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Research Article

Travel Choice Behavior Model Based on Mental Accounting of Travel Time and Cost

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This paper analyzes the utility calculation principle of travelers from the perspective of mental accounting and proposes a travel choice behavior model that considers travel time and cost (MA-TC model). Then, a questionnaire is designed to analyze the results of the travel choice under different decision-making scenarios. Model parameters are estimated using nonlinear regression, and the utility calculation principles are developed under different hypothetical scenarios. Then, new expressions for the utility function under deterministic and risky conditions are presented. For verification, the nonlinear correlation coefficient and hit rate are used to compare the proposed MA-TC model with the other two models: (1) the classical prospect theory with travel time and cost (PT-TC model) and (2) mental accounting based on the original hedonic editing criterion (MA-HE model). The results show that model parameters under deterministic and risky conditions are pretty different. In the deterministic case, travelers have similar sensitivity to the change in gain and loss of travel time and cost. The prediction accuracy of the MA-TC model is 3% lower than the PT-TC model and 6% higher than the MA-HE model. Under risky conditions, travelers are more sensitive to the change in loss than to the change in gain. Additionally, travelers tend to overestimate small probabilities and underestimate high probabilities when losing more than when gaining. The prediction accuracy of the MA-TC model is 2% higher than the PT-TC model and 6% higher than the MA-HE model.

1. Introduction

It is widely known that travel demand or behavior models can be divided into the aggregate and disaggregate models. The aggregate model uses a traffic zone or a specific group as the primary analysis unit. On the contrary, the disaggregate model considers individuals or groups the basic unit. The model does not require aggregate data, and therefore, it will not cause information loss. Besides, the disaggregate model has other advantages, such as good transferability and policy evaluation. Therefore, the model is widely used to analyze travel demand and behavior. Among disaggregate models, the logit model is most extensively used, and it is based on the theory of maximum utility [1]. This theory assumes that the traveler is perfectly rational, has clear objectives and complete information, and can always find the optimal solution in decision-making. This assumption is unrealistic [2, 3]. In actual traffic environments, travelers are often unable to make decisions to maximize their utility due to many factors such as personal cognitive level, information completeness, and environment. This phenomenon is called bounded rationality. The concept of bounded rationality was first proposed by Simon [4], who believed that people always tend to find a satisfactory solution in their decision-making process. Subsequently, bounded rationality has been applied in many fields, such as financial investment and travel behavior [5, 6]. Many scholars have researched the framework of bounded rationality and put forward some new theories, such as satisficing rule, regret theory, and prospect theory (PT). Among them, PT is the most representative and has been extensively applied [7, 8].

The prospect theory was proposed by Kahneman and Tversky [3]. The theory focuses on the risk attitude of decision makers from the change of the value. It can well explain the phenomenon of nonlinear preference, reference-dependent, risk-seeking, and loss aversion in the decision-making process. It has attracted the attention of many scholars in various fields, especially in transportation engineering, who conducted much research on whether the theory is applicable to travel behavior. Through the experimental study, Katsikopoulos et al. [9] and Bogers and Van Zuylen [10] found that the risk preference of travelers was reversed in the process of travel decision-making, which is consistent with PT. Avineri [11], Fujii and Kitamura [12], and Jou et al. [13] also proved that the decision-making behavior of traffic subjects in uncertain situations is similar to that of economic subjects in PT, especially for the departure time and route choices. Senbil and Kitamura [14] chose the acceptable earliest and latest arrival times as reference points and defined two different decision frameworks according to the preferred and latest arrival times. On this basis, they studied the impact of different departure times on the commuter's route choice under the PT framework.

