■ 論 文 ■

Effect of uncertain information on drivers' decision making
(Application of Prospect Theory)

불확실한 정보에 대한 운전자의 의사결정행태 연구

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요 약

교통정보의 정확도는 정보에 대한 운전자의 반응을 결정하는데 중요한 요소이다. 교통상황의 정확한 정보를 제공하는 것은 현실적으로 어렵기 때문에 대부분의 교통정보는 불확실성을 내재하게 된다. 그러나 기존의 많은 관련 연구에서는 정확한 정보와 그에 대한 운전자의 신뢰를 가정하고 있다. 본 논문의 목적은 불확실한 정보가 운전자의 의사결정에 미치는 영향을 분석하는 것이다.

이를 위해 노선선택에서 불확실한 통행료 정보의 선택상황을 가정해 SP 설문조사를 실시하고 통행료 정보의 불확실정도를 정량화 하기 위해 범위값으로 표현하였다. 특히 본 연구는 기존 확률효용이론(Random Utility Theory)이 설명하지 못하는 불확실한 정보가 노선선택에 미치는 영향을 분석하기 위하여 Prospect Theory를 적용하여 정보의 불확실성에 따른 운전자의 노선선택행태를 분석하였다.

분석결과, 운전자는 정보가 주어진 노선을 정보가 주어지지 않는 노선보다 선호하는 것으로 나타났다. 또한 운전자는 확실한 정보를 선호해 노선선택을 하는 것으로 나타났다. 그러나 정보의 불확실정도가 증가하면서(범위값이 증가하면서) 노선의 선호도가 감소하는 경향이 있는 것으로 나타났다. 한편 범위값으로 제공된 정보에 대해서는 범위값의 크기와 더불어서 중위값도 운전자의 의사결정에 영향을 미치는 것으로 나타났다.

위 결과에 Prospect Theory를 적용한 결과, 불확실한 정보에 대한 운전자의 의사결정은 선택상황을 이해하고 평가하여 변형, 재형하는 일련의 과정에 따라서 다양한 행태가 나타나는 것으로 분석되었다. 따라서, 불확실한 정보에 대한 운전자의 의사결정을 분석할 때는 운전자가 선택상황을 해석하는 방식에 따라 다양하고 융통성 있게 접근해야 한다. 본 논문은 Prospect Theory의 기본 개념과 의사결정단계에 따른 원칙만을 적용하였으나 향후 불확실한 정보에 대한 운전자의 행태를 설명할 수 있는 좀 더 상세한 분석과 더불어 다양한 분야의 이론이 적용되는 것이 필요하다고 사료된다.

Ⅰ. Introduction

The effect of traffic information on drivers' decision makings depend on whether it is credible, relevant and clear. In particular, reliability of information is an important factor influencing on the responses to traffic information(Shirazi et al.1988; Bonsall 1992; Zhoa et al, 1995). The reliability depends on the extent to which the information is less uncertain. In fact, it is hardly possible to provide 100% certain traffic information to drivers because of the dynamic characteristics of traffic flow.

However, most existing researches related to the effect of traffic information has been mainly based on the assumption that provided information is certain and accurate and drivers believe information reliable.

From 1950s, the economists found that the decision making under the uncertain situation may be different from under the certain situation and have provided new analysis tools and theories for the decision making process under uncertainty. Prospect Theory is one of the established economic theories which explain how human decisions can at times vary from or be at odds under uncertainty.1The purposes of this paper are to explore the way and the extent to which drivers' decision making were influenced by uncertain information in details. In particular, we apply the Prospect Theory to the analysis of drivers' decision making under uncertain information.[1)]

The next section briefly reviews relevant literatures. Section Ⅲ summarises the survey design and data collection. Section IV reports the descriptive analysis of the survey results. In section V, the process of estimating logit models is discussed. This investigates the way in which uncertain charges influence drivers' route choice and whether the estimated logit models can explain the drivers' behaviour. Section VI briefly introduces Prospect Theory and section VII gives interpretation of the results based on the application of Prospect Theory. Finally, section VIII summarises the results and suggests a further study.

Ⅱ. Literature Review

1. Effect of Information

A number of researchers(Bonsall and Joint 1991; Bonsall 1992; Bonsall et al. 1994) have found that when drivers perceived traffic information to be more reliable, they were more likely to respond to it. Shirazi et al.(1988) reported that the majority of commuters(94%) would consider diverting as a result of receiving traffic information only if more accurate information was available and commuters required that the first more timely and accurate information, secondly more frequent reporting and thirdly better uses of variable message signs. Dingus and Hulse(1993) pointed out that appropriate and timely information is an important factor leading drivers to change their routes. Sheldon and Jones (1993) reported in their study about congestion pricing London that the extent to which uncertain information is provided may influence drivers' responses to the information.

Zhao et al.(1995) suggested that providing high quality traffic information would attract more drivers to use and accept traffic information. Hato et al. (1995) also reported that when the accuracy of information received is low, it tended to have a negative effect on the perceived value of the information and respondents required highly accurate and reliable information. Wardman et al.(1997) reported that drivers with experienced unrealible traffic information from VMS were less sensitive to information and were more likely to believe

1) Daniel Kahneman, who is a professor of Princeton University was honored the 2002 Nobel economics prize primarily for his establishment of Prospect Theory.

their own observations of visible traffic conditions ahead rather than VMS information.

