Review of route choice based on prospect theory

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Abstract. In the face of the traffic system with uncertainty, people often take on the characteristics of the bounded rationality, there is a certain degree of uncertainty, the application of prospect theory has some applicability to the modeling of route choice decision behavior. This paper reviews the development course of prospect theory, then expounds the formula principle of prospect theory and the improved cumulative prospect theory, introduces the research status at home and abroad and makes a certain comb and summary.

1. Introduction
In the transportation system, traffic behavior decision-making is affected by many aspects. The decision-maker’s analysis of traffic behavior will involve the current system road condition, the decision-maker’s personal characteristic and traffic-related characteristics. To consider these factors, it needs to be applied to the economy. Theoretical basis of science, psychology and other disciplines. Some scholars analyze the transportation network on the basis of the expected utility theory and believe that the choice of transportation mode and transportation mode has certain applicability, but because of the existence of the absolute expected utility theory, scholars use prospect theory to analyze and solve practical problems.

2. Development of prospect theory
Expected value theory in the 17th century, as a result of a single decision level, after the further research of scholars put forward expected utility theory, and then in 1952, Ales designed an experiment conflict with the essence of expected utility theory, further in 1979 by Kahneman and Tverskey put forward the famous prospect theory, development process as shown in figure 1. Prospect theory is based on the expected value theory and expected utility theory of innovation and development, after applying to the transportation major, transportation scholars analyze kinds of aspects of the study, attain a lot of valuable research results, the facts prove that the combination of prospect theory and transportation behavior is a successful innovation.

Figure 1. Development of prospect theory
Prospect theory, also known as expectation theory, was proposed by Kahneman and Tverskey in 1979. The main content of the theory is that when it comes to gains, people are more inclined to avoid risks, and they are more willing to accept low risks rather than pursuing risks. When dealing with losses,
people are more inclined to accept risks, and are more likely to pursue risks and accept high risks. People's gains and losses are not absolute, need a reference position to determine, a reference point as a basis for measurement. The way people treat the deviation of results is not that they are more sensitive to the absolute fixed evaluation results, that is to say, the effect intensity of things themselves cannot significantly cause people's reaction, but they are more sensitive to the change of things themselves. The mechanism of this effect is often related to the cognitive law of people's psychology. The mathematical model is as follows:

\[ EP = \sum U(X_i)W(P_i) \]  

(1)

It is worth noting that in prospect theory, not only the utility value is a function, but also the probability of decision is replaced by a probability function, which reflects a psychological weight function for treating risks. It can be seen from the curve that the functions are concave to the origin respectively.

The value function formula is:

\[ v(x) = \begin{cases} 
(x - x_0)^+, & x \geq x_0 \\
-(x - x_0)^-, & x < x_0 
\end{cases} \]

(2)

In the above formula, \(x_0\) serves as the reference point for the question, \(x\) represents the choice of a solution, \(\alpha, \beta\) represents the coefficient of risk attitude, \(\lambda\) is the loss aversion coefficient, and \(\alpha = \beta = 0.88, \lambda = 2.25\), and the probability weight function is divided into gains and losses.

Probability weight of gain:

\[ \omega^+ = \frac{p^\gamma}{[p^\gamma + (1 - p^\gamma)]^{1/\lambda}} \]  

(3)

Probability weight of loss:

\[ \omega^- = \frac{p^\delta}{[p^\delta + (1 - p^\delta)]^{1/\lambda}} \]  

(4)

As shown in figure 2, the weight function is a function of objective probability. For the event with a small probability, the features of the function will give greater psychological weight to the event with a large probability, but it will give a smaller psychological weight to the event with a large probability, which is consistent with the decision psychology of the actual decision maker.

![Figure 2 Decision weights and objective probabilities](image)

In 1992, Kahneman and Tversky again according to the research results to improve the prospect theory, in order to treat the risk of uncertainty, the introduction of the concept of volume of the weight of the original revised, will have a certain arrangement each alternative and the probability of may assume that each scheme \(x_i\) in for \(p_i\), weighting function expression of the revised as follows:
The cumulative prospect value after correction is:

\[ V = \sum_{i=0}^{0} \pi^-(p_i)v(x_i) + \sum_{i=0}^{n} \pi^+(p_i)v(x_i) \] (8)

Compared with prospect theory, cumulative prospect theory can better solve the problem of how to explain the randomness in prospect theory and how to solve the problem of how to solve more than one result, which enhances the adaptability of the theory. The cumulative prospect theory is actually an update and upgrade on the basis of the prospect theory, which can enable the prospect theory to enter more fields and play its role. The application scope of the prospect theory will be broader after this revision.

3. Research review at home and abroad

3.1. Foreign status
The application of prospect theory in the field of transportation involves multiple levels. The decision-making of travelers includes the choice of transportation behaviors, the choice of travel routes, the choice of routes under emergency situations, the choice of routes under dynamic information, and the choice of routes for commuters.

3.1.1. Route choice
The prospect theory extends widely in the direction of route selection. Foreign studies include the case analysis of drivers, commuters, etc. There are also studies on the route choice of travelers by combining the prospect theory with other theories, as well as studies that consider the reference points of travel time and the discussion of reference points.

