Analysis of driver's choice behavior based on the combined model of utility-regret

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Abstract. In the context of increasing urban traffic trajectory data, based on large-scale urban traffic trajectory data, in the field of intelligent transportation, it has become an urgent need to analyze travelers’ routing behaviors and establish effective routing models to provide travelers with efficient and reasonable driving route recommendations. It is often the case that urban taxi groups has better route choice behavior than other travel group under the cost-benefit constraints. Therefore, providing route recommendations for other travelers according to the route choice habits of urban taxi group is a feasible solution to the above need. This paper starts with the utility maximization model and the stochastic regret minimization model, for the problem that the traveler cannot satisfy the premise of the complete rationality of the utility maximization model when choosing routes and the random regret minimization model ignores the traveler's sensitivity to the original value of the alternative attribute, and improve the calculation formula of the regret value in the random regret minimization model. A route choice model under the utility-regret combination rule is proposed based on the combination of the utility model and the improved regret model, and then, based on the historical trajectory data of taxis in Xi'an, the RP data required by the model is extracted, and the parameters of the model are estimated and verified. The experimental results show that the route choice probability calculated by the model is closer to the route choice probability in the real scene than the simple utility maximization model or the simple random regret minimization model.

1. Introduction

In recent years, with the deep integration of mobile Internet, Internet of Things, GIS, big data and other technologies and urban intelligent transportation systems, large-scale urban traffic trajectory data can be efficiently collected, transmitted and stored, which implies the urban residents’ travel laws and reflects the dynamic traffic state of the urban road network, and has now become the main research object in the field of urban intelligent transportation information services [1-5]. Urban public transportation trajectory data mainly includes trajectory data of public transportation such as taxis, buses and subways. In the way of urban public transportation, travelling by taxi has the flexible characteristics of not being limited by time and space, and taxi drivers are familiar with the structure of the urban road network and relatively understand the changing rules of the traffic flow state of the urban road network. Under the condition of cost-benefit constraints, urban taxi driver group usually has better route selection behavior than other travel group. Therefore, through the route choice habits of urban taxi groups, analyzing the route choice behavior of travelers, establishing an effective route choice model, and providing route recommendation information services to other travelers will effectively improve the urban residents’ travel experience.
The MNL model [6] (referred to as the utility model) and the generalized regret minimization model [7], [8] (referred to as the regret model) are the basic models that have been widely used in the research of route choice behavior in recent years:

1) Utility model

Discrete selection model research has been rising since the 1850s, and Marschak introduced the concept of utility to derive and define a utility maximization model [9]. The utility maximization rule is the theoretical basis of the discrete selection model, that is, it is generally assumed that the decision maker chooses the scheme with the greatest utility.

Yang [10] processed the taxi data in Beijing to obtain RP data as the data basis for route choice behavior analysis, analyzed the factors that maybe affect the driver, and used the PSL (Path-Size logit) model of the revised MNL model to perform data analysis. Through analysis and processing, the experimental results show that taxi drivers prefer routes with short travel time and few turns; Duncan [11] proposed an internally consistent adaptive PSL (APSL) model, which determines the path items in the PSL model based on the ratio of path selection probabilities to ensure that the paths defined by PSL as unrealistic are exactly those selection probabilities very low path. The APSL routing probability relationship is an implicit function, expressed as a fixed point problem. A maximum likelihood estimation method is given. The APSL model is estimated using the tracked path observation data, and the method is studied in the simulation study. The results show that the method can usually reproduce the assumed real parameters; Dawei [12] discussed the aggregation traffic flow prediction method based on the multi-level mixed logit route choice model, and further divided the multi-level unobservable item heterogeneity in route choice into OD pair specificity and observation specificity. Quantitative analysis of the impact of multi-level heterogeneity on classification route choice prediction and aggregation network load.

2) Regret theory

Bell’s theory of regret [13], [14] is also a study of decision-making behavior in a state of imperfect rationality. The theory of regret believes that decision makers will compare their own choices with other choices in the alternative set. If the choice is better than other choices The feeling of joy is psychologically generated, whereas the choice of the plan is inferior to other plans, and a feeling of regret is psychologically generated. The decision maker predicts the decision result based on historical experience and tries to circumvent the plan that may cause regret.