Most researches agree with that more reliable and certain information make better effects of providing information. However, they overlooked that providing certain information is hardly possible, and we should consider that the way uncertain information influence drivers' decision making. This study consider this issues and apply Prospect Theory to the analysis of drivers' decision making behaviour under uncertainty.

2. Violation of Utility

Von Neumann-Morgenstern(1947), as quoted in Schoemaker(1980), have shown that under certain circumstances it is possible to construct a set of numbers for a particular consumer that can be used to predict his/her choices in an uncertain situation and these numbers are the utility which was later to be referred to as expected Utility Theory. They also made a set of assumptions about preference orderings and proved that to obey the axioms one must always prefer the alternative with the highest utility. The application of expected utility theory to choice between prospects is based on the following tenets. First, the overall utility of a alternative, $\boldsymbol{U}$ is the expected utility of its outcomes. Secondly, the domain of the utility function is final states rather than gains or losses. Finally, in expected utility theory, risk aversion is equivalent to the concavity of the utility function and it is the best known generalisation regarding risky choicesExpected Utility Theory has dominated the analysis of decision making under risk or under uncertainty and has been widely applied as a descriptive model of economic behaviour(Bell et al. 1988). However, in fact, a number of economic researchers(e.g. Markowitz 1959; Edwards 1962; Kahneman and Tversky 1979; Schoemaker 1980) have found that decision making under uncertainty was very complicated and there were several violation that are inconsistent with expected Utility Theory. They suggested that the traditional Utility Theory does not offer an adequate explanation of decision making under uncertainty.

Therefore, many evaluation models have been devised in order to modify Expected Utility Theory. Markowitz(1959) was the first to propose that utility be defined on gains and losses rather than on final states and also noted risk-seeking in preferences. He proposed that a utility function has convex and concave regions in both the positive and the negative area. Edwards(1962) proposed the replacement of probabilities by more general weights and investigated the models in several empirical studies. Fellner(1965) introduced the concept of a decision weight to explain aversion to ambiguity.

Kahneman and Tversky(1979) showed empirically observed tendencies, Certainty Effect, Reflection Effect and Isolation Effect, and proposed that choices among risky alternatives reveal several effects that are inconsistent with the basic tenets of Utility Theory.

In this study we apply Prospect Theory to the analysis of traffic information, which is the first case in transport field.

Ⅲ. Methodology

1. Uncertain Information Design

In this study we define uncertain traffic information as traffic information which contains uncertainty due to dynamic characteristics of traffic condition.

We use route choice decision making context rather than mode choice because of its simplicity. In order to focus on effect of uncertain information on route choice, the explanatory variables include not all route choice relevant variables but only uncertain information relevant variables.

For the information contents, we use the variable road user charges information. The concept of road user charges is that charges are levied continuously based on the amount of road use and levels of congestion. Recent technical development related to road user charges may make this possible, whereby charge levels are decided depending on the way the charges are calculated, and on current traffic conditions. In implementing these systems, charge information is provided in order to solve the problem of unpredictable charges.

There are two ways of charge information presentations: giving roughly estimated charge information or giving ranges of estimated charges reflecting uncertainty. In order to present the degree of uncertainty, we use the size of ranges of charge estimates as the quantitative measures of uncertainty. In other words, the bigger size of range the information has, the more uncertain information it is. This makes it possible to analyse effect of quantitative difference of uncertainty.

Therefore, this paper investigates the effect of uncertain information on route choice when drivers face a choice with different degree of uncertain information.

2. Survey Design

1) Stated Preference Method

Stated preference(SP) method is used in the survey which is applicable to investigate responses under a hypothetical situation. The SP is a survey tool which obtains information about people's preferences or possible action in response to different hypothetical choice situations. Each respondent is provided with alternative hypothetical situations with different combinations of attributes.

〈Table 1〉 summarises the SP design. Six SP questions were provided to each respondent. The first three of them(A, B and C) varied the range of charges on route 2 with the same median value of charge between two routes, while the next three (D, E and F) varied the ranges of the charges as well as the median value of the charges on route 2. This design was used to determine the effect of the range of the charge and the effect of the median value of the charge on route choice.

2) Questionnaire Design

The questionnaire has two parts. The first part includes general questions about characteristics of the drivers and their travel patterns. It also contains questions asking for the drivers' experience with VMS signs and radio traffic information and whether they found them useful.

The second part of the questionnaire includes seven questions including six SP questions. The first question intends to determine the effect of charge information on drivers' route choice. Subjects were asked to imagine that a traffic information system has been introduced on route 1 which provides an estimate of the charge and so helps drivers to decide which route to use. Respondents have the choice of two routes: route 1 which had charge information and route 2 without charge

〈Table 1〉 SP design

	Set 1		Set 2		Set 3	
Questions	Route1	Route 2	Route1	Route 2	Route1	Route 2
A	£1.00	£0.90~£1.10	£1.50	£1.35~£1.65	£2.00	£1.80~£2.20
B	£1.00	£0.80~£1.20	£1.50	£1.20~£1.80	£2.00	£1.60~£2.40
C	£1.00	£0.70~£1.30	£1.50	£1.05~1.95	£2.00	£1.40~£2.60
D	£1.00	£0.85~£1.05	£1.50	£1.30~£1.60	£2.00	£1.75~£2.15
E	£1.00	£0.70~£1.10	£1.50	£1.10~£1.70	£2.00	£1.50~£2.30
F	£1.00	£0.80~£1.40	£1.50	£1.15~£2.05	£2.00	£1.50~£2.70

information.

