INTEGRATING THE CONCEPTS OF RELATIVE UTILITY AND PROSPECT THEORY CURVATURE TO REPRESENT CONTEXT DEPENDENCE IN TRAVEL CHOICE BEHAVIOR

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ABSTRACT

This study attempts to integrate the concepts of relative utility and prospect to represent the context dependence in travel choice behavior. Relative utility argues that utility is only meaningful relative to some reference point(s) and it conceptually allows the existence of multiple reference points. Prospect theory argues that people's decisions tend to be more sensitive to losses than to gains, where gains and losses are defined with respect to a reference point. One of the disadvantages of the prospect theory is that only one single reference point is usually adopted and there is no clue how to specify the reference point. On the other hand, even though the concept of relative utility could accommodate nonlinear utility structures, no study has been done to capture the non-linearity caused by people's asymmetric responses to gains and losses. The effectiveness of the integrated model is confirmed using an SP data with 1872 samples on the joint choice of departure time and driving route under the provision of dynamic travel information, collected in Beijing of China in May 2008.

Keywords*:* Relative utility, prospect, gain and loss, departure time and route choice, Beijing

INTRODUCTION

Choice behavior is highly adaptive and context-dependent from a psychological viewpoint (Tversky and Simonson, 1993; McFadden, 2001). Kahneman and Tversky (1979) argued that choice behavior depends on the status quo or reference point and a change of reference point may lead to preference reversal. Considering that the development of travel behavior models aims at supporting policy decisions, it is therefore important to properly define the context dependence in order to avoid any seriously biased inferences. In response to this argument,

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Zhang et al. (2004) re-classified the context into alternative-specific context, circumstantial context, and individual-specific context, and formulated a relative utility model that uses these reference points as anchor points. Conceptually, it is assumed that an individual evaluates an alternative in a choice set in comparison with other alternatives (*alternative-oriented relative utility*), or with the alternatives that the individual has chosen in the past (might be also in the future) (*time-oriented relative utility*), or with the alternatives chosen by other individuals (*individual (or decision maker)-oriented relative utility*). Circumstantial context further suggests that such decision-making mechanisms might vary with contextual factors (e.g., weather and economic situation), which are common to all individuals (decision makers) under study.

As a theory of decision making under uncertainty, Kahneman and Tversky (1979) proposed the prospect theory, where prospects are coded in terms of gains and losses with respect to a reference point rather than in terms of final wealth. They found for gambling behavior that people's decisions tend to be more sensitive to losses than to gains. Generally speaking, utility and prospect are two completely different concepts. Moreover, although it is not readily evident that prospect theory is necessarily a sound theory for daily travel decisions (Timmermans, 2009), the curvature of the model may be useful in some travel contexts.

In traditional utility theory, utility is often defined over final wealth. Different from the concept of traditional utility, relative utility argues that utility is a completely relative concept and it is only meaningful relative to some reference point(s). In this sense, the concept of relative utility is similar to the prospect. Both relative utility and prospect emphasize the existence of reference point(s) in people's choice decisions. As clarified by the prospect theory, change of reference could result in the reverse of preference. Therefore, it becomes important how to define the reference point(s) in a more rational and convincible way. However, the prospect theory has not clarified how to define the reference point(s) and it usually adopts one single reference point. However, in reality, there might be two or more reference points. Different from the concept of prospect, the concept of relative utility conceptually allows the existence of multiple reference points, as seen from the above three types of relative utility. More importantly, even for the same type of relative utility, for example, in case of the alternative-oriented relative utility, it allows comparisons with all the alternatives in a choice set to define the relative utility of an alternative under study. Even though relative utility could be used to capture nonlinear utility structures, no study has been done to capture the nonlinearity caused by people's asymmetric responses to gains and losses.

To provide an additional modelling approach, this study attempts to integrate the concepts of relative utility and prospect by making full use of their advantages and overcoming their shortcomings. Taking the alternative-oriented relative utility as an example, this study first defines it as the weighted summation of the differences between the utility of an alternative under study and the utilities of other alternatives in choice set, where the weight is used to reflect individuals' relative interest in the alternative (i.e., the relative importance of the alternative in choice set). This definition follows Zhang et al. (2004). When taking the difference of a variable between two alternatives, gains and losses could be observed. Existing studies (see Zhang et al., 2004; Zhang and Fujiwara, 2004) has treated the gains and losses equally when evaluating the utility. To reflect the asymmetric responses to gains and losses, this study applies the idea given in the prospect theory.

To clarify the effectiveness of the above integrated travel choice model, we use an SP (stated preference) data on the joint choice of departure time and driving route. The SP survey was designed and implemented in May 2008 to evaluate the effects of dynamic travel information on relaxing serious traffic congestion in Beijing, China. As a result, 624 drivers provided 1,872 valid SP responses. In fact, this survey was the first SP survey focusing on dynamic route guidance information in China at the time of survey.

The rest of the paper is organized as follows. First, the integrated travel choice behavior model is developed. Third, the SP data is summarized. Forth, the model is estimated and discussed in comparison with some existing models. Finally, the study is concluded along with a discussion about future research issues.