Luan [15] analyzed the two common forms of multiple choice sets and multiple attributes in regret theory, and studied the structure of the model from the presence or absence of risk, and proposed a path selection behavior analysis model based on random regret theory. The selection results of the model and regret model give suggestions for choosing models in different situations; Jiang [16] introduced regret theory in the research of rail transit route selection, established a simulated road network under the rule of regret minimization, analyzed the influencing factors of route choice and estimated the regret value of traveler's choice of route; Li[17] introduced an indifference curve on the basis of a random minimum model to determine travel time and travel costs as influencing factors for route choice, and established a regret-minimization model based on remaining time for route choice research. Improve the problem of path intersection and perceptual variance. The results of the example show that the model is more reasonable than the utility model based on the remaining time.

But these two models have certain flaws: the former assumes that decision-makers are completely rational, and due to the difference in knowledge reserves and preferences of decision-makers, perfectly rational premise isn’t often met in reality; the regret model introduces the imperfect rational condition of decision-makers' regret-euphoria perception, however, ignoring the sensitivity of decision-makers to the original value of the attribute. For the above problems, this paper combines the utility model and the regret model, and proposes a route choice model based on the utility-regret joint rule. On this basis, a basic expression form of the utility-regret joint model is proposed. The specific research contents are as follows:

(1) analysis of driver's choice behavior under
Set the selection scenario to calculate the selection probability of the utility model and regret model, and analyze the route choice results of the two models to improve the absolute regret items in the regret model;

(2) construct a route choice model based on the utility-regret joint rule

Combine the utility model and the improved regret model to form a utility-regret joint model and its basic expression. According to different influencing factors, six utility models and regret models with different combinations of attributes are proposed respectively. And then extract the RP data required by the models based on Xi’an taxi historical trajectory data, determine the parameters in each model, and select a set of utility model and regret model with good modeling results to form a route choice model of utility-regret joint rule;

(3) comparative analysis of the utility-regret joint model and other models

Use real trajectory data to verify the utility-regret model, utility model, and regret model, and compare the difference between the calculated probability and the actual selection probability of the three models. The experimental results show that the route choice probability of the utility-regret joint model is closer to the route choice probability in the real scene than the simple utility model or simple regret theory model.

2. Analysis of Driver’s Choice Behavior under Utility Model and Regret Model

2.1. Scenario analysis

The utility model and the regret model are analyzed using the case where the taxi driver chooses the path to influence two attributes. Suppose there are three paths L₁, L₂, L₃ between the same OD pair, the path length is 20km, 25km, 30km respectively, the driving time is 8min, 6min, 5min respectively, the average speed attribute parameter is -1/km, the driving time attribute parameter is -2/min, and the regret weight coefficient is 0.5. The probability that the above L₁, L₂, and L₃ route are selected respectively is calculated by the utility model formula [6] \( P_U = \frac{e^{V_i}}{\sum_{j=1}^{k} e^{V_j}} \), where \( V_i = \sum_{j=1}^{k} \beta_{ij} x_j \) is the utility value of the utility model, \( x_j \) is the jth attribute value and \( \beta_{ij} \) is the parameter value of the jth attribute in the ith alternative) and regret model formula [8] \( P_R = \frac{e^{-R_i}}{\sum_{j=1}^{n} e^{-R_j}} \), where \( R_i = \sum_{j=1}^{k} \sum_{n} \ln \{ \gamma_n + \exp [\beta_{nn}(x_{jn} - x_{in})] \} \) is the regret value of the regret model, \( \beta_{nn} \) is the parameter of the nth influencing factor, \( x_{jn} \) is the value of the nth attribute of the selection scheme i). The selected probabilities of the above L₁, L₂, and L₃ paths under the two models are shown in Table 1.

