Loss Aversion Analysis in Route Choice Behavior

Kai Wang*1,2, Hongzhi Guan1,2, Yan Han1,2, Xiaojing XIA3

1. Beijing Key Laboratory of Traffic Engineering
   Beijing, China
2. Beijing University of Technology
   Beijing, China
3. Beijing E-Hualu Information Technology Co.,Ltd
   Beijing, China

Abstract — This paper demonstrates the existence and variety levels of loss aversion in travel behavior using a stated-preference survey and psychology experiment (sample size 76). Loss aversion is one of the key points that differentiate prospect utility from expected utility. Using a psychology experiment based on elicitation methods, this paper identifies loss aversion parameter in route choice behavior of each traveler. The results indicate that 60% percent of respondents show loss aversion with a median value of 1.27. So loss aversion can be found in traveler’s route choice behavior and heterogeneity is significant. The statistic result shows that the risk preference of commuters in loss domain is different from that in gain domain, as well the attributes of traveler contributing to risk preference are quite different. Linear discriminant analysis indicates that in gain domain travelers are more likely to be risk averse and personal socioeconomic characteristics contributing this. On the other hand, in the loss domain travelers are more likely to be risk seeking and traffic conditions relate to this. By looking into proportions of travelers choosing Route A and B, risk preference reversal under different loss aversion levels is found.

Keywords - Travel Behavior; Departure Time; Prospect Theory; Loss Aversion; Risk Preference

I. INTRODUCTION

Risk and uncertainty in Travel behavior have attracted many researchers’ attention in recent years. Prospect theory is widely used because of its advantage in dealing with risk and uncertainty in the decision process. Loss aversion, refers to a phenomenon people evaluate outcomes as gain and loss relative to a reference point and more sensitive to losses than gains, it is one of the main reasons for invalidation of expected utility comparing with prospect theory. This paper demonstrates the existence of loss aversion in commuters’ route choice behavior, heterogeneity of loss aversion in travel behavior is significant which should be considered in the modeling process. Risk preference is researched in gain domain and loss domain respectively, most people show risk aversion in gain domain and risk seeking in loss domain. Linear discriminant analysis shows travelers’ different attributes related to different risk preference when arriving early or late. At last risk preference reversal in route choosing is found under different loss aversion levels by looking into choosing proportion for different routes.

II. LITERATURE REVIEW

A. Definition of Loss Aversion

Loss aversion and risk preference in gain and loss domain are provided in prospect theory by Kahneman and Tversky (1992), the effort in this field is bearing fruit. Bleichrodt and Wakker (2001) believe the deviation of expected utility because of probability transformation and loss aversion. They defined loss aversion as a tendency that people overweight perceived losses relative to perceived gains. Paolo (2012) thinks loss aversion is an asymmetry in evaluation of gain choice and loss choices and loss is valued more heavily than gains. In RDSUE model they set loss aversion rang from 1 to 3. Hjorth and Fosgerau (2011) define loss aversion as people who are more averse to losses than they are attracted to the same gains, they identify factors that contribute to loss aversion. Schwanen and Ettema (2009) show loss aversion changing in a range of 1.27-1.37 for the travelers to collect their child from nursery school in an uncertain network. Avineri and Bovy (2008) estimate loss aversion by VOTT for late and early arrival. Results show loss aversion is 0.76 for morning commuters, 1.62 for the afternoon and 1.28 for off peak. Stott (2006) designs an experiment to compare different function of CPT by combining eight value functions, eight risky weighting functions and four choice functions. The result shows that parameters for different function are different, but statistic acceptable.

B. Risk Preference

Avineri and Bovy (2008), Köbberling and Wakker (2004) think risk aversion closely related to loss aversion. Köbberling and Wakker (2004) find agent acceptance sets of gain and loss are the same, but in a mixed game they are different, so different risk aversion is mainly due to the different loss aversion in agent. Gao et al. (2010) think the traffic network is inherently risky, CPT model capture twofold attitudes toward travel time loss: risk seeking and risk averse under high probability and low probability respectively. Palma and Picard (2006) define risk aversion by concave of utility function which can also represent by comparing function values of different points.