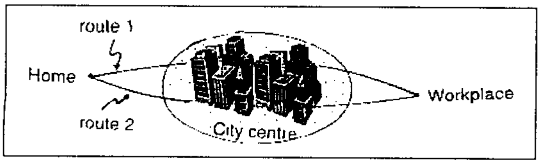
The remaining six SP questions are designed to investigate the effect of uncertain charge information on route choice. Respondents were asked to imagine that an information system has been installed for route 2 but it is not able to give accurate charge estimates but rough estimates because of the unpredictable traffic conditions on route 2. They were asked to make a route choice decision between certain charge information and uncertain charge information.

There were three sets of questionnaires depending on the level of base charges on route 1(£1.00, £1.50 and 2.00). To avoid overloading respondents, each respondent was asked only one of the three sets including 6 questions. Each set of questionnaires was distributed randomly to respondents.

3) Journey Scenarios in SP questions

A hypothetical network was used because of its simplicity and ability to exclude the effect of respondents' experience and preference on a specific route. ⟨Figure 1⟩ shows a hypothetical journey from home to work. The workplace is the other side of the city centre. It is assumed that the respondent is driving from home to work on a normal working day in the morning.

There are two routes available in the SP network. Both are about 4 miles long, and go through the city centre. The normal travel time on each route is approximately 30 minutes. The travel distance and travel time in this survey were designed based on the characteristics of typical commuter journeys in Leeds in order to make the survey design credible for the respondents.



⟨Figure 1⟩ A hypothetical network

In this questionnaire, respondents are asked to imagine that charges have been introduced for driving through the city. The charges would be automatically deducted from the credit stored in a prepaid smart card in the vehicle. The charge information is given to drivers because of unpredictable charges. Degree of uncertainty was presented as the size of ranges of given information reflecting the uncertain charge information.

3. Data Collection & Overview

The questionnaires were distributed to car commuters who arrived at car parks in Leeds city centre in UK during the morning peak between 7:00 am and 9:00 am. Three hundred questionnaires were handed out and 160 were returned giving a response rate of 53.3% with a total of 1120 choice observations.

Slightly more men(56%) than women responded to the survey. Most of respondents(87%) were between 25 and 54 years old. The income distribution shows that 51% of respondents had annual incomes between £20,000 and £40,000 and 31% indicated an income of more than £40,000. 93% of respondents were in full time employment. This sample seems to well represent the characteristics of the population of Leeds commuters.

Respondents were asked about their experience of using traffic information systems such as VMS information and radio messages about traffic conditions. About 82% of respondents said they had had experience with Variable Message Signs(VMS) before, and of those 33% had used them frequently. Among the 82%, 77% thought that they were useful. These results indicate that responses to the traffic information on VMS are based on the fact that the respondents are familiar with VMS and think them useful. 83% of respondents had made use of radio messages about traffic conditions and 80% of them said they had found them useful.

Ⅳ. Descriptive Analysis

1. Effect of Providing Information on Route Choice

The first question in the second part of the questionnaire was designed to investigate the extent to which providing charge information influenced drivers' route choice. It was assumed that a traffic information system had been introduced on route 1, which provided an estimate of charges and so helped drivers to decide which route to use. No charge information was available on route 2, so drivers would not know how much the charge on route 2 would be. However, in order to help them to estimate their charges on route 2 by themselves, the charge rate and normal travel time on route 2 were given to them. This feature was designed deliberately so that the charge estimated for route 2 would be approximately the same as the charge on route 1. Therefore, the only difference between the two routes was whether precise charge information was given or not.

Approximately 78% of drivers chose route 1 for which information was provided regardless of levels of charges, shown in 〈Table 2〉. This result indicates that providing information encourages drivers to choose the routes for which information is provided in preference to those for which it is not provided.

〈Table 2〉 Effects of Providing information on route choice

Route1	Route2	Route Choice(%)	
Information	Information	Route1	Route2
£1.00	Not available	79%	21%
£1.50	Not available	72%	28%
£2.00	Not available	80%	20%
Average		78%	22%

2. Effect of Uncertain Information

The survey also included six SP hypothetical choices between two routes with precise and certain charge information being provided on route 1, while a range of possible charge(i.e. an imprecise charge) was provided on route 2 which implied different degree of uncertain information.

1) Effects of the Ranges of Charges on Route Choice

This section analyses the first three questions of the six SP questions which vary only the range of the charges on route 2. These questions were designed deliberately so that the median values of charges estimated for route 2 was the same as the(known) charge on route 1. The ranges of the charges on route 2 varied across questions(from ±10% to ±30% of the median value of the charges, see 〈Table 1〉). 〈Table 3〉 summarises respondents' route choice in response to different ranges of the charges.