MODEL DEVELOPMENT

Relative utility theory

The concept of relative utility has its roots in the research about income (van de Stadt et al, 1985). Duesenberry's (1949) relative income hypothesis is probably the best-known example of a theory that rests on the concept of relative utility. Zhang et al. (2004) argued that an individual (or a decision maker) evaluates an alternative by comparing it to other alternatives in a choice set, or perhaps to the alternatives that the individual chose in the past, or to the alternatives chosen by other persons. More specifically, three types of relative utilities can be defined, depending on whether it focuses on an alternative (*i*), a decision maker (*n*), or time (*t*). Even though the time dimension refers to the past behavior in Zhang et al. (2004), it could also be the future behavior when people make a decision considering the future expectation. The influence of future expectation on travel choice behavior has been confirmed in our previous study (Wang et al., 2009). To accommodate all the above aspects in travel behavior models, it is necessary to develop a systematical framework. The three types of relative utility are conceptually defined below.

(1) Alternative-oriented relative utility
Dealing with alternatives in a choice set as reference points, this type of relative utility U_{nit} of alternative *i* that decision maker *n* derives at time *t* is defined as a function of the standard utility u_{nit} of the alternative *i* and the standard utility $u_{njt}\{j \neq i\}$ of other alternatives in the choice set.

$$U_{nit} = f\{u_{nit} \mid (u_{njt} : \forall \ j \neq i)\} \quad (1)$$

(2) Time-oriented relative utility
This type of relative utility assumes alternatives in the past or in the future as reference points, and it focuses on both alternatives and time. The relative utility U_{nit} is defined as a function of u_{nit} and $u_{njt'}$, where *t'* refers to the previous or future point of time.

$$U_{nit} = f\{u_{nit} \mid (u_{njt'} : t' \neq t \ and \ \forall \ j)\} \quad (2)$$

(3) Decision maker-oriented relative utility

This type of relative utility argues that a decision maker makes a choice by considering the existence of other persons, which could be a small group of persons like household members, or an unspecified group of persons (e.g., neighborhood, younger generation). These persons form the social reference group for the decision maker. This type of relative utility U_{nit} is defined as a function of u_{nit} and $u_{n'jt}$, with respect to both individuals (decision makers) and alternatives, where *n'* refers to the social reference group for individual *n*.

$$U_{ni,t} = f\{u_{nit} \mid (u_{n'jt} : \; n' \in social \;\; reference \;\; group)\} \tag{3}$$

Since this is the first time to integrate the concepts of relative utility and prospect, for simplifying the discussion, this study only deals with the first type of relative utility, i.e., the alternative-oriented relative utility, at a given time point. For the sake of simplifying model description, hereafter, the subscript *t* is omitted. Following Zhang et al. (2004), this type of relative utility can be specified concretely as follows, where r_{ni} indicates the relative interest of decision maker *n* in the alternative *i* and it can take any real value.

$$U_{ni} = r_{ni} \sum\nolimits_{j \neq i} (u_{ni} - u_{nj}) \tag{4}$$

Considering that the relative utility U_{ni} is defined as the difference of standard utilities and the fact that the smaller the difference between the attributes of two alternatives, the similar the two alternatives, U_{ni} can be also used to represent the alternative similarity. Furthermore, it can be interpreted that U_{ni} regards the standard utilities of all other alternatives except for the alternative *j* of interest as the reference points. Therefore, we can adopt this concept of relative utility as an alternative means of representing context dependence in choice models. Comparing with the prospect theory, this type of relative utility includes *I-1* reference points, where *I* is the number of alternatives in choice set.

In addition, conventional choice models assume that individuals recognize different alternatives in the choice set equally. This assumption can be easily violated in real situations since individuals are usually more interested in one alternative than in another. To accommodate such unequal evaluations of alternatives in choice set, r_{ni} is introduced. The greater the relative interest r_{ni}, the more important the individual attaches to the choice of the alternative in question, vice versa. For the ease of interpretation, it is usually assumed that r_{ni} > 0 and $\sum_i r_{ni}$ =1. In the relative utility theory, choice models are developed under the following principle of relative utility maximization.

> ***The principle of relative utility maximization***
> *An individual is assumed to choose an alternative with the highest relative utility considering his/her relative interests in alternatives from his/her choice set, where the relative utility reflects the context- dependence and the relative interest represents the relative importance of different alternatives.*

By assuming all the relative interest parameters to be equal, the relative utility maximization comes to the maximization of standard utility. This implies that the choice models based on relative utility can include those based on the standard utility as special cases.

Assume that the relative utility U_{ni} consists of a deterministic term V_{ni} and an error term ε_{ni} as follows, where v_{ni} describes the influence of the observed information on alternative *i* and v_{nj} represents the influence of other alternatives in choice set.

$$U_{ni} = r_{ni} \sum_{j \neq i} (u_{ni} - u_{nj}) = V_{ni} + \varepsilon_{ni} = r_{ni} \sum_{j \neq i} (v_{ni} - v_{nj}) + \varepsilon_{ni} \quad (5)$$

Equation (5) assumes that analysts know the relative utility is a linear combination of deterministic term and error term, but do not know exactly about the standard utility since the utility is a relative concept and meaningful only in the presence of some reference point(s). Then, the choice probability can be expressed as,

$$P_{ni} = \Pr\{U_{ni} > U_{nj}, \forall\ j \neq i\} = \Pr\{V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}, \forall\ j \neq i\}\ . \quad (6)$$

Different assumptions on the error terms lead to different choice models. This definition of relative utility provides an alternative way of representing substitution/similarity effects and has two important features. First, it introduces the influence of other alternatives on the utility of the alternative under consideration based on the utility comparisons as opposed to adding the utility of other alternatives. Second, it does not impose any extra restriction on the error terms compared with most of the existing non-IIA models. In this sense, this relative utility can be directly incorporated into almost all of the existing choice models, to represent substitution/similarity effects.