Katsikopoulos et al. (2002) think drivers are risk averse when face with a route has shorter travel time than the certain time of a reference route while risk seeking when
choosing a route with longer travel time than the reference routes. Abdellouai and Han (2008) find the coexistence of risk seeking and concave utility function under prospective theory, risk aversion mainly found in gain domain and risk seeking mainly existed in loss domain. Considering risk aversion, Knoop and Bell (2008) research different road user classes simultaneously in a same network based on a two-parameter route choice formulation. Basing on the trade off between speed and reliability network routes, a traffic assignment model is established to deal with different degree of risk attitude. Katsoiopoulos (2002) thinks if the mean travel time lower than a reference point, the traveler can classified as risk averse, if mean travel time higher than a reference point, it is risk seeking. A similar definition of risk attitude can be found from a paper of Boger (2004). Risk seeking is a behavior that seeks the small chances to gain huge savings in travel time, in this research route A means risk averse and Route B risk seeking.

C. Psychology Experiment Design

Abdellouai (2008) finds an efficient way to measure utility basing on prospect theory. The method balance achievement between the advantages of nonparametric and parametric measurement. The number of the elicitations in an experiment to measure prospective value and cognitive burden from respondents can be minimized. Hjorth (2008) designs a stated choice experiment basing on the trade off method to look into loss aversion. In the experiment, subjects made trade-offs between travel time and travel cost. Bleichrodt and Wakker (2001) proposed elicitation procedure to modify the standard utility basing on estimation of probability transformation and loss aversion in prospect theory. They think elicitation processors can use to deal with utility deviations from rational model. The certainty equivalence method can avoid distortion from loss aversion, but not probability transformation. Stott (2006) design an experiment with questions contain a pair of two outcome options. The experiment is to separate subjects with different risk attitudes and minimum interaction of parameters of different functions. The result indicates stimuli, the size of the outcome can affect risky weighting functions; large outcomes make the result more applicable to the real world, even though respondents may not show their express in such a large outcome.

III. THEORY

Some axioms in expect utility theory can be used in prospect theory. In this section theory of the experiment will be introduced to describe commuters’ route choice behavior. According to Von Neumann–Morgenstern axiom, for \( x_1, x_2, x_3 \in X \) and \( x_1 > x_2 > x_3 \), there is \( 1 > p_1 > p_2 > 0 \) to make Eq. (1) exist.

\[
p_1 x_1 + (1 - p_1) x_3 > x_2 > p_2 x_1 + (1 - p_2) x_3
\]

Where \( x \) is travel time, and \( p_1, p_2 \) are probabilities. For, \( p_2 > x > p_1 \), there are \( x > x_1 + (1 - x)x_2 \) exist, \( x_2 \) is the indifferent value of route B.

Following theory is based on NM method and theory provided in Mohammed (2008). In prospective theory, prospect value of travel time \( x \) can be expressed as Eq. (2):

\[
U(x) = \begin{cases} u(x) & \text{if } x \geq 0 \\ \alpha u(x) & \text{if } x < 0 \end{cases}
\]

In this paper power form is adopted as utility function:

\[
u(x) = x^\alpha
\]

Similarly, in loss domain, when commuter chooses route B, they will be \( x_3 \) mins late with a probability of \( p_3 \) and \( x_3 \) mins late with a probability of \( 1-p_3 \), so prospect value of route B in loss domain is:

\[
w^*(p(U(x_1) - U(x_3))) + U(x_3)
\]

where \( x \) = \( p \) and \( u \) = \( u \) are weight probability for gain domain and loss domain respectively.

In the gain domain commuters will arrive in advance and indifferent value \( (G_i) \) of route B can be elicited by \( x_2 \) from route A:

\[
U(G_i) = w^*(p(U(x_1) - U(x_3))) + U(x_3)
\]

Parameter of probability weight \( w^*(p) \) and value function \( \alpha \) in the gain domain will be estimated by Eq. (6).

