence) per minute in terms of total time-based charging; and 29.0 won (1.2 pence) per minute in terms of delay time-based charging. The value of time in terms of perceived cost is 65.9 won (2.6 pence) per minute. This result shows that the value of time in terms of the fixed charge is smaller than those of total time-based charge and delay time-based charge and indicates that certainty of charge decreases the value of time. As in the Leeds study, this indicates that the values of time in terms of road user charges are less valued than would be implied by normal values of time in terms of perceived costs.

5.3. Comparison of the survey results between Seoul and Leeds

This section briefly summarises the results from the Seoul survey and compares them with those from the main survey in Leeds. Drivers in both Seoul and in Leeds were familiar with traffic information systems and considered them useful like those in Leeds. However, the drivers' responses to the road user charges were different between Leeds and Seoul. If a charge was introduced, the first response of drivers in Seoul was travelling earlier to avoid charges regardless of the charge levels and as the levels of charge increased they would consider using public transport. While drivers in Leeds would consider paying a charge first and as the charge levels increased, they would consider travelling earlier to avoid charges.

Drivers in both Leeds and Seoul have perceived the additional cost caused by congestion. The perceived additional cost caused by the congestion were 9.9 pence per mile (= 6.2 pence per km) in Leeds and 102.4 won (4 pence) per km in Seoul.

The key findings from the Seoul SP data were that drivers were more likely to change their route as the extra delay on VMS increased and as the levels of charges increased. The detailed analysis were discussed in Cho and Kim(1998). Among three charging regimes, the fixed charge has more influence on route choice than the time-based charges and the delay time-based charges. These results were also found from the main Leeds survey results. Although the key findings were similar, the model segmentation results by the age and income levels showed that drivers responses patterns were slightly different. In Leeds, the old drivers were less sensitive to the extra delay time and charges, while in Seoul the old drivers were much sensitive to the extra delay time and charges. In Leeds, the lower income drivers were more sensitive to extra delay, while in Seoul it was the high income drivers who were more sensitive to extra delay. These different results seem to be caused by the cultural difference. These results echo those of Bonsall (1992) who investigated the response to VMS and IVG system and found that although the aggregate findings were generally same across the several cities, the disaggregated results were different.

6. Implication & Further Study

Among the different variable road user charging regimes, the fixed charges were found to have a stronger impact on route choice than the others. This indicates that fixed charges may be most likely to induce drivers to change their behaviour. Also, the technology required for the fixed charges is cheaper and less sophisticated than that required for variable charges. Therefore, fixed charges may be the best option for the purpose of the efficient use of network by changing drivers behaviour and in terms of the easy and cheap implementation. However, if the purpose of the charge is to raise the revenue, the fixed charges might be less preferable option than time-based charges and delay time-based charges.

It was also found that the fixed charges always had a stronger effect on route choice than the other charges, regardless of sex age and income levels. This result indicates that introducing the fixed charge can influence drivers behaviour equally. Therefore, the fixed charge can be also a feasible policy tool in terms of equity issue.

This study estimated values of time in terms of variable road user charges including the fixed charges, the time-based charges, the delay time based charges. These values will be useful to help to decide optimal charge rates for the each charging regime.

There was some indication that the uncertainty of information has influenced route choice slightly. It is also interesting to investigate the way drivers responses to uncertain information. Therefore, in order to explore the way and the extent to which uncertainty of information influence drivers decision in detail, an additional survey was conducted and the results were discussed elsewhere(Bonsall and Cho, 1999).

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