It can be seen from the above table that most drivers chose route 1 indicating that drivers prefer to avoid the uncertain charges. However, as the degree of range of charges on route 2 increased, drivers' preference for route 1 decreased slightly. This indicates that the percentage of drivers choosing route 2 was slightly affected by the size of the ranges. As the range of charge on route 2 increased from ±20% to ±30%(through interestingly, not from ±10% to ±20%), the percentage of drivers

〈Table 3〉 Effects of Ranges of Charges on Route Choice

Route 1	Route2		Route choice	
Charge Information	Charges Information	Ranges	Route1 (%)	Route2 (%)
£1.00	£0.90-£1.10	±10%	76%	24%
£1.00	£0.80-£1.20	±20%	76%	24%
£1.00	£0.70-£1.30	±30%	71%	29%
£1.50	£1.35-£1.65	±10%	65%	35%
£1.50	£1.20-£1.80	±20%	68%	32%
£1.50	£1.05-£1.95	±30%	61%	39%
£2.00	£1.80-£2.20	±10%	72%	28%
£2.00	£1.60-£2.40	±20%	72%	28%
£2.00	£1.40-£2.60	±30%	59%	41%

choosing route 1 decreased slightly. It seems that drivers' route choices are influenced not only by the relative size of the range of the charges but also by the absolute value of the range of the charges. The responses to uncertain charges are slightly different depending on the base charge levels. As it can be seen in Table 3, those who face £1.00 base charge levels are more likely to choose route 1.

2) Effect of Ranges and Median of information on Route Choice

This section analyses the other three SP questions which vary the range of the charges and the median value of the charge on route 2(see 〈Table 1〉). Comparison of the responses between these two sections of questions indicates the effect of the range of the charges and the median value of the charges on the route choice. These questions are designed deliberately to investigate the way uncertain information is presented affect drivers. In other words, we designed in order to investigate the way drivers notice the uncertain information presentation: whether drivers notice only the size of ranges or both size and the relative position of charges i.e. median.

〈Table 4〉 summarises the respondents' route choice in response to different ranges of charges and different median values of charges. The only difference between two sections was the median value of charge between routes. Comparison of results from section 1 and section 2 indicates that when median values of the charges on routes are different, the percentages choosing each route are quite different between them even though the same ranges of the charges on route 2 are given.

As it can be seen, as the median values of charges on route 2 decreases, the percentage of choosing route 2 rapidly increase and vice versa. This indicates that drivers are very sensitive to the median values of charges. The result also indicates that drivers' route choices are influenced more by the median value of the ranges of the potential charges than by the size of the overall ranges of the charges.

〈Table 4〉 Effect of Ranges and Median of information on Route Choice

	Question section 1 (a, b, c)			Question section 2 (d, e f)		
Route 1	Route 2		route1 choice	Route 2		route1 choice
charge	median	range		median	range	
£1.00	£1.00	±10%	76%	£0.95	±10%	47%
£1.00	£1.00	±20%	76%	£0.90	±20%	35%
£1.00	£1.00	±30%	71%	£1.10	±30%	100%
£1.50	£1.50	±10%	65%	£1.45	±10%	53%
£1.50	£1.50	±20%	68%	£1.40	±20%	46%
£1.50	£1.50	±30%	61%	£1.60	±30%	81%
£2.00	£2.00	±10%	72%	£1.95	±10%	54%
£2.00	£2.00	±20%	72%	£1.90	±20%	38%
£2.00	£2.00	±30%	59%	£2.10	±30%	82%

V. Model Estimation

In order to investigate the extent to which ranges of charge and median values of charge influence route choice, two binary logit models were estimated. Three variables in utility functions were used in models: median values of charges(pence); relative range of charges on route 2(%); and absolute value of the range of the charges on route 2(pence). Model 1 was estimated using the relative size of the range of the charges, while Model 2 was estimated using the absolute value of the range of the charges.

The utility functions of Model 1 are

$$U_{route1} = \alpha \times mcharge_1 \quad (1)$$

$$U_{route2} = \alpha \times mcharge_2 + \beta \times prange_2 \quad (2)$$

The utility functions of Model 2 are

$$U_{route1} = \alpha \times mcharge_1 \quad (3)$$

$$U_{route2} = \alpha \times mcharge_2 + \beta \times arange_2 \quad (4)$$

Where :

macharge : coefficient for the median value of charge(pence)

prange : coefficient for relative range of charge (%)

arange : coefficient for absolute value of range of charge(pence)

The estimated model results of Model 1 and Model 2 are summarised in ⟨Table 5⟩. The coefficients of mcharge of Model 1 and Model 2 have negative signs, which indicate that drivers are less likely to choose a route as the median value of charge on the route increases. The relative range coefficient of Model 1, prange shows that as the relative range of charge(%) on route 2 increases, the attractiveness of the route tends to decrease. The absolute range coefficient of Model 2, arange also indicates that drivers' preference on the route decreases, as the absolute value of range of charge on route 2 increases. Model 1 seems to be slightly better than Model 2 because of its slightly higher final likelihood ratio and Rho-squared. The prange coefficient of Model 1 also has a higher t-ratio value.