The indifferent value in loss domain can get by Eq. (7) and parameters in loss domain can be estimated:

\[
U(L_i) = w^*(p(U(x_1) - U(x_3))) + U(x_3)
\]

Obviously, prospect function goes through point \( (0,0) \) so loss aversion coefficient can get by Eq. (8).

\[
w^*(p(U(G_i))) + w^*(1 - p)\alpha U(L_i) = u(0) = 0
\]

Basing on equivalent-weight probability method (NM method), an elicitation method was used in the psychological experiment. The above model in the experiment focus on commuters who departing in the morning and they will make a choice between route A and route B.

![Figure 1 Commuter Route Choice Scenario Sketch](image)

IV. EXPERIMENT

A. Subjects

The subjects were 76 commuters in Chao Yang District in Beijing, the age of subjects mainly lies between 20 - 30, and the salary is mainly 3000-6000RMB and 6000-8000RMB. Driving year are mainly less than half years and more than 3 years. Most of the subjects have a master's degree in educational background.
B. Experiment design

The travel survey in this paper contains two parts, the socioeconomic characteristics of the subject and psychology experiment (all subject responses to social-economic characteristic part in the survey and only 56 of them responded to psychology experiment effectively). There are 26 items involved in this survey and 9 of them are to inspect the commuter’s socioeconomic characteristics. It follows like educational background, income and family structure etc. 17 items are traffic environment condition: departure time, travel time, travel distance, travel cost, trip frequency and degree of route familiarity. Travel cost refers to the cost of travel in one month, travel frequency means the travel times in a week, family construct means commuters may have to take child to school so their route choosing will be affected.

By three steps travelers’ indifferent can be elucidated, in which expect arrival time of route A and B should be equal. Firstly the indifferent value in the gain domain was elucidated (Eq. (6)) Then an indifferent value in loss domain is elucidated (Eq. (7)), at last by combining two domains the loss aversion can be gotten (Eq. (8)). Elicitation question for three steps are designed as Table 1. To inspect loss aversion under different probabilities, an unbalance probability of 1/2, 1/3 is made.

In the first step gain domain indifferent point was elicited. By route A, commuters will arrive at a certain time; Choosing route B, commuters will arrive x1, x3 mins in advance under probability of 1/2 separately. When subject chooses route A, x2 will decrease half of last change otherwise x2 will increase a same value. The experiment goes to next elicitation when same value of x2 shows twice and subject makes a same choice or difference value of two choices less than 10%. The mean value of the last two iterations is indifferent value Gi. The next step is to get indifferent point at the loss domain. In the third step, the gain domain and loss domain need to be done simultaneously. Eq. (6), (7) will be estimated by the data from first step and second step and estimated parameters can be used in Eq. (8), so loss aversion of this individual subject can be computed.

<table>
<thead>
<tr>
<th>Gain domain (mins)</th>
<th>Loss domain (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 vs (6,1/2, 20,1/2)</td>
<td>12 vs (8,1/2, 16,1/2)</td>
</tr>
<tr>
<td>32 vs (18,1/2, 45,1/2)</td>
<td>32 vs (25,1/2, 40,1/2)</td>
</tr>
</tbody>
</table>

C. Procedure

The experiment was run on a computer. At first travelers with a job and driving a car were selected, a brief introduction of the experiment is made to them. Then the experiment was emailed to them and after the experiment the result will be emailed back. Subjects were told there is no right or wrong, they just make a choice as their everyday travel to work, the experiment last about 50mins. All indifferent points were elicited through a set of binary choice question as shown in table 1. The eliciting binary question can significantly reduce inconsistencies comparing with the traditional way of asking subject directly. During the experiment, subject always face two prospects, prospect A traveler can arrive with 100%, mean risk aversion and prospect B rise seeking.

V. RESULT

This section makes a statistical analysis of subjects’ loss aversion and risk preference as well the relationship between them.

A. Description Result of attributes

55.3% of families have three persons or more, who may have to take their child to school and their departure time will be affected, therefore their route choice will also change by making school as an anchor.
Trip duration is the time difference between departure time and arrival time. In the survey most trips last 20-40 mins, and the average trip duration is about 1 hour. Commuting time is about 10 hours, which accounts for 1/4 of work time in a week.