| route | utility value U | selected probability P_U | regret value R | selected probability P_R |
|-------|----------------|--------------------------|---------------|--------------------------|
| L₁    | -36            | 0.7214                   | 2.2187        | 0.1617                   |
| L₂    | -37            | 0.2654                   | 1.4727        | 0.3409                   |
| L₃    | -40            | 0.0132                   | 1.0947        | 0.4974                   |

It can be seen from the results of the selected probabilities of the path L₁, L₂, L₃ under the maximum utility model and the minimum regret model that under different models, there is a certain gap in the probability of the path being selected: the comprehensive path length and driving time in the utility model are two factors path L₁ is the most effective, with the highest probability of being selected and far higher than the other two paths; in the regret model, the smallest regret value of the path L₃ is the regret that is more likely to occur when the other two paths are selected. Although the attribute values of the route L₁ are not all optimal, the driving time attribute value is the smallest and the parameter of this attribute value is larger. Time is more important in path selection than average vehicle speed, so the probability of being selected is higher than the other two paths.
2.2. Improvement of regret model

Based on the analysis of the single-attribute data of the generalized random minimization regret model, it is assumed that there are two optional paths between the two OD pairs, the path length is 2km/5km, 30km/33km respectively, the estimated parameter of the path length is -1/min, and the regret weight coefficient is 0.3. The probability that two paths in each OD pair are selected is calculated by the regret model formula with the result: \( P(L_1)=P(L_3)=0.98313, P(L_2)=P(L_4)=0.01687. \)

Because the absolute difference of the path lengths in the two paths is the same, the probability of choosing the short path length is calculated to be equal according to the regret value formula of the regret theory and the probability formula. The length of path 1 differs from the length of path 2 by more than twice, so the selection probability differs greatly. Although the length difference between path 3 and path 4 is the same as the length difference between path 1 and path 2, for paths with lengths of 30km and 33km, the distance difference of 3km has little effect on the probability of being selected, and it is not yet reached probability difference calculated above. It shows that the absolute difference is used to calculate the regret value while ignoring the sensitivity of the decision maker to the original value of the attribute, so the above model does not meet the decision-making thinking of the decision maker in the actual decision-making environment.

To this end, the attribute difference value in the regret value formula of the regret model is changed to the ratio of the attribute difference value and the original value of the attribute as formula 1, and the path selection probabilities of the above cases calculated by the modified model are \( P(L_1)=0.80224, P(L_2)=0.19776, P(L_3)=0.5366, P(L_4)=0.4634. \) Obviously, in the above case, the improved model has a probability that the first pair of ODs chooses 2km path 1 is significantly less than the probability of choosing 5km path 2, and the second pair of ODs has a small difference between the probability of choosing 30km path 3 and the probability of choosing 33km path 4. The improved regret model is more in line with the actual path selection scenario. For the convenience of subsequent description, the improved generalized random regret minimization model is simply referred to as the improved regret model.

\[
R_i = \sum_{j \neq i} \sum_n \ln \{ y_n + \exp \left[ \beta_n (x_{jn} - x_{in}) / x_{in} \right] \} 
\]

3. Utility-regret Route Choice Model

Under the premise of determining the starting point and ending point (OD), the driver will have multiple paths to choose and finally select a path based on comprehensive consideration of road factors, vehicle dynamic factors and his own historical experience. Synthesizing the previous model theory analysis, the utility model pursues the principle that the utility is the largest, that is, the passenger travel comprehensive cost is the smallest, while the regret theory considers the principle of passenger's psychological perception of route choice to avoid regret. The combination of two models will accord with the comprehensive model that the decision maker should consider the realistic factors rationally and estimate the consequences according to the historical experience. When the driver as a decision-maker chooses a route, he will tend to have the greatest utility, the smallest travel cost, and avoid regret. The combination of the two models will accord with the reality that the decision-maker must not only consider realistic factors rationally, but also estimate the consequences based on historical experience when choosing a plan. Therefore, this section proposes a route choice model under the utility-regret joint rule (referred to as utility-regret joint model) based on the utility model and the improved regret model, estimates the model parameters and verifies the rationality of the model.