These findings about the relative and absolute ranges of charges explained that due to charges with ranges i.e. uncertain charges on route 2, route 1 was preferred to route 2. However, this does not explain the tendency in which as the range of charge increases, the preference on route 2 slightly increases, as shown in the descriptive analysis in section Ⅳ. Next section will introduce Prospect Theory for the explanation of this tendency.

⟨Table 5⟩ Logit Model Estimates

	Model 1		Model 2	
	Coefficient	T-ratio	Coefficient	T-ratio
Mcharge	-0.089	-7.2	-0.087	-7.2
Prange	-0.031	-8.8		
Arrange			-0.009	-8.2
Observation	960		960	
L(0)	-665.334		-665.575	
Final. Likilihood	-593.478		-599.683	
Rho-Squared w.r.t. zero	0.108		0.099	

Ⅵ. Prospect Theory

The descriptive analysis of results reported some seemingly inconsistent findings; drivers prefer a route with a precise and certain charge over one with imprecise and uncertain charge, but as the uncertainty of the charges increases, the preference for the route with the certain charge decreases slightly. As shown in section Ⅴ, logit model is not able to give an explanation about the results. However, these results are in fact consistent with key features of Prospect Theory.

Kahneman and Tversky(1979) developed Prospect Theory, to account for individual decision making processes under risk or uncertainty. The Certainty Effect, Reflection Effect and Isolation Effect are incorporated into Prospect Theory. They postulate that decision makers interpret the choice situation via a decomposition of the choice situation into gains and losses with respect to expected outcomes.

This section briefly summarises Prospect Theory, which is heavily based on Kahneman and Tversky (1979).

1. Observed Tendencies

1) Certainty Effect

In Utility Theory, the utilities of outcomes are weighted by their probabilities. Certain outcomes overweigh merely probable outcomes. This is known as "Certainty Effect". This tendency contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses. In cases where the possibilities of wining are very small, most people choose the prospect that offers the larger gain. This illustrates the common attitudes toward risk or chance that cannot be captured by the expected utility.

In the description that follows we use the following notation. A option is expressed as (x, p), where x is the expected value of outcome and p is the probability. Thus, for example, if there are two options: option (4000, 0.8) and option (3000, 0.25), where 4000 and 3000 are the outcomes and 0.8 and 0.25 are their probabilities. Thus the Certainty Effect indicates that option (3000, 1.0) is much preferred over option (4000, 0.8). However, option (4000, 0.2) is preferred to option (3000, 0.25) because the probability are small, drivers prefer the larger gain.

2) Reflection Effect

The preference between negative prospects is the mirror image of the preference between positive prospects. This phenomenon is known as the "Reflection Effect". The Reflection Effect implies risk aversion in the positive domains and risk seeking in the negative domains. In the positive domain, the Certainty Effect contributes to a risk averse preference for a sure gain over a probable larger gain. In the negative domain, the same effect leads to a risk seeking preference for a loss that is merely probable over a smaller loss that is certain.

The Reflection Effect also implies that people prefer prospects that have high expected value and small variance. This was assumed by a number of researchers(e.g. Allais 1953; Markowitz 1959), which leads an apparent inconsistency. For example, the option (3,000, 1.0) was preferred over (4,000, 0.8) because (3,000, 1.0) has no variance while (4,000, 0.8) has large variance. Option (-3,000, 1.0) was preferred over option (-4,000, 0.8) because (-3,000, 1.0) has higher expected values and lower variance than (-4,000, 0.8). This makes it necessary that the sure loss should be preferred, that is, the certainty is generally desirable. Thus it appears that certainty increases the aversion to losses as well as the desirability of gains.

3) Isolation Effects

In order to simplify the choice between alternatives, people often disregard components that the prospects share, and focus on aspects where they differ. This phenomenon is referred as the "Isolation Effect", This approach to choice problems may produce inconsistent preferences, because a pair of prospects can be decomposed into common and distinctive components in more than one way and different decomposition's sometimes lead to different preferences. The Isolation Effects can cause the choice between prospects to be determined by the difference in the perceived gains and losses.

2. Key phases : Editing & Evaluation

There are two phases in the choice process, proposed in Prospect Theory: an early phase of editing and a subsequent phase of evaluation. The editing phase is a preliminary analysis stage which organises and reformulates the options in order to simplify the choice. In evaluation phase, the edited prospects are evaluated and the highest value of prospect is chosen.

Editing consists of several operations which transform the options and probabilities. The major operations of the editing phase are described below.

1) Coding

People normally perceive outcomes as gains and losses rather than as final states of wealth or welfare. Gains and losses are defined relative to some neutral reference point. The reference point usually corresponds to the current asset position, in which case gains and losses coincide with the actual amounts that are received or paid. However, the location of the reference point, and the consequent coding of outcomes as gains or losses, can be affected by the formulation of the offered prospects and by the expectations of the decision maker.

2) Combination

The prospects can be simplified by combining the probabilities associated with identical outcomes.

3) Segregation

Some prospects contain a riskless component that is segregated from the risky component in the editing phase. For example, option (300, 0.8) and option (200, 0.2) are decomposed into a sure gain of 200 and option (100, 0.8).