![Figure 5 Trip distance](image)

Figure 5 Trip distance

Trip distance from house to work place mainly focus between 0-5km, the average trip distance in the survey is about 11.25km, average speed in the survey can be roughly estimated which indicates traffic condition is not good.

![Figure 6 Departure time and arriving time](image)

Figure 6 Departure time and arriving time

Departure time and arrival time are travelers’ entering and exiting of a traffic network system which rise congestion. In figure 4, departure time focuses on 7:00 and 8:00, arrival time 8:00 and 9:00, which verify that trip duration is about 1 hour in the survey, indicating rush hours.

![Figure 7 Expect arriving time](image)

Figure 7 Expect arriving time

Expect arriving time in the survey shows people’s preference to arrive. The proportion of people likes to arrive in advance and late is similar, and most subjects like to 10 mins early or late.

### B. Statistic Result of loss aversion

Loss aversion for each individual changes greatly, also weighting probability affect loss aversion. Magnitude of outcomes has little influence on loss aversion. Mean and median values are effective to represent loss aversion.

| TABLE II PARAMETER ESTIMATION OF PROSPECT VALUE (QUARTILE IN PARENTHESES) |
|-------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1/2 gain domain | 1/2 loss domain | 2/3 gain domain | 3/3 loss domain |
| \( \frac{w^+}{w^-} \) | 0.23(0.2-0.69) | 0.76(0.21-0.9) | 0.23(0.2-0.9) | 0.82(0.31-0.99) |
| \( \frac{\alpha}{\beta} \) | 0.26(0.23-0.29) | 0.26(0.22-0.3) | 0.26(0.22-0.3) | 0.26(0.23-0.32) |

Table 2 shows the median value of subjective probability and prospect value function. The median value of parameters for prospect value function is 0.26 while the parameters of subjective function change from 0.23 to 0.76. So weight probability changes greatly by objective probability and decision scenarios. Exponents of prospect value function are less than one so risk aversion in gain domain and risk seeking in loss domain should be found (Gao and Razo, 2011).

![Figure 8 Prospect value function with probability of 1/2](image)

Figure 8 Prospect value function with probability of 1/2

Prospect value curve under probability of 1/2 is shown in Figure 8. Loss aversion is quite obviously under probability of 1/2, the median value of loss aversion is 1.27. When people make a decision about which route to choose, they will be more sensitive lateness.

![Figure 9 Prospect value function with probability of 2/3](image)

Figure 9 Prospect value function with probability of 2/3

Figure 9 is a curve of prospective value under probability of 2/3. This is different from the case with probability of 1/2. With a larger probability of gain outcome, commuters put more value on this route. So we can reason out that loss aversion will change when the probability of loss and gain obviously different.
Subject median value of loss aversion are almost the same, so mean and median value both can be used to represent loss aversion. The case with probability of 2/3 is the same with Figure 11.

Table 3 shows the mean value of loss aversion coefficient (standard deviations are in the brackets). In table 3 the median value of Loss aversion coefficient under 1/2 probability is 1.27, upper quartile and lower quartile are 0.86 and 2.85 respectively. 0.61% of subjects have a loss aversion coefficient larger than 1. The median value of loss aversion coefficient under probability of 2/3 is 1, upper quartile and lower quartile are 0.29 and 1.30 respectively. 0.34% of subjects have a loss aversion coefficient larger than 1.

In table 4, median value of loss aversion does not change a lot with magnitudes of outcomes under probabilities of 1/2 and 2/3. In the 1/2 scenario loss aversion values range between the upper quartile and lower quartile is wider for the larger outcomes, but in the 2/3 scenario, this scale does not change very much. It is a balance of weight probability and magnitude of outcomes.

C. Linear Discriminant Analysis of Risk Preference

In prospect theory, risk preference consists with concave and convex of prospect function, considering the research made by Katsi Kopoulou (2002), Bogers (2004) and Abdellaoui (2007), Risk preference classified by comparison expect travel time in route B and eliciting indifferent value in route A. traveler intend to get a chance of saving by choosing route B is risk seeking. Among the four experiment tests a subject is risk aversion if they show risk aversion more times.