In recent years, PT has been widely used in transportation [15–17]. However, with the development of PT applications, scholars have found some problems, such as estimated parameters' applicability and reference points' setting. Many scholars have researched these two issues [18–20]. In addition, the descriptive ability of PT to multiresult decision-making problems is also minimal [21]. By introducing cumulative weights into the original prospect theory [22], the CPT made up for the shortcomings of the original PT, which was only applicable to two outcome decision-making problems. However, PT or CPT still cannot explain the individual's choice behavior in some scenarios (see the analysis of Section 2). The mental account theory (MAT) can make up for the deficiency of PT and CPT [23]. According to the MAT, an individual will construct multiple accounts by dividing his/her income source, consumption items, or wealth storage mode. Each account for a particular classification has a budget constraint. The difference between MAT and other economic behavior theories is that it violates the substitutability of money in traditional economics.

The MAT provides a theoretical explanation of the human boundedly rational decision-making behavior that deviates from rationality and has attracted the attention of scholars in various fields. Shefrin and Statma [24] believed that investors would consider the security and potential of the investment plan simultaneously, and its asset structure should be a pyramid-like hierarchical mental accounting structure. Based on the security potential/aspiration theory and PT, the authors proposed the behavior portfolio theory. Shefrin and Thaler [25] introduced mental accounting to explain actual people's consumption behavior and then put forward the behavioral life-cycle hypothesis. Prelec and Loewenstein [26] proposed a double-entry mental accounting theory to describe the different psychological feelings of consumers in consumption and payment. Shafir and Thaler [27] used MAT to explain why people consider buying luxury jewelry an investment behavior rather than a consumption behavior when buying is separated from consumption. Li [28] used field and experimental data to verify Chinese mental accounts' structure and internal mechanism and revealed the inherent rule between mental accounts and irrational decision-making behaviors. In addition, many scholars experimentally investigated whether individuals would establish time accounts under the MAT framework. For example, Rajagopal and Rha [29] confirmed the similarity between time and money through five experiments. The results showed that individuals would create mental accounts for time and allocate them to different accounts for evaluation, which is like money. Leclerc et al. [30] took PT and MAT as a theoretical framework to explore whether individuals perceive time as money. The results showed that when faced with time loss in a deterministic situation, individuals showed risk-seeking, while in a risky situation, individuals showed risk aversion.

At present, some scholars have proved that MAT is also applicable in transportation engineering and applied it to the study of travel choice behavior, but the relevant research is relatively few. Hess and Sheldon [31] explored the consistency and nonfungibility of cost and time, time and safety, and safety and cost through stated choice experiments and found that cost is not fungible, which verified the existence of money mental account in travel. Using a questionnaire, Bai [32] made the independent trade-off of walking time, waiting time, and in-car time. The results showed that the three types of travel time accounts could not be substituted for each other, which proved that travelers would set up time account in travel. Bao et al. [33] introduced the concepts of mental account and mental budget and defined travel utility function with an over-budget penalty. They proposed a user-equilibrium model with a mental budget as a constraint condition. Yang et al. [34] elaborated on how to combine PT with MAT to study travelers' travel decision-making behavior and proposed a travel choice behavior model that considered an individual's preference for time and money.

However, there are some problems in the application of MAT. Specifically, the specific form of the value function needs to be determined and how to edit and integrate the relevant attributes involved in decision-making needs to be developed. Thaler [23, 35] only pointed out that the MAT value function has the characteristics of reference-dependent, loss aversion, and diminishing sensitivity and did not give a specific form. However, because the characteristics of MAT are consistent with those of PT, the author took the PT function as the basis of measuring MAT utility. Yang et al. [34] believed that travelers have two mental accounts: time and money. The new forms of the value and weight functions of time and money accounts were obtained, respectively, using a questionnaire and data fitting. The segregation principle was used to integrate the utility. According to MAT, the principle of segregation applies to two accounts with both gains or with a large loss and a small gain. However, the authors did not specify the gains or losses of travelers' money or time accounts and directly used the segregation principle to integrate the two accounts. The research did not explain the reason for adopting this calculation principle.