3.1. Construction of route choice model based on utility-regret joint rule

Suppose there are \( J \) alternative paths between the same fixed starting point and ending point (OD) from the start point to the end point, each path has \( k \) attributes. The utility-regret joint rule considers that the path selection model is determined by the utility maximization rule and the regret minimization rule. The driver selects the utility of path \( i \) from the set of alternative routes as formula 2. It comes from a linear combination, where \( a \) and \( b \) are the proportion coefficients in the model.
respectively representing the proportion of the utility model and the regret model in the total model, and a and b satisfy 0≤a, b≤1 and a + b = 1.

\[ U(URM) = aU(MNL) + bU(R) = a( \sum_{k=1}^{n} \beta_k x_{nk}) + b( \sum_{j=1}^{m} \sum_{N} \ln(\gamma_n + \exp[\beta_n x_{jm} x_{in}]]) \]  

(2)

The factors that may affect the path selection include the length of the road section, the number of left and right intersections, the number of straight intersections, the driving time, the average speed, the average sampling speed, and the extremely poor speed. According to the driver's preference for choosing a route, it likes that the length of the road segment is short, the driving time is short, the driving speed is high, there are many straight intersections, and there are few left-turn intersections. The speed, average sampling speed, and speed difference are determined as the speed influencing factors, which are recorded as V. The number of left and right turn intersections/straight intersections, the number of left turn intersections/straight intersections, and the number of right turn intersections are determined as intersection preference factors. The influencing factors of the utility model and regret model take all of the basic influencing factors X and speed influencing factors Y, and any of the intersection influencing factors into six groups. The utility model and regret model composed of four influencing factors are shown in figure 1.

![Fig.1 Six models under different variable combinations](image)

According to formula 1, the utility value of the utility-regret joint model of the jth path selected from the multiple different continuous passenger trajectory paths among the selected OD is formula 3:

\[ U_j = a \cdot U_j + b \cdot R_j \]  

(3)

\[ U_j \] is the utility value considering all variables as in formula 4, where \( V_{x1j} \) is the utility value of the driving time \( \text{loadtime}_j \), \( V_{x2j} \) is the utility value of the link length \( \text{length}_j \), \( V_{v1j} \) is the utility value of the average speed \( \bar{v}_j \), \( V_{v2j} \) is the utility value of the average sampling speed \( \bar{v}_c_j \), \( V_{v3j} \) is the utility value of the speed difference \( R_{vj} \), \( V_{N1j} \) is the utility value of the number of left and right turn intersections/number of straight intersections \( N_{LR/ST_j} \), \( V_{N2j} \) is the utility value of the number of left-turn intersections/right-turn intersections/straight intersections \( N_{LR/ST_j} \), \( \beta_{x1}, \beta_{x2}, \beta_{v1}, \beta_{v2}, \beta_{v3}, \beta_{N1}, \beta_{N2} \) are the corresponding undetermined parameter of each attribute, \( \alpha \) is the constant parameter to be determined and \( \epsilon_j \) is the random error term.

\[ U_j = \alpha + V_{x1j} + V_{x2j} + V_{v1j} + V_{v2j} + V_{v3j} + V_{N1j} + V_{N2j} + \epsilon_j = \alpha + \beta_{x1} \text{loadtime}_j + \beta_{x2} \text{length}_j + \beta_{v1}\bar{v}_j + \beta_{v2}\bar{v}_c_j + \beta_{v3}R_{vj} + \beta_{N1}N_{LR/ST_j} + \beta_{N2}N_{LR/ST_j} + \epsilon_j \]  

(4)