For gain domain, 71.05% of subjects show risk aversion and 64.47% of subjects in loss domain are risk seeking, so commuters have different risk preference in gain domain and loss domain, Xu and Zhou (2011) draw a similar conclusion.

The result of linear discriminate analysis of gain domain can find in table 4, the predicting rate for gain domain is about 84.3%.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gain1/2</th>
<th>Gain2/3</th>
<th>Subject</th>
<th>Gain1/2</th>
<th>Gain2/3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.66(0.21)</td>
<td>1.15(0.05)</td>
<td>2</td>
<td>2.70(0.33)</td>
<td>1.65(0.49)</td>
</tr>
<tr>
<td>3</td>
<td>1.01(0.03)</td>
<td>1.04(0.03)</td>
<td>4</td>
<td>1.25(0.01)</td>
<td>0.80(0.03)</td>
</tr>
<tr>
<td>5</td>
<td>9.20(1.09)</td>
<td>3.16(2.23)</td>
<td>6</td>
<td>0.28(0.06)</td>
<td>3.26(0.14)</td>
</tr>
<tr>
<td>7</td>
<td>0.29(0.00)</td>
<td>0.97(0.01)</td>
<td>8</td>
<td>6.18(1.44)</td>
<td>2.98(0.05)</td>
</tr>
<tr>
<td>9</td>
<td>0.87(0.02)</td>
<td>1.09(0.04)</td>
<td>10</td>
<td>1.96(0.34)</td>
<td>0.30(0.01)</td>
</tr>
<tr>
<td>11</td>
<td>2.03(0.33)</td>
<td>0.67(0.04)</td>
<td>12</td>
<td>1.97(0.03)</td>
<td>0.79(0.07)</td>
</tr>
<tr>
<td>13</td>
<td>0.25(0.01)</td>
<td>0.89(0.01)</td>
<td>14</td>
<td>1.22(0.10)</td>
<td>0.38(0.07)</td>
</tr>
<tr>
<td>15</td>
<td>1.13(0.13)</td>
<td>0.97(0.11)</td>
<td>16</td>
<td>3.29(0.20)</td>
<td>0.43(0.04)</td>
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<tr>
<td>17</td>
<td>3.67(0.07)</td>
<td>0.16(0.01)</td>
<td>18</td>
<td>0.37(0.01)</td>
<td>0.27(0.00)</td>
</tr>
<tr>
<td>19</td>
<td>3.00(0.32)</td>
<td>0.26(0.01)</td>
<td>20</td>
<td>4.97(0.43)</td>
<td>0.19(0.00)</td>
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<tr>
<td>21</td>
<td>1.78(0.11)</td>
<td>0.19(0.00)</td>
<td>22</td>
<td>4.67(0.91)</td>
<td>0.29(0.02)</td>
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<tr>
<td>23</td>
<td>3.61(0.12)</td>
<td>0.23(0.00)</td>
<td>24</td>
<td>1.54(0.02)</td>
<td>0.26(0.01)</td>
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<tr>
<td>25</td>
<td>1.57(0.01)</td>
<td>0.71(0.03)</td>
<td>26</td>
<td>1.17(0.09)</td>
<td>0.93(0.00)</td>
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<tr>
<td>27</td>
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<td>0.31(0.01)</td>
<td>28</td>
<td>0.94(0.01)</td>
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<td>0.59(0.06)</td>
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<tr>
<td>35</td>
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<td>0.37(0.00)</td>
<td>36</td>
<td>0.19(0.03)</td>
<td>0.65(0.13)</td>
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<tr>
<td>37</td>
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<td>1.29(0.08)</td>
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<td>2.29(0.29)</td>
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<td>0.21(0.01)</td>
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<tr>
<td>43</td>
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<td>1.47(0.13)</td>
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<tr>
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<td>0.67(0.04)</td>
<td>46</td>
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<td>0.17(0.01)</td>
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<tr>
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<td>1.47(0.05)</td>
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<tr>
<td>49</td>
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<td>51</td>
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<td>53</td>
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<td>6.41(1.38)</td>
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<td>55</td>
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<td>0.76(0.00)</td>
<td>56</td>
<td>0.93(0.04)</td>
<td>0.93(0.00)</td>
</tr>
</tbody>
</table>