Prospect theory

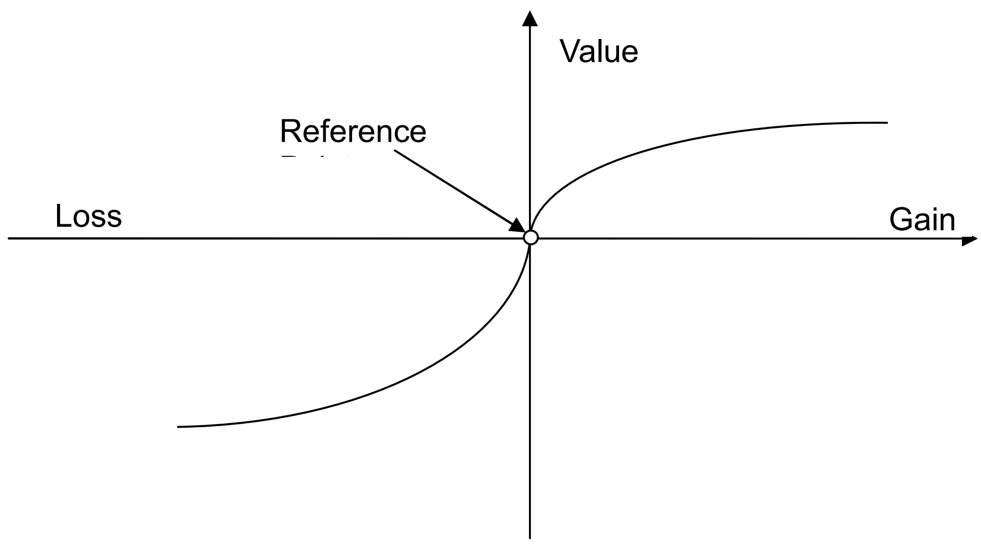

Figure 1. Value Function in Prospect Theory

The prospect theory was proposed to explain the major violations of expected utility theory in choices between risky prospects with a small number of outcomes (Kahneman and Tversky, 1979; Tversky and Kahneman, 1986). It is argued that people's decisions are more sensitive to losses than to gains. To reflect such mechanism, a value function (see Figure 1 and equation (7)) is usually adopted, and it is concave for gains, convex for losses, and steeper for losses than for gains.

$$v(x)=\begin{cases} x^{\alpha} & if\ x\geq 0 \\ -\lambda(x)^{\beta} & if\ x<0 \end{cases} \tag{7}$$

The parameter λ, which is equal to or larger than 1, describes the degree of loss aversion. The parameters α and β, which are equal to or smaller than 1, measure the degree of diminishing sensitivity. The case in which α is equal to β is equal to 1 represents the case of pure loss aversion. Tversky and Kahneman (1992) estimated that α is equal to β, which is equal to 0.88 and that λ is equal to 2.25.

Integrating relative utility and prospect

This study deals with a joint choice of departure time and driving route. In this case, driver*s* may define the gains and losses in various ways. Drivers may compare the travel time of a route with that experienced by drivers previously, which might be average travel time, maximal travel time, or minimal travel time. They may compare the travel time with that of some alternative routes. They may also compare the travel time with that experienced by other drivers. This choice situation is consistent with the argument of the relative utility. As shown previously, the relative utility could conceptually accommodate all the above considerations in a unified and consistent way. The above behavioral mechanisms require the existence of multiple reference points. To respond to this requirement, the relative utility could be applied.

The integrated new utility function is specified as follows:

$$U_{ni}=r_{ni}\{\sum_{j\neq i}[\sum_{k}(\gamma_k^{+}(d_{nij,k}^{+}\Delta x_{nij,k})^{\alpha}-\gamma_k^{-}\lambda(-d_{nij,k}^{-}\Delta x_{nij,k})^{\beta})]+\sum_{s}\mu_s z_{ns}\}+e_{ni}\,, \tag{8}$$

$$0\leq r_{ni}\leq 1,\ \sum_{i} r_{ni}=1\,. \tag{9}$$

There are two types of explanatory variables: alternative-generic variables (z_{ns} : the *s*th variable introduced to the utility function) such as age, sex, and driving license ownership, and alternative-specific variables (e.g., travel time, travel cost, and waiting time). Since gains and losses occur when comparing an alternative-specific variable ($x_{ni,k}$: the *k*th variable of alternative *i*) between two alternatives, here, the variable difference between alternatives *i* and *j* is defined as $\Delta x_{nij,k}$ = $x_{ni,k}$ - $x_{nj,k}$. Two dummy variables are further introduced: dummy variable $d_{nij,k}^{+}$ is set to 1 if $\Delta x_{nij,k}$ is non-negative, otherwise 0; and dummy variable $d_{nij,k}^{-}$ is set to 1 if $\Delta x_{nij,k}$ is negative, otherwise 0, where $d_{nij,k}^{+}\Delta x_{nij,k}$ represents the gain and $-d_{nij,k}^{-}\Delta x_{nij,k}$ indicates the loss. Parameters *α* and *β* determine the convexity/concavity of the utility function, and *λ* describes the degree of loss aversion. Finally, e_{ni} is an error term.