\( R_j \) is the regret value formula considering all variables as in formula 5, where \( R_{x1j} \) is the regret value of the driving time \( \text{loadtime}_j \), \( R_{x2j} \) is the regret value of the link length \( \text{length}_j \), \( R_{v1j} \) is the regret value of the average speed \( \bar{v}_j \), \( R_{v2j} \) is the regret value of the average sampling speed \( \bar{v}_c_j \), \( R_{v3j} \) is the regret value of the speed difference \( R_{vj} \), \( R_{N1j} \) is the regret value of the number of left and right turn intersections/number of straight intersections \( N_{LR/ST_j} \), \( R_{N2j} \) is the regret value of the number of...
left-turn intersections/right-turn intersections interiors+straight intersections $N_{L/RST_j}$, $Y_{x1}, Y_{x2}, Y_{v1}, Y_{v2}, Y_{v3}, Y_{N1}, Y_{N2}$ are the regret weight coefficient corresponding to each attribute and $\alpha_{x1}, \alpha_{x2}, \alpha_{v1}, \alpha_{v2}, \alpha_{v3}, \alpha_{N1}, \alpha_{N2}$ is are the regret perception coefficient corresponding to each attribute.

$$R_j = R_{x1} + R_{x2} + R_{v1} + R_{v2} + R_{v3} + R_{N1} + R_{N2}$$

$$= \sum_{j=1}^{N} \ln \{y_{x1} + \exp[\alpha_{x1}(\text{loadtime}_i - \text{loadtime}_j)]/\text{loadtime}_j\}$$

$$+ \sum_{j=1}^{N} \ln \{y_{x2} + \exp[\alpha_{x2}(\text{length}_i - \text{length}_j)]/\text{length}_j\}$$

$$+ \sum_{j=1}^{N} \ln \{y_{v1} + \exp [\alpha_{v1}(\bar{v}_i - \bar{v}_j)]/\bar{v}_j\} + \sum_{j=1}^{N} \ln \{y_{v2} + \exp [\alpha_{v2}(\bar{v}_i - \bar{v}_j)]/\bar{v}_j\}$$

$$+ \sum_{j=1}^{N} \ln \{y_{v3} + \exp [\alpha_{v3}(R_{v_i} - R_{v_j})]/R_{v_j}\}$$

$$+ \sum_{j=1}^{N} \ln \{y_{N1} + \exp [\alpha_{N1}(N_{L/RST_i} - N_{L/RST_j})]/N_{L/RST_j}\}$$

$$+ \sum_{j=1}^{N} \ln \{y_{N2} + \exp [\alpha_{N2}(N_{L/RST_i} - N_{L/RST_j})]/N_{L/RST_j}\}$$

(5)

According to the utility function formula and regret function formula of all variables, the utility function and regret function under different combinations of variables from model one to model six can be obtained as formula 6. Let $V_j$ be the utility function composed of the variables in model 1, $R_j$ be the regret function for the combination of variables in model 1 and so on.

$$V1 = \alpha_1 + V_{x1} + V_{x2} + V_{v1} + V_{N1}, R1_j = R_{x1} + R_{x2} + R_{v1} + R_{N1}$$

$$V2 = \alpha_2 + V_{x1} + V_{x2} + V_{v1} + V_{N2}, R2_j = R_{x1} + R_{x2} + R_{v1} + R_{N2}$$

$$V3 = \alpha_3 + V_{x1} + V_{x2} + V_{v2} + V_{N1}, R3_j = R_{x1} + R_{x2} + R_{v2} + R_{N1}$$

$$V4 = \alpha_4 + V_{x1} + V_{x2} + V_{v2} + V_{N2}, R4_j = R_{x1} + R_{x2} + R_{v2} + R_{N2}$$

$$V5 = \alpha_5 + V_{x1} + V_{x2} + V_{v3} + V_{N1}, R5_j = R_{x1} + R_{x2} + R_{v3} + R_{N1}$$

$$V6 = \alpha_6 + V_{x1} + V_{x2} + V_{v3} + V_{N2}, R6_j = R_{x1} + R_{x2} + R_{v3} + R_{N2}$$

(6)

3.2. Utility-regret joint model parameter estimation

Select a pair of high-frequency OD (Northwestern Polytechnical University Friendship Campus-Wuluoku) RP data using SPSS software to perform parameter estimation and model test on the utility function and regret function under six variable combinations, as shown in Table 2.