MAT is still at the initial research stage, and previous research has mainly focused on individual investment, consumption decision-making behavior, and human resources. The attributes involved in the research are usually single, such as money or time. However, travel decision-making problems often involve both money and time [33, 34, 36], and the existing mental accounting research on multiattribute decision-making is very scarce. Therefore, it is necessary to conduct further research on travel behavior decision-making from MAT perspective that considers both money and time attributes. In addition, although a few scholars have used MAT to conduct travel behavior research, a thorough analysis of its utility measurement system has not been made and a general model has not been proposed. To make up for the lack of a theoretical model in the application of MAT in multiattribute travel decision-making, this paper assumes, based on previous studies, that travelers have two mental accounts: time and money. Considering both travel time and cost, we propose a travel choice behavior model based on MAT and PT. Then, behavior-choice data in different hypothetical situations are obtained using a questionnaire, and the expression of a multiattribute utility function and the estimation of model parameters are discussed. In addition, this paper also uses the survey data to determine the MAT utility calculation principle in the traffic context. Finally, the paper verifies whether the hedonic editing (HE) criterion for economic subjects is also applicable to travel subjects.

The rest of this paper is organized as follows. Section 2 reviews the concepts and operation methods of PT and MAT. Section 3 discusses the possible utility calculation forms considering time and money in various scenarios from the mental accounting perspective and proposes a choice behavior model (MA-TC model) considering travel time and cost. Section 4 describes the design of the questionnaire situation in detail and presents the statistical analysis of the questionnaire data. In Section 5, the least square fitting method is used to calibrate the model parameters, and the specific utility calculation principle and the expression of the MA-TC model are determined. In Section 6, the proposed model is validated by comparing the proposed model with two traditional models. Finally, the conclusions and further research areas are presented in Section 7.

2. Theoretical Basis

2.1. Prospect Theory. Because the value function model of the prospect theory is often introduced into the utility function of the mental account theory, we will introduce the prospect theory first. The prospect theory divides the decision-making process of an individual in an uncertain situation into two phases: editing and evaluation. In the editing phase, the reference point is used as the basis for evaluation, and the possible results of each alternative are transformed into gains or losses relative to the reference point. In the evaluation phase, the value function $v(\cdot)$ and decision-weighting function $\pi(\cdot)$ are used to calculate the prospects of each alternative. Finally, the individual selects the alternative according to the values of the prospects. The main content of PT can be divided into the following three parts.

Reference point: in the study of travel behavior, the reference point is usually the predefined criteria of gains and losses according to historical travel experience, travel purpose, travel information, and other factors. These factors can be used to determine whether the utility of travelers after trips is gain or loss.

Value function: Kahneman and Tversky believed that individuals paid more attention to the change of wealth rather than the final amount in their decision-making and proposed a value function that can reflect the change of value relative to the reference point. The function takes the reference point as the dividing point between gain and loss, and it is convex in the area of gain and concave in the loss area, so its curve is S-shaped (Figure 1). This form well describes the preference characteristics of the decision makers who prefer risk aversion in gain and risk-seeking in loss. The specific expression is given as

$$v(x) = \begin{cases} (x - x_0)^{\alpha}, & \text{if } x \geq x_0, \\ -\lambda (x_0 - x)^{\beta}, & \text{if } x < x_0, \end{cases} \tag{1}$$

where x_0 is the reference point, α and β are the risk attitude parameters, which measures the degree of diminishing sensitivity of the decision makers to risk changes (the greater the value is, the more sensitive the decision makers are to risk), and $\lambda (\lambda \geq 1)$ is the loss aversion coefficient, which indicates that individuals are more sensitive to losses than the same gains (the greater the value is, the more sensitive the decision makers are to losses).