DATA

This study adopts an SP data collected in Beijing, China. The survey was about how drivers in Beijing make a joint choice of departure time and driving route under the dynamic travel information provision.

Background

Transportation networks in Beijing have been remarkably improved; until September 2009, Beijing has built six ring roads. However, traffic congestion is still very serious due to the rapid growth of automobile ownership. The ownership of automobile growth rapidly since 1990, from 1.0 to 3.0 million vehicles it took 10 years, and moreover, from 3.0 to 4.0 million vehicles it took only two years and seven months. At the end of August 2009, the total number of automobiles have surpassed 4.0 million vehicles (the number of automobiles increased with the speed of 1,000 vehicles per day). To relax the traffic congestion in Beijing, of course, various measures should be taken, especially from the perspective of promoting the use of public transportation systems and non-motorized travel modes. Number plate control measure has been effectively taken prior to the opening of the Olympic Game. It is also planned to construct more subway lines. To drastically solve the traffic congestion issue, land use development should be further controlled and transit-oriented development should be more actively promoted. On the other hand, effective use of existing road network should not be ignored. Especially, since Beijing city has a grid street structure, circled with six ring roads, there are many alternative routes for a driver to choose from an origin to a destination, making the choices complicated. To help drivers' route choices, experiences in Japan and other developed countries suggest that ITS technologies could be helpful. This motivated us to evaluate the effects of dynamic travel information on drivers' route choice behavior as well as departure time choice behavior.

Survey design

In the SP survey, in total, four joint choice alternatives are assumed: trunk road during off-peak hours, ring road, trunk road, and branch road during peak hours. The assumed attributes for choice are shown in Table 1 and levels for each attribute were set based on a pilot survey and opinions of some transportation experts in Beijing. All of the attributes are statistically combined together to form a set of attributes for SP choice tasks by applying orthogonal table method to guarantee the independence among attributes. As a result, 16 SP profiles were obtained. Furthermore, the probability for arrival time delay in off-peak hours is set at 0% (i.e., early arrival) and travel time for trunk road in off-peak hours is also fixed. In addition, in-home activity time before departure was selected as the choice context variable. Drivers were told if they chose peak hours for departure, they would have 2 hours to stay at home; on the contrary, they would only have 30 minutes to stay at home if they chose departure during off-peak hours. It is expected that in-home activity time might affect departure time choice.

In order to reflect traffic conditions in Beijing, four areas were selected to capture typical OD (origin and destination) trips and to service as survey areas. The above-mentioned travel distance and travel time were calculated based on the selected four areas. Besides that, the geographic distribution of the four areas is independent and located in four orientations separately, therefore it is expected that the general geographic characteristic of driver population in Beijing could be observed.

- CBD (Central Business District): It represents the area with commercial function and is located between the famous WangFuJing street and Beijng station
- WangJing District: It represents the area with residential function and is located in the northeastern area between the 4th and 5th ring roads (close to Beijing Airport).
- ZhongGuanCun District: It represents the area with educational and IT-related functions and is located in the northwestern area between the 3rd and 5th ring roads.
- The Second Office Area: It represents the governmental function area and is located the southern area between the 2nd and 3rd ring roads.

Table 1. Assumed Attributes and Levels

Attributes	Levels
Travel purpose	Business and Recreation
Error of dynamic travel information prediction	Big (30%) and Small (10%)
Timing constraint for arrival time	whether being late is allowed or not
Travel distance for the three routes	Long-, Medium- and Short-distances
Travel time for ring road in peak hours	Long and Short Time
Travel time for trunk road in peak hours	Long and Short Time
Travel time for branch road in peak hours	Long and Short Time
Probability of arrival time delay when using rind road in peak hours	Low (20%) and High (60%)
Probability of arrival time delay when using trunk road in peak hours	Low (20%) and High (60%)
Probability of arrival time delay when using branch road in peak hours	Low (20%) and High (60%)

As the final SP choice task, respondents were asked to choose one out of the four alternatives under the following two cases for each SP profile, assuming that the dynamic travel information is provided via an in-vehicle personal navigation device (PND). Individual attributes and actual travel behavior were also reported. This study only uses the data about Case 1. It is a straightforward way to extend our analysis into the analysis of Case 2.

- Case 1: Refer to dynamic travel information
- Case 2: Do not refer to dynamic travel information

Survey implementation

The SP survey was conducted using the face-to-face interview at major parking facilities of the above four survey areas in May 21~23, 2008 with the help of local university students. Drivers who parked their cars at the selected parking facilities of the four survey areas were randomly reached and as a result, 624 drivers agreed to participate in the survey and 2,496 valid SP responses were successfully obtained in total. For this study, 1,872 valid SP responses were extracted by excluding some SP profiles with three alternatives.