| model | $\alpha$ | $\beta_{x1}$ | $\beta_{x2}$ | $\beta_{v1}$ | $\beta_{v2}$ | $\beta_{v3}$ | $\beta_{N1}$ | $\beta_{N2}$ | $\rho^2$/modeling results |
|-------|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------------------|
| V1    | 1.375   | -0.967      | -1.256      | 0.489       | -2.673      |             |             |             | 0.569/poor               |
| V2    | 2.767   | -1.032      | -1.681      | 0.563       |             |             |             | -4.253       | 0.516/poor               |
| V3    | 1.876   | -1.133      | -1.584      | 3.162       | -1.985      |             |             |             | 0.451/good               |
| V4    | 2.146   | -1.347      | -1.661      | 2.908       |             |             |             | -2.576       | 0.372/perfect            |
| V5    | 2.719   | -2.905      | -1.890      | -1.122      | -2.136      |             |             |             | 0.488/poor               |
| V6    | 3.653   | -0.724      | -2.317      | -0.971      | -4.132      |             |             |             | 0.659/poor               |

As can be seen from the modeling results in Table 2, the modeling results of model 4 are preferably the four variables: driving time, path length, average sampling speed, number of left-turn intersections/straight travel + right-turn intersection number. The rule has an important influence on the choice of route, and the average sampling speed has the greatest influence, followed by the number of left-turn intersections/straight travel+right-turn intersections, path length, and travel time. The
positive and negative values of the attribute value parameters can determine that the driver prefers to choose a route with a large average speed, a short route, a relatively small number of left turn intersections, and a short driving time when choosing a travel route. Therefore, the utility function part of the utility-regret joint function selects model 4. According to the parameter estimation results in the above table, the observable part of the utility function of model 4 can be obtained as formula 7.

\[ V_{ij} = \alpha_j + \beta_{x1} \text{loadtime}_j + \beta_{x2} \text{length}_j + \beta_{v1} \bar{v}_c + \beta_{N2} N_{L/RST_j} \]

\[ = 2.146 - 1.347 \text{loadtime}_j - 1.661 \text{length}_j + 2.908 \bar{v}_c - 2.576 N_{L/RST_j} \quad (7) \]

As can be seen from the modeling results in Table 3, the modeling results of model 6 are best: the travel time, the length of the path, the speed difference, the number of left-turn intersections/straight-way + right-turn intersection numbers. The rules have an important influence on path selection. Among them, the speed difference has the greatest influence on the path selection in this model, followed by the path length, the number of left-turn intersections/straight travel+the number of right-turn intersections, and the travel time. The positive and negative values of the attribute value parameters can determine that the driver prefers to choose a route with a small speed change, a short route, a relatively small number of left-turn intersections, and a short driving time when choosing a travel route. Therefore, the utility function part of the utility-regret joint function uses model 6. According to the parameter estimation results above, the observable part of the regret function of model 6 is formula 8.

\[ R6_j = R_{x1_j} + R_{x2_j} + R_{v3_j} + R_{N2_j} \]

\[ = \sum_{j \neq i} \ln \left\{ 0.13 + \exp \left[ -0.12 \left( \text{loadtime}_i - \text{loadtime}_j \right) / \text{loadtime}_j \right] \right\} \]

\[ + \sum_{j \neq i} \ln \left\{ 0.21 + \exp \left[ -0.149 \left( \text{length}_i - \text{length}_j \right) / \text{length}_j \right] \right\} \]

\[ + \sum_{j \neq i} \ln \left\{ 0.68 + \exp \left[ -0.326 \left( R_{v_i} - R_{v_j} \right) / R_{v_j} \right] \right\} \]

\[ + \sum_{j \neq i} \ln \left\{ 0.17 + \exp \left[ -0.268 \left( N_{L/RST_i} - N_{L/RST_j} \right) / N_{L/RST_j} \right] \right\} \quad (8) \]

A utility-regret model is formed combined with the specific function forms of the above utility and regret model as shown in formula 9, with its probability selection formula \( P_{UR} \) shown in formula 10.