Decision weighting function: the decision-weighting function is a nonlinear monotone increasing function about probability, which reflects the subjective psychological perception of the decision maker on the objective probability of events. At present, the most widely used form of the decision-weighting function is the inverse S-shaped function proposed by Tversky and Kahneman [22], as shown in Figure 2, which is given by

$$\pi(p) = \begin{cases} \pi^{+}(p) = \dfrac{p^{\gamma}}{\left(p^{\gamma} + (1-p)^{\gamma}\right)^{1/\gamma}}, & \text{if } x \geq x_0, \\ \\ \pi^{-}(p) = \dfrac{p^{\delta}}{\left(p^{\delta} + (1-p)^{\delta}\right)^{1/\delta}}, & \text{if } x < x_0, \end{cases} \tag{2}$$

where p is the probability of an event occurrence and γ and $\delta (0 \leq \gamma, \delta \leq 1)$ are parameters denoting the curvature of the weight function. Note that a smaller value of the two parameters γ and δ indicates that the decision maker's tendency to overestimate small probability events and underestimate high probability events is more obvious.

Thus, let a simple event with two outcomes in an uncertain situation be represented by $A(x, p; y, q)$, where x and y represent the two possible outcomes of the event and p and q represent the possibility of the two outcomes. Then, the prospect value of $A(x, p; y, q)$ is given by

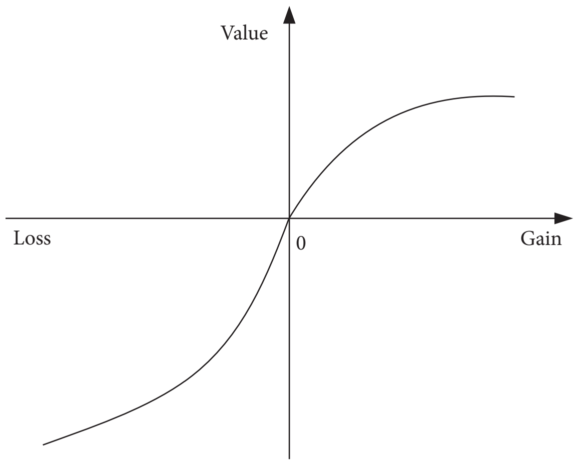

Figure 1: Value function of prospect theory.

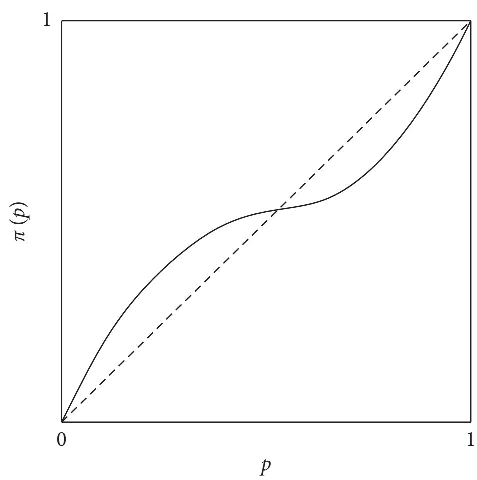

Figure 2: Decision-weighting function of prospect theory.

$$V_{PT}(A) = v(x)\pi(p) + v(y)\pi(q). \quad (3)$$

2.2. Mental Accounting Theory

2.2.1. Concept. Mental accounting is a cognitive operating system for individuals, families, or organizations to psychologically code, classify, and evaluate, especially economic outcomes. One of the core ideas of MAT is that money is not fungible. The money in one account will not be spent as well in another account. Individuals will manage funds from different sources and uses, and each subaccount has its mental budget and control rules. Thereby, it is difficult to transfer money from one account to another. This is also the most significant difference between MAT and traditional economics. According to the relevant experimental MAT research, nonfungibility can be divided into three situations [23, 28, 32]. First, the mental accounts established by different sources of wealth are nonfungibility. For example, people will deposit hard-earned money and unexpected wealth in different accounts. Usually, people will not go to the casino with $100,000 earned by themselves. However, if they win $100,000 from the lottery, the possibility of going to the casino is much higher. Second, the mental accounts established for different consumption items are nonfungible. For example, a wife is willing to receive expensive gifts from her husband, but not willing to buy expensive things by herself. Rationally speaking, the family's total wealth does not change, but for the same amount of money spent for different reasons, people's subjective psychological feelings are different. Third, different storage methods lead to the nonfungibility of mental accounts. For instance, people are reluctant to embezzle housing funds for temporary expenses.