Under choosing probability of 1/2, mean value and median value of loss aversion are almost the same, so mean and median value both can be used to represent loss aversion. The case with probability of 2/3 is the same with Figure 11.
time, so tolerant lateness was put in the first place, this is also why they more likely to risk aversion, in this case they also likely to consider how to reduce the travel cost, the older commuter the more they will like to maximize personal prospect value.

A function to predict risk preference of commuters who arrive in advance:

Risk aversion = -26, 137+8, 169* age + 2, 142*family structure - 1, 393*working year - 0, 681*driving year + 5, 378*travel frequency + 9, 426*tolerate lateness + 6, 547*travel cost - 1, 934*activity during travel (10)

Risk seeking = -29, 81+9, 031* age + 2, 895* family in structure - 1, 205* working year - 0, 459* driving year + 5, 080* travel frequency + 9, 826* tolerate lateness + 6, 441* travel cost - 1, 338* activity during travel (9)

Risk aversion = -19. 785 + 7. 839*Age + 2. 422* family in structure - 1. 393*working year - 0. 459*driving year + 5. 080* travel frequency + 9. 826* tolerate lateness + 6. 441* travel cost - 1. 338* activity during travel (10)

A regression of loss aversion and risk preference is made as show in table 8. In gain domain loss aversion value is positively correlated to risk preference and in the loss domain is opposite. This means risk preference will change as loss aversion more sensitive and risk preference reversal will happen.

Loss aversions under objective probability of 1/2 and 2/3 are quite different, so this section looks at the route preference of traveler with different loss aversion level.

Under probability of 1/2, the median value of loss aversion is 1.27 and 0.74 for 2/3 scenario respectively, according which, all the subjects are divided into four groups: subjects with loss aversion higher than 1.27 and lower than 1.27 in gain domain and loss domain(sign by $G_{>1.27}$, $L_{>1.27}$, $G_{<1.27}$, $L_{<1.27}$), similar for scenarios with probability of 2/3, (sign by $G_{>2/3}$, $L_{>2/3}$, $G_{<2/3}$, $L_{<2/3}$). During the psychology experiment, travelers choose route A can arrive at a certain time, meaning risk averse, and route B with a probability meaning risk seeking. Experiment result records subjects’ choice after they press button A or B, so the proportion of subject choosing route A and B can be calculated to show traveler’s risk preference.

$G_{>2/3,A}$ : Proportion of subjects choosing route A in i iteration in gain domain.

$L_{>2/3,B}$ : Proportion of subjects choosing route B in i iteration in loss domain.

$I$ : Total times of iteration.

$G_{>1.27,A} = \frac{\sum G_{>1.27,A,i}}{I} - \frac{\sum G_{>1.27,B,i}}{I}$ (13)

$L_{>1.27,B} = \frac{\sum L_{>1.27,A,i}}{I} - \frac{\sum L_{>1.27,B,i}}{I}$ (14)

$G_{>1.27,A}$ : Average proportion difference of subjects with loss aversion higher than 1.27 choosing route A and B in gain domain.

$L_{>1.27,B}$ : Average proportion difference of subjects with loss aversion higher than 1.27 choosing route A and B in loss domain.

A function to predicted commuter’s risk preference when facing of lateness

Risk aversion = -19. 785 + 7. 839*Age + 2. 422* Departure time + 3. 228* Travel time + 0. 026* Travel distance

Risk seeking = -18. 514 + 6. 831*Age + 2. 304* Departure time + 3. 410* Travel time + 0. 067* Travel distance

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**TABLE VI STATISTIC RESULT OF LINEAR DISCRIMINATION ANALYSIS**

<table>
<thead>
<tr>
<th></th>
<th>Eigenvalue</th>
<th>Cumulative%</th>
<th>Canonical correlation %</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain domain</td>
<td>0.321</td>
<td>100.0</td>
<td>0.493</td>
<td>0.012</td>
</tr>
<tr>
<td>Loss domain</td>
<td>0.312</td>
<td>100.0</td>
<td>0.341</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Table 6 shows statistic results of linear discrimination analysis. Both the significant are below 0.05. Function (9), (10) in gain domain and (11) (12) in loss domain can explain 100% of the data.