\[ UR_j = a \cdot V_{ij} + b \cdot R_{6j} + \varepsilon_j \quad (9) \]

\[ P_{UR}(j) = a \cdot P_V + b \cdot P_R = a \frac{\exp (V_{ij})}{\sum_{i=1}^{J} \exp (V_{ii})} + b \frac{\exp (-R_{6i})}{\sum_{i=1}^{J} \exp (-R_{6i})} \quad (10) \]
Since the ratios a and b of the utility function and regret function in this formula are still undetermined, the probability selection formula of the utility-regret model is replaced by \( P_{AC} = n / M \), where \( n \) is the number of times a path is selected in the actual path selection process and \( M \) is the total number of passenger trajectories between the OD. \( P_{AC} \) together with the calculated utility function probability value \( P_U \) and regret function probability value \( P_R \) are used for parameter estimation by SPSS software.

Input 1000 continuous passenger trajectory segments to calculate the calculated utility function probability value \( P_U \) and regret function probability value \( P_R \) to obtain the utility function and regret function in the combined function and regret function, the proportion coefficients of the regret function are \( a = 0.3159, b = 0.6841 \). Finally, the utility-regret joint model formula 11 is obtained, that is, excavated in the route selection, the taxi driver considers the utility maximization rule to account for 0.3159, and the regret minimization rule accounts for 0.6841.

\[
UR_j = 0.3159V_{4j} + 0.6841R_{6j} + \varepsilon_j
\]  

(11)

4. Comparative analysis of utility-regret joint model and other models

Use a set of high-frequency OD (Xi’an High-tech Software Park-Xiaozhai) different 5 consecutive passenger trajectory fragment data Trip1 ~ Trip5 to verify the above model:

(1) Use the attribute values of the utility model and the regret model to calculate the selected probability \( P_U \) of each continuous passenger trajectory Trip in the utility model, the selected probability \( P_R \) in the regret model, and the selected probability \( P_{UR} \) in the utility-regret joint model, respectively.

(2) According to the number of trips \( n \) selected by Trip1 ~ Trip5 in the actual path selection process and the total number of passenger trajectories \( M \) between the OD, the probability of the trip actually selected is calculated by \( P_{AC} = n / M \).

(3) Draw a line chart of the four probabilities of Trip1 ~ Trip5.

As shown in Figure for the three models, the calculated probabilities \( P_U, P_R, P_{UR} \) and the actual selection probability \( P_{AC} \) are line charts. From the figure, it can be seen that the three probability curves derived from different models are basically consistent with the actual path selection probability curve. In the longitudinal comparison of Trip1, the path with the highest frequency actually selected, the probability obtained by the utility-regret model is closer to the true value, and the probability of other road segments being selected is also closer to the true value than the utility model and the regret model.

(4) Calculate the total error of each model’s calculated probability and actual selected probability on multiple road sections: \( P_U, P_R, P_{UR}, P_{AC} \) as shown in formula 12.
\[ E_{UR/UR} = \sum_{\text{Trip}1-5} |P_{UR/UR} - P_{AC}| \] 

The calculation result of total error is \( E_t=10.84\% \), \( E_R=6.82\% \), \( E_{UR}=2.34\% \). The final verification shows that the utility-regret joint model proposed in this chapter is closer to the result of the taxi driver's path selection in the real scene than the simple utility model and the simple regret model.

5. Conclusion

Based on the analysis results of each route choice model and comprehensively considering the driver's route choice scenario, this paper uses the utility model and the improved regret model to construct a combined model of utility-regret rule. First, the influencing factors are analyzed to form six variable combinations and to determine the specific forms of the utility function and regret function in the model under different variable combinations; secondly, the maximum likelihood estimation method is used to estimate the parameters in the utility model and regret model using the RP data generated by a pair of high-frequency OD, and the combination with the best fit is selected to become the utility-regret joint model; thirdly, in order to determine the specific form of the utility-regret model, the utility value and regret value are calculated, and the proportion coefficient in the utility-regret joint model is estimated. From the model fitting results, it can be analyzed that the driver prefers to choose a route with a small average sampling speed, a small speed change, a short route, a relatively small number of left-turn intersections, and a short driving time when choosing a travel route. In the final form determined by the utility-regret joint model, the utility maximum rule accounts for 0.3159, and the regret minimum rule accounts for 0.6841. Finally, the RP data generated by another pair of OD is used to verify the rationality of the combined utility-regret model. The verification results show that the route choice probability \( P_{UR} \) under the utility-regret joint model is closer to the route choice probability \( P_{AC} \) in the real route choice scenario than the route choice probability \( P_U \) and the regret model route choice probability \( P_R \).