To illustrate the concept of mental accounting, it is helpful to describe it first using the following example.

Tversky and Kahneman [37] conducted a classical experiment and found an interesting phenomenon. Both scenarios assumed that people were going to a $10 concert and found that they had lost something worth $10 before leaving. The only difference between the two scenarios was that one scenario was the loss of a calling card. The other scenario was the loss of the concert ticket (if the missing item was a ticket, people had to pay another $10 to go to the concert). In the two scenarios, people were asked whether they would continue to attend the concert. Curiously, the choice results were pretty different. In the case of losing the calling card, 88% of the respondents said they would still go to the concert, while in the case of losing the ticket, only 46% of respondents said they would continue to attend the concert.

Whether the individual lost a calling card or a concert ticket, the lost item is worth $10. Why are people's choices different? According to the substitution axiom in traditional economics and PT, the prospects of the two scenarios or measures in each case are equal. Therefore, the individual's choice results in the two scenarios should be the same, but they are not. In response to this phenomenon, Thaler [35] offered a reasonable explanation that people have mental accounts in their minds, and there is nonfungibility between money/time from different sources and uses. When evaluating the alternatives, people will put different kinds of money/time into different mental accounts and evaluate the gains and losses of each account according to the preset mental budget of each account. In the concert experiment, people subconsciously divided the calling card and the concert ticket into different expenditure accounts. Losing a calling card would not affect the budget and the expenditure of the concert ticket account, so most people still chose to go to the concert. While the lost concert ticket and subsequently the re-purchased ticket were grouped into the same account, which seemed that it would cost $20 to listen to a concert, so people naturally thought it was not worthwhile.

It can be seen from the preceding example that if people have mental accounts in their minds when making choices, it will be biased to use PT to describe their choice behavior. In contrast, using MAT can accurately explain their decision-making behavior. Therefore, if travelers have mental accounts when they make travel choices, it is necessary to use MAT to describe the boundedly rational travel behavior. To more accurately characterize this behavior, this paper attempts to model and analyze the travel behavior of travelers from the perspective of mental accounting. The research results will hopefully enrich and advance the theory of travel behavior.

2.2.2. Hedonic Editing Criteria. For an economic activity, how does an individual use mental accounting to evaluate it and make decisions? Thaler [23] thought that the individual maximizes emotional satisfaction in decision-making. The process of psychological calculation for each account involves evaluating the gains or losses of alternatives and assessing in which alternatives will bring better psychological experience. In other words, the individual will combine perceived gains or losses into an account, psychologically encode them according to specific operational rules, and ultimately choose the alternative that makes the individual feel more pleasant. The author named these operational rules "Hedonic Editing Criteria" in "Mental Accounting Matters," which is different from the traditional economic and mathematical operational rules. Unfortunately, individuals affected by these rules often make decisions that violate the economic rules.

To better study how the HE criterion affects individual decision-making behavior, Thaler [23] introduced the value function concept to describe the value of alternatives quantitatively. Compared with the traditional utility theory, the MAT value function has three essential characteristics: reference-dependent, diminishing sensitivity, and loss aversion. It is basically consistent with the PT function. Therefore, researchers often use PT to represent the MAT value function [23, 30, 34, 35]. The present paper also combines PT with MAT. $V_{MA}(\cdot)$ is used to represent the MAT value function. In addition, because MAT studies the decision-making problem of joint outcomes and the PT value function is only applicable to the decision-making problem of describing single and one-dimensional outcomes, Thaler [23] expanded the value function in the application process. He proposed the following two principles (integration and segregation) to calculate the utility of the joint outcomes, which are expressed by $V_{\mathrm{MA}}(x+y)$ and $V_{\mathrm{MA}}(x)+V_{\mathrm{MA}}(y)$, respectively, where x and y represent two outcomes. In addition, he used the characteristics of value function to study individuals' preferences in the different combinations of gains and losses and summarized them into the following four principles:

(1) Segregate gains: since $V_{MA}(\cdot)$ is a concave function in the region of gain (see Figure 3(a)), so when x and y are both gains, then $V_{\mathrm{MA}}(x)+V_{\mathrm{MA}}(y)>V_{\mathrm{MA}}(x+y)$ and the decision makers prefer segregation.