MODEL ESTIMATION

Models to be estimated

Since the developed integrated choice model combines the concepts of relative utility and prospect, in addition to estimating the integrated model, we also estimated the following three existing models: the relative utility model, the prospect model, and the traditional multinomial logit model. The utility functions of these additional models are given below.

1) Relative utility model
The relative utility function is defined below.

$$u_{ni} = r_{ni}\{\sum_{j\neq i}\sum_k \gamma_k (x_{ni,k} - x_{nj,k}) + \sum_s \mu_s z_{ns}\} + e_{ni} \tag{10}$$

To define the relative utility of alternative *i*, conceptually, equation (10) could be extended to allow unequal influences of other alternatives in choice set. To do so, a new weight parameter w_{nij} is usually introduced to incorporate the relative influence of the term $\sum_k \gamma_k (x_{ni,k} - x_{nj,k})$ in the form of $w_{nij}\sum_k \gamma_k (x_{ni,k} - x_{nj,k})$ on the choice of alternative *i* (Zhang and Fujiwara, 2004). One of the troublesome issues when introducing this weight parameter is that with increase of the alternatives in choice set, the number of weight parameters becomes very large, sometimes making model estimation unstable when the sample size is small. For simplifying the discussion on the integration of relative utility and prospect, we ignore this weight parameter in this study.

2) Prospect model
For the prospect model, the utility function is rewritten as follows based on equation (8).

$$u_{nj} = \{\sum_{j'\neq j}[\sum_k (\gamma_k^+ (d_{njj',k}^+ \Delta x_{njj',k})^{\alpha} - \gamma_k^- \lambda(-d_{njj',k}^- \Delta x_{njj',k})^{\beta})] + \sum_s \mu_s z_{ns}\} + e_{nj} \tag{11}$$

Note that gains and losses are defined with respect to each alternative-specific variable.

3) Multinomial logit (MNL) model
The MNL model is the most popular model to describe travel choice behavior.

$$u_{nj} = \sum_k \gamma_k x_{nj,k} + \sum_s \mu_s z_{ns} + e_{nj} \tag{12}$$

This study adopts an SP survey data on the joint departure time and driving route choice behavior. To explain the choice behavior, the SP survey incorporated a set of variables. Since this study will not attempt to explore the best set of variables to explain the behavior, we arbitrarily selected the following variables based on a preliminary study.

Level-of-service variables
There might be various factors affecting the departure time and driving route choice behavior.

Since the SP was designed to evaluate the effects of dynamic travel information, in the survey we introduced two time variables: travel time on each route and activity time at home before departure. It is expected that the travel time will negatively influence the target choice behavior and the activity time will have some positive effects on the choice. Since the preliminary study confirmed that a composite variable by combining the two time variables, which is shown below, performs better than introducing them separately into the model, we decided to adopt this composite time variable. It is expected that the larger the value of this composite variable, the higher the probability that an alternative will be chosen, i.e., its parameters should be positive.

Composite time variable (ATTT) = Activity time at home divided by travel time

In the integrated model and the prospect model, we need to define gains and losses. Here we only define the gains and losses related to the above composite variable. Intuitively, it is much more understandable to separately define the gains and losses with respect to the activity time and the travel time. Since the preliminary study confirmed that using this composite variable resulted in relatively high model accuracy, we decided to define the gains and losses only related to this composite variable. Note that this composite variable is an alternative-specific variable.

Other alternative-specific variables

Since the SP survey only introduced the above activity time and travel time as the alternative-specific variables, to improve the model accuracy, we tried to independently introduce some alternative-generic variables into the utility functions of different alternatives. This selection was done based on behavioral considerations, but it is still arbitrary without a sound behavioral support. Traditionally, analysts usually introduce alternative-generic attributes simultaneously into the utility function without differentiating the roles of different alternative-generic attributes in explaining the choice behavior. It is not an easy task to properly assign the attributes to different utility functions, but it is worth exploring a systematical and rational way. This will be left as a future research issue. Based on the preliminary study mentioned previously, we selected sex, age, and timing constraint of arrival for the first alternative (i.e., ring road during peak hours), familiarity of road network for the second alternative (i.e., trunk road during peak hours), ownership of car navigation system and error of travel time prediction for the third alternative (i.e., branch road during peak hours), and trip purpose for the fourth and the last alternative (i.e., trunk road during off-peak hours).

Relative interest

In previous studies (e.g., Zhang and Fujiwara, 2004), we introduced some variables to explain the heterogeneity in the relative interest. Since the main purpose of this study is to clarify the effectiveness of integrating the concepts of relative utility and prospect, we directly estimated the relative interest parameters without defining it them as a function of some variables for the sake of simplifying the discussion.

In addition, we introduce a common constant term into the utility functions of the first three alternatives (i.e., the alternatives during peak hours) to explore the traveler's propensity of departing during peak and off-peak hours.