**TABLE VII COMMUTER ATTRIBUTES FOR RISK PREFERENCE IN LOSS DOMAIN**

<table>
<thead>
<tr>
<th>Constant</th>
<th>Age</th>
<th>Departure time</th>
<th>Travel time</th>
<th>Travel distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk aversion</td>
<td>-18.514</td>
<td>6.832</td>
<td>2.304</td>
<td>3.41</td>
</tr>
<tr>
<td>Risk seeking</td>
<td>-19.785</td>
<td>7.839</td>
<td>2.422</td>
<td>3.228</td>
</tr>
</tbody>
</table>

In table 7, when facing lateness, commuter attributes for risk preference is mainly traffic conditions.

A function to predicted commuter’s risk preference when facing of lateness

Risk aversion = -19. 785 + 7. 839*Age + 2. 422* Departure time + 3. 228* Travel time + 0. 026* Travel distance

Risk seeking = -18. 514 + 6. 831*Age + 2. 304* Departure time + 3. 410* Travel time + 0. 067* Travel distance

---

**D. Route Preference Considering Loss Aversion Level**

**TABLE VIII REGRESSION OF LOSS AVERSION VALUE AND RISK PREFERENCE**

<table>
<thead>
<tr>
<th>Objective probability</th>
<th>Gain domain</th>
<th>Loss domain</th>
<th>Reversal point</th>
</tr>
</thead>
<tbody>
<tr>
<td>With reference point</td>
<td>1/2</td>
<td>$\lambda = -2.311$</td>
<td>$\lambda = 2.360$</td>
</tr>
<tr>
<td></td>
<td>2/3</td>
<td>$\lambda = 0.909$</td>
<td>$\lambda = -0.849$</td>
</tr>
<tr>
<td>Without reference point</td>
<td>1/2</td>
<td>$\lambda = -2.452$</td>
<td>$\lambda = 2.318$</td>
</tr>
<tr>
<td></td>
<td>2/3</td>
<td>$\lambda = 0.666$</td>
<td>$\lambda = -1.145$</td>
</tr>
</tbody>
</table>

---

**Figure 12** Proportion difference of subjects route choosing under probability of 1/2
Obviously similar pattern can be found both in Fig. 12 and Fig. 13, though the values for different scenarios are quite different. Firstly the values become quite small as the earliness and lateness increase, which verifies finding in Gao (2013) about diminishing sensitivity of travel time. Secondly, comparing research of Xu and Zhou (2011), a further conclusion obtained, people risk aversion when loss aversion lower than 1.27/0.74 in gain domain and higher than 1.27/0.74 in loss domain, otherwise risk seeking. Basically travelers show risk averse in gain domain and risk seeking in loss domain but this is not always the case, risk preference will reversal as loss aversion rising.

VI. CONCLUSION

This empirical study shows the decision mechanism of route choice which can also improve existing models for travel behavior and stochastic network equilibrium. In the experiment actual decision-making process of individual is modeled and following conclusion is draw.

In the experiment, the median loss aversion value is 1.27 for 1/2 and 0.74 for 2/3. Commuters are more sensitive to late, which changes a lot for different people, so heterogeneity is significant. Mean and median value can both represent loss aversion for an individual.

There is obvious risk preference in route choice behavior. Commuters more likely to show risk aversion in gain domain which can be explained by personal socio-economic attributes and risk seeking in loss domain which related to traffic environment conditions. This can explain psychology process when commuters make a route choice.

By comparing proportion of commuter’s route choice, Risk preference reversal can be found in gain domain and loss domain as loss aversion changes. As People’s sensitivity to arrive early and late changes, risk preference of different routes will change.

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REFERENCES