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References

[1] D. E. Bell, “Regret in decision making under uncertainty,” Operations Research, vol. 30, no. 5, pp. 961–981, 1982.
[2] G. Cheng, S. Zhao, and S. Xu, “Estimation of passenger route choices for urban rail transit system based on automatic fare collection mined data,” Transactions of the Institute of Measurement and Control, vol. 41, no. 11, pp. 3092–3102, 2019.
[3] C. G. Chorus, T. A. Arentze, and H. J. P. Timmermans, “A random regret-minimization model of travel choice,” Transportation Research Part B, vol. 42B, no. 1, pp. 1–18, 2008.
[4] C. G. Chorus, “A generalized random regret minimization model,” Transportation Research Part B, vol. 12, no. 6, pp. 224–238, 2014.
[5] D. L. a b, C. jie Jin a, M. Y. a et al., “Incorporating multi-level taste heterogeneity in route choice modeling: From disaggregated behavior analysis to aggregated network loading,” Travel Behaviour and Society, vol. 19, pp. 36–44, 2020.
[6] L. C. Duncan, D. P. Watling, R. D. Connors et al., “Path size logit route choice models: Issues with current models, a new internally consistent approach, and parameter estimation on a large-scale network with gps data,” Transportation Research Part B: Methodological, vol. 135C, pp. 1–40, 2020.
[7] Y. Jiang and J. Yang, “Research on passenger route selection of urban rail transit based on regret theory,” Logistics Sci-Tech, vol. 42, no. 03, pp. 108–110, 2019.
[8] M. Li, X. Ji, J. Zhang et al., “Route choice behaviour based on time surplus random regret-minimization model,” Journal of Transportation System Engineering and Information...
Technology, vol. 14, no. 06, pp. 158–163, 2014.
[9] L. Graham and S. Robert, “Regret theory: An alternative theory of rational choice under uncertainty,” The Economic Journal, vol. 96, no. 3, pp. 1670–1678, 2013.
[10] K. Luan, Z. Jun, and A. Ni, “Random regret minimization model of travel route choice,” Journal of Transport Information and Safety, vol. 30, no. 6, pp. 77–80, 2012.
[11] J. Marschak, “Binary-choice constraints and random utility indicators,” 1960.
[12] M. Yap, O. Cats, and B. van Arem, “Crowding valuation in urban tram and bus transportation based on smart card data,” Transportmetrica A: Transport Science, vol. 16, no. 1, pp. 23–42, 2020.
[13] Train and K. E., “Discrete choice methods with simulation || gev,” vol. 10.1017/CBO9780511805271, no. 4, p. 60, 2009.
[14] H. Wu, R. Huang, L. You et al., “Recent progress in taxi trajectory data mining,” Acta Geodaetica et Cartographica Sinica, vol. 48, no. 11, pp. 1341–1356, 2019.
[15] S. Xu, “Real-time prediction of subway passenger travel destinations based on automated fare collection data,” Journal of Transportation Engineering and Information, vol. 017, no. 002, pp. 81–90, 2019.
[16] Y. Yang, E. Yao, and L. Pan, “Taxi route choice behavior modeling based on gps data,” Journal of Transportation Systems Engineering and Information Technology, vol. 15, no. 01, pp. 81–86, 2015.
[17] P. Zhao, X. Liu, K. Mei-Po et al., “Unveiling cabdrivers’ dining behavior patterns for site selection of "taxi canteens" using taxi trajectory data,” Transportmetrica A: Transport Science, vol. 16, no. 1, pp. 137–160, 2020.