In the SP survey, two types of SP questions were presented, i.e., refer to dynamic travel information, and do not refer to dynamic travel information. Here the former type of SP data is used in this study to examine the proposed model. For the parameters of value function in prospect theory, during the model estimation, α and β are fixed at 0.88, and λ is set at 2.25, respectively, following Tversky and Kahneman (1992). This is because it is not easy to estimate these parameters endogenously, and for example, λ cannot be estimated jointly with γ_k^-. We leave the endogenous estimation of the above three prospect parameters for future research. Model estimation results are shown in Tables 2~5.

A comparison of model accuracy

The adjusted McFadden's Rho-square of the integrated model is the highest with the value of 0.0975, among the four models. Even though model accuracy is not high, it is good enough for us to show the effectiveness of the integrated model. To enhance the model accuracy, it might be necessary to segment the samples into different homogeneous groups. It might also be necessary to introduce more different types of explanatory variables. We further conducted the CHISQ test by comparing the integrated model with the remaining three models and found that the CHISQ values against the prospect model, the relative utility model, and the MNL model are 25.32, 22.54, and 35.94, which are all larger than the respective critical values (7.81 with DF=3, 3.84 with DF=1, and 9.49 with DF=4). These test results suggest that the developed integrated relative utility and prospect model is superior to existing models. Looking at the model accuracy as well as the CHISQ test results, it is confirmed that the relative utility model and the prospect model are almost equivalent, which both excel the MNL model. The above results justify the reason why the relative utility and prospect are combined together in this study.

To make a much clearer comparison, relative differences of choice probabilities between the integrated model and other models are first calculated in the following way.

Relative difference = (P(I) – P(O)) / P(O)

where, P(I) indicates the choice probability of the integrated model, and P(O) refers to that of one of the other three models.

The calculation results are shown in Figure 2, which include three figures. Samples on the horizontal axis are re-ordered with respect to the fourth alternative (i.e., trunk road during off-peak hours) for each figure. In this sense, samples in the three figures do not correspond with each other one by one. One can see that the relative differences range between -40% and 60%, suggesting serious biased estimation obtained from the other three models.

Table 2. Estimation Results of Relative Utility and Prospect Model

Explanatory Variables	Estimated Parameter (t-score in parenthesis)			
	Peak hours			Off-peak
	Ring road	Trunk road	Branch road	Trunk road
Alternative-generic parameters				
Constant term	-1.1321 (1.497)			
Gain of Composite Time	1.6468 (6.765)			
Loss of Composite Time	-0.4889 (4.847)			
Alternative-specific parameters				
Sex (1: Male, 0: Female)	0.0265			
Age	0.4315			
Timing constraint of arrival (1: Being later is permitted, 0:	3.2654			
Familiarity of road network in Beijing		-0.0708 (0.970)		
Ownership of car navigation system (1: Yes, 0: No)			-1.7973 (2.722)	
Error of travel time prediction (two levels: 10% and 30%)			0.1636 (0.235)	
Trip purpose (1: Business, 0: Recreation)				2.6943 (4.959)
Relative interest parameters				
Peak hours - Ring Road	0.1555			
Peak hours - Trunk Road		0.3436 (16.72)		
Peak hours - Branch Road			0.2540 (11.18)	
Off-peak hours - Trunk Road				0.2469 (11.26)
Initial log-likelihood	-2595.14			
Converged log-likelihood	-2342.15			
McFadden's Rho-square	0.0975			
Sample size (Person * SP profile)	1872			

Table 3. Estimation Results of Relative Utility Model

Explanatory Variables	Estimated Parameter (t-score in parenthesis)			
	Peak hours			Off-peak
	Ring road	Trunk road	Branch road	Trunk road
Alternative-generic parameters				
Constant term	-2.3866 (3.194)			
Composite Time	0.1698 (3.786)			
Alternative-specific parameters				
Sex (1: Male, 0: Female)	-0.3017			
Age	-0.1197			
Timing constraint of arrival (1: Being later is permitted, 0:	1.6989			
Familiarity of road network in Beijing		-0.5646 (0.871)		
Ownership of car navigation system (1: Yes, 0: No)			-0.2771 (0.823)	
Error of travel time prediction (two levels: 10% and 30%)			0.5809 (1.537)	
Trip purpose (1: Business, 0: Recreation)				11.462 (0.396)
Relative interest parameters				
Peak hours - Ring Road	0.2633			
Peak hours - Trunk Road		0.1045 (1.307)		
Peak hours - Branch Road			0.5870 (4.611)	
Off-peak hours - Trunk Road				0.0452 (0.392)
Initial log-likelihood	-2595.14			
Converged log-likelihood	-2353.42			
McFadden's Rho-square	0.0885			
Sample size (Person * SP profile)	1872			

Table 4. Estimation Results of Prospect Model

Explanatory Variables	Estimated Parameter (t-score in parenthesis)			
	Peak hours			Off-peak
	Ring road	Trunk road	Branch road	Trunk road
Alternative-generic parameters				
Constant term	-0.4924 (2.201)			
Gain of Composite Time	0.1470 (3.824)			
Loss of Composite Time	-0.0479 (2.111)			
Alternative-specific parameters				
Sex (1: Male, 0: Female)	-0.0634			
Age	0.0070			
Timing constraint of arrival (1: Being later is permitted, 0:	0.4711			
Familiarity of road network in Beijing		0.0087 (0.457)		
Ownership of car navigation system (1: Yes, 0: No)			-0.4245 (2.550)	
Error of travel time prediction (two levels: 10% and 30%)			0.0058 (0.033)	
Trip purpose (1: Business, 0: Recreation)				0.5505 (5.580)
Initial log-likelihood	-2595.14			
Converged log-likelihood	-2354.81			
McFadden's Rho-square	0.0888			
Sample size (Person * SP profile)	1872			