4) Cancellation

The essence of the Isolation Effects is the discarding of components that are shared by the offered prospects. There are two examples of cancellation. First, in the sequential game, respondents apparently ignore the first stage because the first stage was common to both options and they evaluate the prospects with respect to the results of the second stage. Secondly, in a single stage game, people discard the common component of both options(i.e. outcome-probability pairs).

5) Simplification & Detection of dominance

In order to simplify prospects, people round probabilities or outcomes and discard extremely unlikely outcomes.

This editing phase leads to inconsistent preferences which may not be explained by Utility Theory. For example, the cancellation of common components causes the inconsistencies associated with the Isolation Effect results. Utility Theory assumes that if an individual prefer A to B and prefer B to C, A will be preferred to C(this assumption is known as 'transitivity'). Some intransitivities of choice are explained by a simplification that eliminates small differences between prospects. It is not necessary for the preference order between prospects to be the same across contexts, because the same offered prospect could be edited in different ways depending on the context in which it appears.

The evaluation of choices is formulated in Prospect Theory as a series of equations. Details regarding evaluation are in elsewhere(Kahneman and Tversky 1979).

There are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo. A difference between the reference point and the current asset position may also arise because of recent changes in wealth to which one has not yet adapted. A change of reference point changes the preference order for prospects. In particular, Prospect Theory implies that a negative translation of a choice problem, such as arises from incomplete adaptation to recent losses, increases risk seeking in some situations.

Those briefly summarized are mainly key concepts and principles in Prospect Theory. The reference point moving and establishing value function are discussed in Kahneman and Tversky(1979).

3. Prospect Theory Vs Utility Theory

Prospect Theory has a made a substantial contribution by offering a framework to understand decision making under uncertainty. While there are many similarities, Prospect Theory differs from Utility Theory in the following ways.

- Prospect theory defines a value function which deviates from the reference point, it is generally concave for gains and convex for loss and is steeper for losses than for gains.
- Instead of the objective probabilities used in Utility Theory, Prospect Theory introduced decision weights, $\pi(P_i)$, that reflect the impact of outcomes on the prospect's attractiveness. It was suggested that low probabilities are generally overweighed and high ones underweighed.
- Prospect theory treats choice situations involving strictly positive or negative outcomes differently than those involving zero and/or both positive and negative. In the former case, the sure gain or loss is factored out.
- Prospect Theory proposes an editing phase prior to the evaluation of the choice situations. Various

editing operations are suggested in order to simplify choice.

- Finally, the value function in Prospect Theory measures the subjective value of outcomes relative to some reference point that may vary as a function of problem presentation. The emphasis is on changes in wealth, not on final states as in Utility Theory.
- To summarize the features of the value function in Prospect Theory, the value function is defined on deviations from the reference point; generally concave for gains and commonly convex for losses; and steeper for losses than for gains.

Ⅶ. Application of Prospect Theory

This section applies Prospect Theory to the results and gives an explanation about the reason why people prefer certain charge route to uncertain charge route and the way uncertainty of charges increases influence drivers' preference on the route. The essential feature of the present theory is that people make a decision by evaluating changes or differences of outcomes rather than final outcomes.

1. Preference for Certain Charge Route

One of the main findings from section Ⅳ was that people much prefer route 1 with a precise and certain charge information over route 2 with an imprecise and uncertain charge. Considering the context of choice situation and applying Prospect Theory gives an explanation.

For example, three choice questions with a base charge £1.00 on route 1 are considered. In the editing phase, the questions are organised and reformulated to simplify the choice questions. By applying 'Coding' and 'Segregation' editing phases to questions, associated with 'Isolation Effect', the charges on both routes were segregated into risky and riskless components.

According to segregation, choice questions are decomposed into a sure loss of £1.00 on both routes and reformulated options. The reference point is defined as the median value of the ranges of the charges on route 2 which is the same value of the charge on route 1. This is because the model estimate results showed that the median value is important impact on their route choice than the ranges. The process of transforming the questions is shown in ⟨Table 6⟩.

In the 'Evaluation' phase, people evaluate and make a choice based on the transformed options. As it can be seen, route 1 gives no additional charge except the sure loss, while route 2 has still uncertain charges. Therefore, drivers prefer the route 1 with the sure loss over the route 2 with the uncertain loss. This is consistent with Certainty Effect in which any alternative with certainty outweighs uncertain outcomes. It is also explained in Reflection Effect of Prospect Theory that sure loss is preferred with low variation. This shows the way drivers approach the route choice decision between certain and uncertain charges and explains the way drivers prefer the certain charge to the uncertain charge.

⟨Table 6⟩ Transformation of questions after coding and segregation operations

	Initial Choice		Choices after Segregation			
	Route 1	Route 2	Route 1		Route 2	
	Information	Information	Certain	Uncertain	Certain	Uncertain
Question 1	-£ 1.00	-(£0.90-£1.10)	-£ 1.00	0	-£ 1.00	-£0.10~£0.10
Question 2	-£ 1.00	-(£0.80-£1.20)	-£ 1.00	0	-£ 1.00	-£0.20~£0.20
Question 3	-£ 1.00	-(£0.70-£1.30)	-£ 1.00	0	-£ 1.00	-£0.30~£0.30

2. Preference for Increase of Uncertainty

It was also found in section Ⅳ that as the range of the charge on a route increases, the preference for the route with uncertain charges slightly increases. However, drivers still prefer the route1 with the certain charge.