(2) Integrate losses: since $V_{MA}(\cdot)$ is convex in the region of loss (see Figure 3(a)), so when $-x$ and $-y$ are both losses, then $V_{\mathrm{MA}}(-(x+y))>V_{\mathrm{MA}}(-x)+V_{\mathrm{MA}}(-y)$ and the decision makers prefer integration.

(3) Integrate smaller loss with larger gain: in this case, one of the two outcomes is gain and the other is loss, and the gain is greater than the loss, i.e., $x>0, -y<0$, and $|x|>|-y|$. According to the value function curve shown in Figure 3(b), $V_{\mathrm{MA}}(x-y)$ is always greater than zero, while $V_{\mathrm{MA}}(x)+V_{\mathrm{MA}}(-y)$ has a high probability of being less than zero, so the individual prefers to integrate.

(4) Small gain and large loss need specific analysis: in this case, the first situation is that one of the two outcomes is gain and the other is loss, and the gain is much less than the loss, $x>0, -y<0$, and $|x|\ll|-y|$. From the value function curve shown in Figure 3(c), it is noted that the curve is very flat at $-y$. At this time, the pleasure of small gain is not large enough to offset the pain of a big loss, so the integration principle cannot bring good utility. However, if we use the segregation principle, the pleasure of small gain can be obtained, so the individual prefers to separate. The second situation is that the individual prefers to integrate when the gain is slightly less than the loss, as shown in Figure 3(d). Because when the two are integrated, although the overall outcome is still a loss, the individual will psychologically transform the loss from $-y$ into $x-\mathrm{y}$. The gain offsets most of the loss, and the individual has a better psychological experience.

In short, when individuals make decisions in different combinations of gains and losses, they will follow the HE criterion to choose an evaluation principle that makes their psychological experience better. The value expression of the joint outcomes is given by [23]

$$V_{MA}(x\&y)=\max\left[V_{MA}(x+y), V_{MA}(x)+V_{MA}(y)\right]. \tag{4}$$

3. Proposed Model

3.1. Account and Reference Point Settings. As previously mentioned, this paper focuses on travel choice behavior, considering both travel time and cost from the perspective of mental accounting (MA-TC model). The model assumes that travelers have time and money accounts in mind, and they will set up a corresponding mental budget for each account. Compared with the preset reference point of the traveler, the time and cost of the travel plan have a gain or loss. Only when travelers get more gain or less loss from one plan than the others will they choose the plan. If multiple alternatives meet the requirements, the alternative which makes the traveler get the best psychological experience (maximum utility) is selected. The time and money accounts in this study refer specifically to travel time and cost, respectively.

Several methods can be used for setting the reference points. The present study adopts the method proposed by Levy et al. [38], Li and Hensher [20], Yang et al. [34], and others, considering the actual travel time and cost in the traveler's previous trip experience as reference points. It considers the heterogeneity of travelers' reference points and the influence of travel experience. Also, the reference points between the accounts do not affect each other. If the traveler is traveling for the first time, the traveler will take the expected travel time and cost as a reference.