Table 5. Estimation Results of MNL Model

Explanatory Variables	Estimated Parameter (t-score in parenthesis)			
	Peak hours			Off-peak
	Ring road	Trunk road	Branch road	Trunk road
Alternative-generic parameters				
Constant term	-0.9076 (5.752)			
Composite Time	0.1209 (3.766)			
Alternative-specific parameters				
Sex (1: Male, 0: Female)	-0.0577			
Age	0.0248			
Timing constraint of arrival (1: Being later is permitted, 0:	0.4706			
Familiarity of road network in Beijing		-0.0065 (0.341)		
Ownership of car navigation system (1: Yes, 0: No)			-0.4519 (2.725)	
Error of travel time prediction (two levels: 10% and 30%)			0.0202 (0.115)	
Trip purpose (1: Business, 0: Recreation)				0.5071 (5.228)
Initial log-likelihood	-2595.14			
Converged log-likelihood	-2360.12			
McFadden's Rho-square	0.0871			
Sample size (Person * SP profile)	1872			

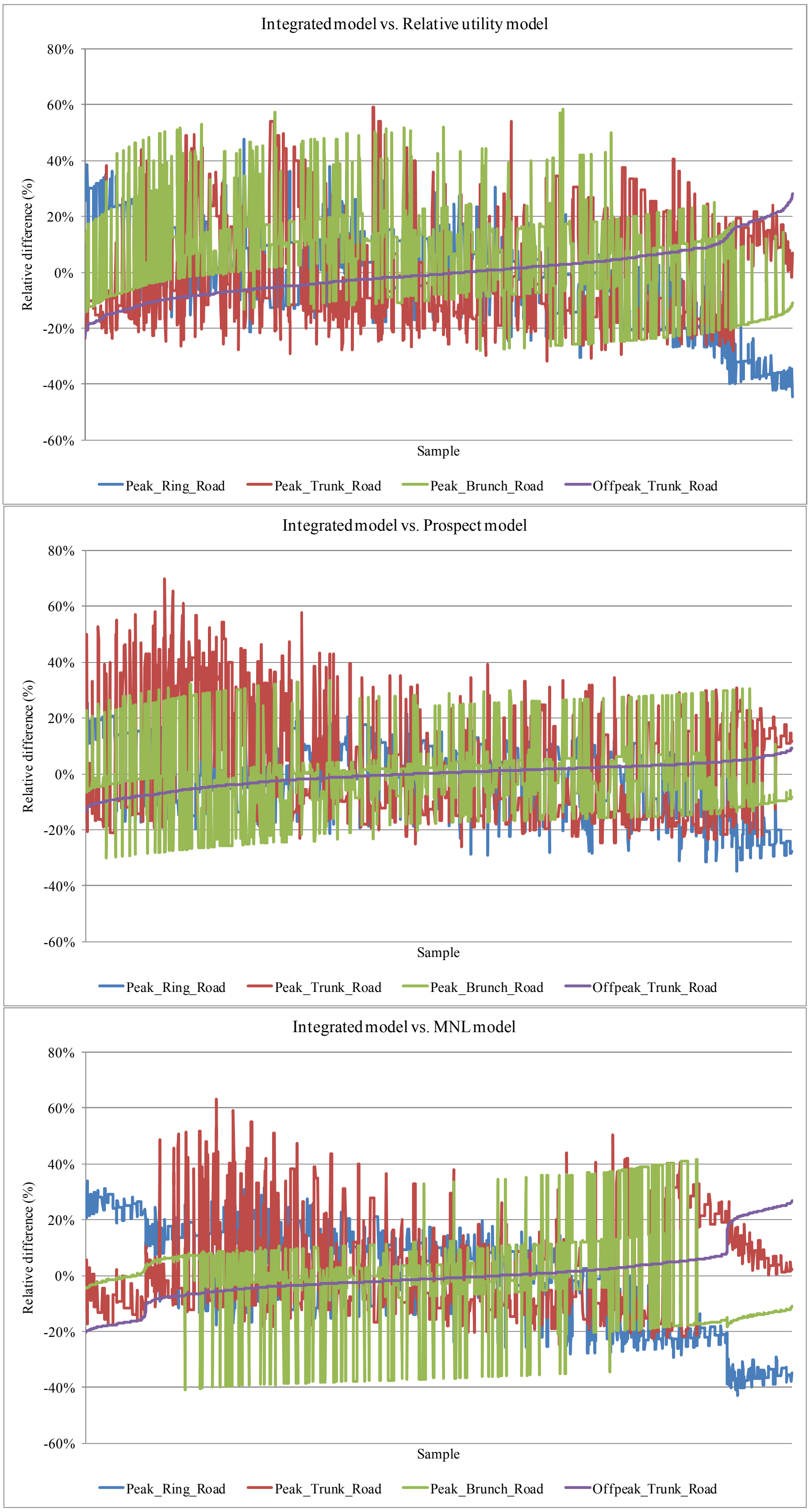

Figure 2. Relative differences of choice probabilities: Integrated model vs. other models