The same examples of the questions from the previous section were used, which have the base charge £1.00 on route1. Transformed questions after application of 'Segregation' editing phase are shown in ⟨Table 6⟩.

When people make the three sequential choices, they tend to ignore common components. In this example, sure loss of £1.00, which are common between two routes are ignored and respondents focus on the different charges between questions. Application of 'Cancellation' implies that respondents might consider the serial questions in the SP survey not separately but sequential. That is, their decision was based on the difference between questions rather than the difference between route 1 and route 2. Thus 'Cancellation', editing phase is applied to the reformulated questions and three questions become two sequential questions shown in ⟨Table 7⟩.

These transformed questions show the way when drivers make sequential choices, the three separate questions become two relevant questions and they focus on the different charges on route 2 in the different questions. The Reflection Effect in Prospect Theory suggests that in negative domains(of which this is surely one since we are dealing with charges) decision makes will be risk seeking and so prefer the ±30 pence to the ±20 pence. This indicates why as the amount of the uncertainty of the charges on route 2 increases, the preference for route 2 slightly increases.

⟨Table 7⟩ Transformation of questions after Cancellation

	Values of Charges (£) on route 2	
Sequential question 1′	Question 1	Question 2
	-£0.10~+£0.10	-£0.20~+£0.20
Sequential question 2′	Question 2	Question 3
	-£0.20~+£0.20	-£0.30~+£0.30

3. Discussion

This section applied Prospect Theory to the results in order to interpret the results and give an explanation. Application of Prospect Theory explains the way drivers may be interpreting the choice situation and how they make a route choice in response to uncertain charges. The process of editing and reformulating options shows that inconsistency of the two findings are, in fact, caused by different choice context, which drivers approach and interpret differently. The inconsistent results were that drivers prefer to avoid an uncertain charge, while they show a tendency of preferring a very uncertain charge. In the first finding, drivers focus on the difference of the charges between routes, while in the second finding, people are considering the change of charges between questions. Therefore, it is possible that these two findings contain totally different matters. As Kahneman and Tversky(1979) pointed out, the way people edit and simplify the choice context causes inconsistent preference.

Ⅶ. Conclusion and Further Studies

This paper explores the way and the extent to which drivers′ decision making was influenced by uncertain information in details.

We apply the Prospect Theory to the analysis of drivers′ decision making under uncertain information. We compared the analysis of the existing Random Utility theory with those of Prospect Theory. We use route choice decision making context the variable road user charges information. In this study in order to present the degree of uncertainty we use the size of ranges of estimates of charge as the quantitative measures of uncertainty.

The main findings are first, drivers tend to prefer a route with information than one without information. This indicated that providing charge information encouraged drivers to choose the routes for which information is provided in preference to those for which it is not provided. Secondly, drivers also prefer a route with a certain and precise information over one with uncertain and imprecise information, which is given with ranges. Thirdly, when the information is given as a range, the size of the range of the information influenced route choice slightly and as the range of the charge increases, the route becomes slightly less unattractive. Fourthly, when the information is given as a range, drivers' route choices are influenced more by the median value of the ranges than by the size of the overall ranges of the information.

In the second finding, drivers show their preference for avoiding uncertain charges, while in the third finding they also show a tendency of preferring a very uncertain charge, more than a somewhat uncertain charge.

Application of Prospect Theory to the inconsistent results explains the way drivers may be interpreting the choice situation and how they make a route choice in response to uncertain information. The process of editing and reformulating options shows that inconsistency of the two findings are, in fact, caused by different choice context, which drivers approach and interpret differently.

The results of this paper implicate that drivers' decision making under uncertainty seem not to be simple like risk-averse or risk-seeking but to be very complicated and flexible, depending on the way drivers interpret the choice situation.

In this paper we only apply the main concepts and phases of interpreting drivers' decision makings. The essential assumption of Prospect Theory is that the carriers of value are changes in the evaluation of changes or differences rather than to the evaluation of absolute magnitudes. It is recommendable to apply Prospect Theory to in-dept analysis of uncertain information choice behaviours. It is also recommended to apply wider related theories to the analysis of the drivers behaviour(which deal with decision making under uncertainty).

One of key features of Prospect Theory is that drivers interpret the choice situation via a decomposition of the choice situation into gains and losses with respect to expected outcomes. We can find examples with ease which Prospect Theory may be applied.

For example, there is a driver who drives every morning to his work place. If a charge is given to him which is less than he usually paid and expected to be, he may consider the difference of the charges as a gain. This is explained by 'Segregation' editing phase and 'shift of reference point' in Prospect Theory. This may influence his decision making differently.

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Traffic separation schemes have now been established in most of the major routes and congested waters of the world, and the number of collisions and groundings have often been dramatically reduced. In this part, the relationship between the alleviation of ship handling difficulty and the reduction of encounter figures among ships is quantitatively clarified by applying the ES model.