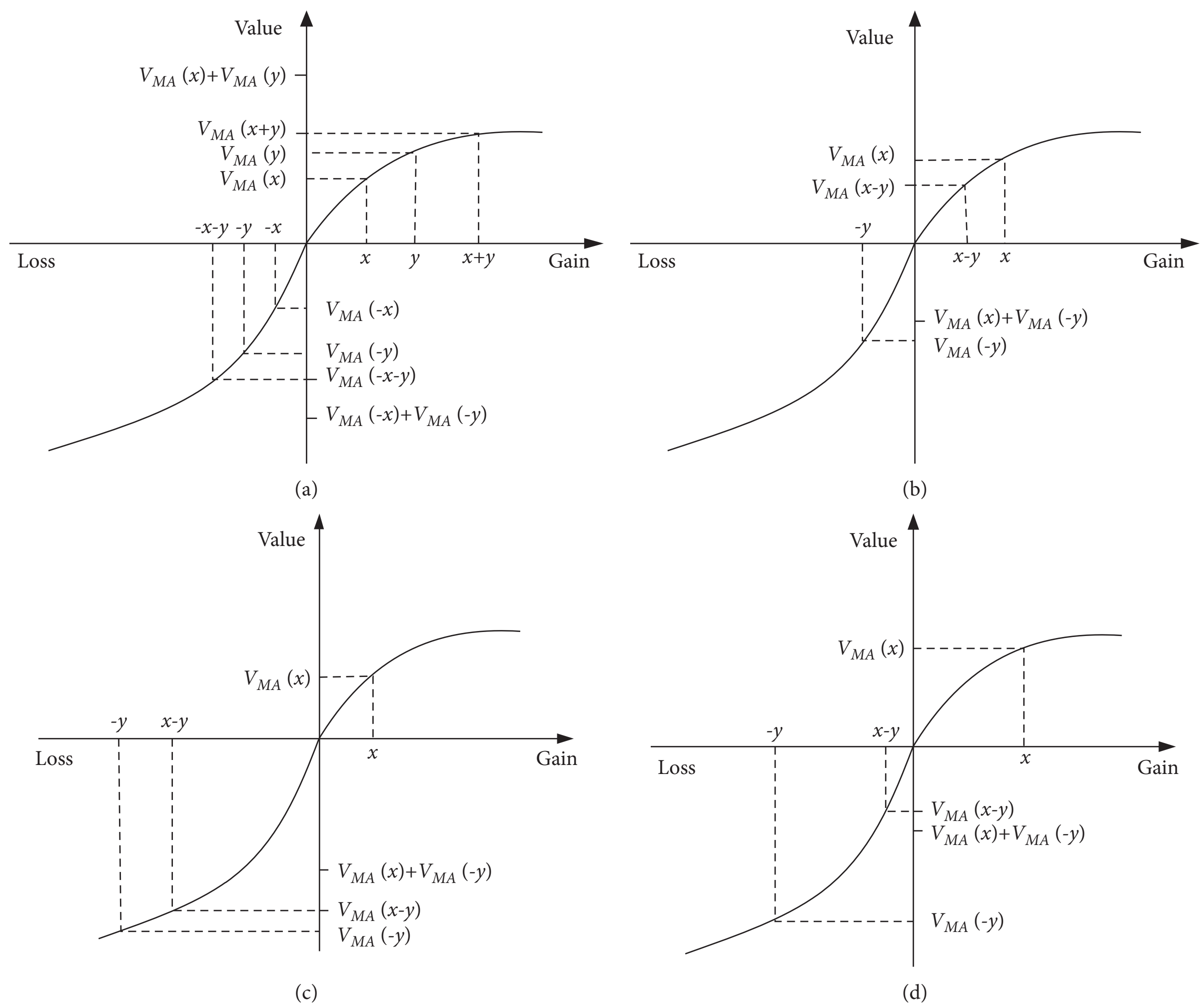

Figure 3: Value function of mental accounting theory. (a) Both outcomes are gains or losses. (b) One is gain and the other is loss (gain is greater than loss). (c) One is gain and the other is loss (gain is much less than the loss). (d) One is gain and the other is loss (gain is slightly less than the loss).