Gains/Losses and Relative Interests

In the integrated model, parameters of gains and losses are both estimated to be statistically significant at the 95% level, where the gains parameter is positive and that of losses is negative. In other words, drivers derive positive utility from gains of time and negative utility from losses. This is also true for the relevant parameters estimated from the prospect model. Comparing the relative influences of gains and losses parameters, the ratio of gains and losses is 0.30 in the integrated model and 0.33 in the prospect theory. Even though the discrepancy between the two models is not so large, both models support drivers' asymmetric responses to gains and losses.

Observing the relative interest parameter, the relative utility model estimated that drivers attach the lowest importance to the fourth alternative, i.e., the departure during off-peak hours (the parameter is 0.0452), and the highest is the third alternative with the relative interest parameter being 0.5870. In contrast, the lowest importance is found in the integrated model with respect to the first alternative, i.e., driving on the ring road during peak hours (the relative interest parameter is 0.1555), while the integrated model estimated that drivers show almost equivalent interests in the other three alternatives, even though relatively the off-peak hours are least preferred.

Performance of Explanatory Variables

All the models estimated a negative constant term. This means that drivers in Beijing prefer to drive during off-peak hours. This is understandable. In reality, even though Beijing is the only city in the world to have six ring roads, due to the rapid growth of car ownership and the concentration of urban functions at central urban areas, traffic congestion is extremely serious during peak hours.

Focusing on the composite time variables in the relative utility and the MNL models, their parameters are estimated to be positive at the 95% significance level, meaning that drivers prefer staying at home and dislike traveling a longer time.

For the introduced variables to play the roles of the alternative-specific variables, which were selected from the alternative-generic variables, first, the four models all estimated that drivers prefer to depart during off-peak hours for business trips. Intuitively, this is understandable because business drivers' time schedule is much stricter than other drivers and as a result, they tend to avoid the busy peak hours. We expected that error of travel time prediction may play an important role in influencing drivers' choice behavior. However, all the models estimated an insignificant influence of this error variable. We also expected that ownership of car navigation system might assist drivers to choose the branch road, but it was estimated to be negative in all the four models, and only the relative utility model got the insignificant parameter. In fact, at the time of survey, there was no dynamic route guidance system in China. The car navigation system owned by drivers could not provide reliable travel information on the branch road. In this sense, the estimated negativity of the car navigation system ownership is accountable. Familiarity of road network in Beijing is estimated to be insignificant in all the four models. Estimation results of the four models suggest that if being late is permitted, drivers prefer to use ring road during peak hours (the relevant parameters are all statistically significant with positive values). This might imply that drivers think that it is more convenient to perform various activities during peak hours. Concentration of traffic during peak hours supports this argument. Unfortunately, age and sex are not significant in any model.

CONCLUSION

Human behavior is context-dependent and people's responses to gains and losses in making choices are not always symmetric. In evaluating different alternatives in a choice set, people may not attach equal importance to each alternative. Such behavior mechanism can be also observed in travel behavior. However, little has been done in existing literature including transportation to simultaneously deal with these behavioral aspects. To fill in this gap, this study has proposed to integrate the concepts of relative utility and prospect, where the relative utility is used to represent the context dependence and relative importance of choice alternatives, and the prospect is applied to capture people's asymmetric responses to gains and losses. The integrated model can accommodate multiple reference points simultaneously in a more comprehensive way. Three types of reference points are conceptually specified with respect to alternatives in choice set, decision makers, and time. To the best of the authors' knowledge, no model has been developed to incorporate the influences of multiple reference points in literature including transportation.

In this study, we only dealt with the relative utility defined with reference to alternatives in choice set, and as a result, I-1 reference points are identified to serve as reference points to define the relative utility of an alternative, where I is the number of alternatives in choice set. The proposed integrated model is used to represent the joint choice of departure time and driving route in the context of Beijing, China based on an SP data collected from 620 drivers in May 2008. The sample size used in this study is 1,872 SP responses. Model estimation results showed that parameters related to the introduced gains and losses parameters as well as relative utility parameters are all statistically significant. The effectiveness of the integrated model was also confirmed by comparing three existing models, including the relative utility model, the prospect model, and the multinomial logit model.

The findings of this study have convinced us that integrating the concepts of relative utility and prospect could further deepen our understanding about travel behavior. This study should be extended to deal with other types of human decisions. Especially, we have proposed three types of reference points, but this study only examined one type of reference points. It is worth exploring the applicability of the other two types of reference points in explaining human behavior in the future. At the same time, it is also important to explore a robust set of reference points. Focusing on the estimation issues, this study adopted the parameters related to gains and losses from existing studies. Those parameter values may not best fit the data from both behavioral and statistical perspectives. Therefore, it is necessary to find a promising method to endogenously estimate those gains and losses parameters together with other parameters. The conceptual modeling framework proposed in this study should be examined using various sets of choice behavior data.

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