Zhang [1] was built with the social travel information daily route choice model, the study design and laboratory experiments, the high rate of social interaction in the online travel community is not always for the individual or the whole system to bring better results of route choice and select the number of each line and the percentage of the overall impact on the perception of travel time may be either negative or positive. Wang [2] built a new framework to model the evolution of risky traveler route selection, embedded the prospect theory in replicator dynamics (RD), and proposed a new model based on the linear piecewise value function. The new framework showed the flexibility in combining the different factors of individual bounded rationality and population dynamics. Researchers from different angles of modeling analysis will give their own results, how to integrate these research results and apply them to similar situations is still a topic worth studying.

3.1.2. Reference point
Yang [3] improved the method of determining travel time reference points by considering the limitation of reserved travel time for travelers, and established a random user equilibrium model based on CPT that integrated Wardrop equilibrium principle. Erel [4] discusses the options that can be used to determine the key parameter values of the prospect theory travel selection model, describes the modeling challenges due to the lack of a consistent reference point value, and other difficulties in setting values for other parameters, and proposes several methods that can be used to set the prospect theory parameter values. KaisaHerne [5] switched the position of asymmetric dominant reference points without changing the dominant relationship. The reference dependence model was tested in two experiments on asymmetric dominant reference points, and the experimental results further confirmed the applicability of the dependent reference point model. Determine standard for reference point is always a problem worthy of studying, the different point of reference for the researchers in different models, and a method
for determining determined on the basis of it is not the same, in this problem is the lack of a complete system of thought, to guide the Settings of the reference point in the model under different conditions of the specific applicable method.

3.2. Domestic situation
Prospect theory application in route choice model including the traveler to make decisions under different circumstances, these conditions include traffic congestion, emergency response, the researchers use prospect theory study to analyze traveler in different situations, it may make the decision, the study of commuters’ route choice, and spread to the research of double reference point, under different application of dynamic routing, etc.

3.2.1. Route choice
The research of prospect theory on route choice can be divided into commuters, students and other travelers according to the object category of travelers. Most of them are for the route selection of commuters. Researchers have established a large number of route selection models, in which category classification should be carried out according to the research emphasis. Some scholars proposed to build a route choice model based on dynamic information. Under this model, the participants can adjust their route choice according to the real-time information they receive, so as to make the decision result conform to the traveler's expectation. Yang zhiyong [6] believed that in the context of dynamic information, the arrival time of travelers should be set as the reference point. Before establishing the model, Bayesian theory should be used to adjust the appearance time of the path, and then the route choice model with dynamic information should be established. Zhang bo [7] established the stochastic user equilibrium model on the basis of the cumulative prospect theory, gave the equivalent variational inequality, and established the dynamic reliability index to evaluate the operation efficiency and service level. On route choice under the influence of dynamic information, scholars combine the travel time, cost, comfort, congestion change degree and dynamic path, consider to the decision-making of quantifiable factors and applied it to the model obtained better applicability, but most of the study did not involve paths and time correlation and associated probability problems, this vacancy needs to be filled by scholars.

3.2.2. Reference point
The setting of reference points is the key of the model, which plays a decisive role in the results of the model. Inappropriate reference points may lead to the deviation of the model and lead to wrong conclusions. Domestic scholars on reference points have done a lot of examples for verification and obtained valuable research results for reference. Huang haijun [8] believes that travelers with high reference points and low reference points tend to choose the path with high risk in order to obtain high perceived value, while travelers with medium reference points tend to choose the path with low risk. Chu yao-cheng [9] analyzed the factors affecting the selection of reference points, analyzed the sensitivity of the selected reference points, evaluated the accuracy of the selection of reference points, and analyzed the updating and changing rules of the reference points. Sun huijun [10] selected the expected excess travel time as the reference point and established a stochastic network equilibrium based on the cumulative prospect theory and its equivalent variational inequality model. Li xueyan [11] combined cellular automata to establish a multi-agent route choice model with an individual interaction mechanism, and designed a dynamic reference point of travelers with heterogeneous characteristics and its evolution rules.
Table 1 Route choice model comparison

| Researchers | Model                          | Application          | Data source    | Parameter          |
|-------------|--------------------------------|----------------------|----------------|--------------------|
| Huang haijun | Heterogeneous reference point equilibrium model | Route choice        | Computer experiment | \( \gamma=0.74, \xi=1/3 \) |
| Zhu yaocheng | Reference point path selection model | Route choice        | Questionnaire survey | \( \gamma=0.61, \delta=0.69 \) |
| Sun huijun  | Equivalent variational inequality model | Route choice        | Traffic network   | \( \gamma=0.65, \eta=2.25 \) |
| Li xueyan   | Multi-agent path selection model  | Route choice        | Actual survey     | \( \gamma=0.74 \) |

Reference points of the parameters according to the actual instance of calibration, the choice also requires a lot of experiments and methods to further explore the consummation, a large number of research results also show that can be the reference point on combing and analysis of the principle of level fundamentally reveals a level reference point selection method, to broaden the reference surface after verified its applicability, study of reference point level also needs a large number of scholars to work together.

4. Conclusion

This article mainly carries on the outlook for scholars in recent years in theoretical research in terms of route choice of a comb, combined with domestic and foreign literature can be seen: The researchers of traveler’s route choice usually adopt different research methods, such as multi-path, multi reference point model and multi-agent behavior model. However, the research of prospect theory still has a broad field to explore. Based on prospect theory, the influence of time and space on human’s choice is considered. Considering the possibility of reappearing regional features and the lack of experiments, a lot of research results are needed to fill in.

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