As results of simulation analysis, it is recognized that a traffic separation system is most effective in the case of narrow width and heavy traffic volume. The centre buoy installation reduces about 1/4 of the alleviation of ship handling difficulty, TSS establishment 1/3, and design change to one-way traffic from two-way traffic reduces 1/2.

Selection of the Optimal Location of Traffic Counting Points for the OD Travel Demand Estimation

LEE, Seungjae · LEE, Heonju

The Origin-Destination(OD) matrix is very important in describing transport movements in a region. The OD matrix can be estimated using traffic counts on links in the transport network and other available information. This information on the travel is often contained in a target OD matrix and traffic counts in links. To estimate an OD matrix from traffic counts, they are the major input data which obviously affects the accuracy of the OD matrix estimated, Generally, the quality of an estimated OD matrix depends much on the reliability of the input data, and the number and locations of traffic counting points in the network. Any process regarding the traffic counts such as the amount and their location has to be carefully studied.

The objective of this study is to select of the optimal location of traffic counting points for the OD matrix estimation. The model was tested in nationwide network. The network consists of 224 zones, 3,125 nodes and 6,725 links except to inner city road links. The OD matrix applied for selection of traffic counting points was estimated to 3-constrained entropy maximizing model.

The results of this study follow that : the selected alternative to the best optimal counting points of six alternatives is the alternative using common links of OD matrix and vehicle-km and traffic density(13.0% of 6,725 links), however the worst alternative is alternative of all available traffic counting points(44.9% of 6,725 links) in the network. Finally, it should be concluded that the accuracy of reproduced OD matrix using traffic counts related much to the number of traffic counting points and locations.

A Transit Assignment Model using Genetic Algorithm

LEE, Shinhae · CHOI, Injun ·
LEE, Seungjae · LIM, Kang-Won

In these days, public transportation has become important because of serious traffic congestion. But, there are few researches in public transportation compared with researches in auto. Accordingly, the purpose of paper is development of transit assignment model, which considers features of public transportation, time table, transfer, capacity of vehicle, common line, etc.

The transit assignment model developed in this paper is composed of two parts. One part is search for optimum path, the other part is network loading. A Genetic algorithm has been developed in order to search for alternative shortest path set. After the shortest paths have been obtained in the genetic algorithm, Logit-base stochastic loading model has been used to obtain the assigned volumes.

Effect of uncertain information on drivers' decision making(Application of Prospect Theory)

CHO, Hye-Jin · KIM, Kang-Soo

This paper explores the way and the extent to which drivers' route choice was influenced by uncertain information. In particular, this paper investigates the effect of qualitative information on route choice when drivers face a choice with different degrees of uncertain information. The SP survey was conducted and route choice logit models were estimated. We also applied Prospect Theory to the analysis of drivers' decision making under uncertain information.

The main findings are firstly, drivers tend to prefer a route with information than(to) one without information. This indicated that providing charge information encouraged drivers to choose the routes for which information is provided in preference to those for which it is not provided. Secondly, drivers also prefer a route with a certain and precise information over one with uncertain and imprecise information. Thirdly, when the information is given as a range, the size of the range of the information influenced route choice slightly and as the range of the charge increases, the route becomes slightly less unattractive. Fourthly, when the information is given as a range, drivers' route choices are influenced more by the median value of the ranges than by the size of the overall ranges of the information.

Application of Prospect Theory to the results explains the way drivers may be interpreting the choice situation and how they make a route choice in response to uncertain information. The results of this paper implicate that drivers' decision making under uncertainty seem to be very complicated and flexible, depending on the way drivers interpret the choice situation. Therefore, it is recommended to apply wider related theories to the analysis of the drivers' behaviour.

A Study on Link Travel Time Prediction by Short Term Simulation Based on CA

LEE, Seungjae · CHANG, Hyunho

There are two goals in this paper. The one is development of existing CA(Cellular Automata) model to explain more realistic deceleration process to stop. The other is the application of the updated CA model to forecasting simulation to predict short term link travel time that takes a key rule in finding the shortest path of route guidance system of ITS.

Car following theory of CA models don't makes not response to leading vehicle's velocity but gap or distance between leading vehicles and following vehicles. So a following vehicle running at free flow speed must meet steeply sudden deceleration to avoid back collision within unrealistic braking distance. To tackle above unrealistic deceleration rule, "Slow-to-stop" rule is integrated into NaSch model. For application to interrupted traffic flow, this paper applies "Slow-to-stop" rule to both normal traffic light and random traffic light. And vehicle packet method is used to simulate a large-scale network on the desktop.

Generally, time series data analysis methods such as neural network, ARIMA, and Kalman filtering are used for short term link travel time prediction that is crucial to find an optimal dynamic shortest path. But those methods have time-lag problems and are hard to capture traffic flow mechanism such as spill over and spill back etc. To address above problems, the CA model built in this study is used for forecasting simulation to predict short term link travel time in Kangnam district network. And it's turned out that short term prediction simulation method generates novel results, taking a crack of time lag problems and considering interrupted traffic flow mechanism.

A Route Search of Urban Traffic Network using Fuzzy Non-Additive Control

LEE, Sang Hoon · KIM, Sung Hwan

This paper shows alternative route search and preference route search for the traffic route search,