3.2. Value Function. Since the MAT value function has the same characteristics as the PT value function, the latter can be used to carry out MAT research. However, there are differences between the two value functions. Compared with the PT value function, the MAT value function focuses more on the utility calculation of the joint outcomes. For convenience and without loss of generality, the joint utility of the two outcomes is used in this study. We set up two accounts (time and money) and adopt the two principles (integration and segregation) to calculate the joint utility. The specific expressions are given by

$$V(T\&M)=\begin{cases} V(T+M)=\begin{cases}\left((T_0-T)+(M_0-M)\right)^{\alpha}, & \text{if } T_0+M_0>T+M,\\ -\lambda\left((T-T_0)+(M-M_0)\right)^{\beta}, & \text{if } T_0+M_0<T+M,\end{cases}\\ V(T)+V(M)=\begin{cases}(T_0-T)^{\alpha}+(M_0-M)^{a}, & \text{if } T_0>T, M_0>M,\\ -\lambda(T-T_0)^{\beta}-\lambda(M-M_0)^{\beta}, & \text{if } T_0<T, M_0<M,\\ -\lambda(T-T_0)^{\beta}+(M_0-M)^{\alpha}, & \text{if } T_0<T, M_0>M,\\ (T_0-T)^{\alpha}-\lambda(M-M_0)^{\beta}, & \text{if } T_0>T, M_0<M,\end{cases}\end{cases} \quad (5)$$

where T and M represent time and money accounts, respectively, $V(T\&M)$ represents the joint utility of time and money accounts, $V(T+M)$ and $V(T)+V(M)$ represent integrated and segregation utilities, respectively, T_0 and M_0 are reference points, α and β are parameters representing the degree of risk aversion and risk-seeking, respectively, and λ is the loss aversion coefficient, where $\lambda > 1$ indicates that individuals are more sensitive to losses than to gains.

It should be noted that the units of time and money are not considered in equation (5). Therefore, this equation is only used to show the form of the value function of the two accounts under different calculation principles. In Section 3.3, we will introduce a unified metric for multiple attributes in detail.

3.3. Multiattribute Utility Function. As previously described, the mental accounts have different utility calculation principles from general ones. Therefore, based on HE criterion, this section summarizes all the gain-loss scenarios of time and money accounts and presents the multiattribute utility function expressions for different scenarios under the deterministic and risky conditions. Before calculating the multiattribute utility, the problem of unifying the measurement criteria of multiattribute utility should be first solved. With the help of the Value of Time (VOT), the gain and loss corresponding to the two attributes of time and money can be transformed into a unified time or monetary unit, thus achieving the integration of multiattribute utility. It should be noted that most of the existing studies on travel time and cost used VOT to convert time into the monetary unit, so the unit of VOT is yuan/hour ($/hr). To internationalize and standardize the travel expenses, we exchange RMB into U.S. dollars according to the exchange rate on the survey day. However, to make the statistics more intuitive, we did not modify the RMB in the table. To simplify the calculations, we carried out a specific conversion to VOT, where cost is converted into time unit to achieve the unified measurement of the two attributes. To distinguish between the two conversion coefficients, VOT′ is used to represent the travel time value coefficient, where its unit is minute/yuan (min/$).

According to the account type and the HE criterion, we divided the gain-loss combination of time and money accounts into four scenarios: gain for both time and money, loss for time and gain for money, gain for time and loss for money, and loss for both time and money (expressed as Scenarios 1 to 4). According to the value of $\Delta T + \mathrm{VOT}' * \Delta M$, the combination of gain and loss (Scenarios 2 and 3) was subdivided into three categories: mixed gain, mixed loss with similar gain and loss, and mixed loss with a large difference between gain and loss. Therefore, there are 8 groups of decision scenarios. The specific scenarios are as follows:

Scenario 1: gain for both time and money

Scenario 2: loss for time and gain for money, mixed gain (Scenario 2-1), mixed loss with similar gain and loss (Scenario 2-2), and mixed loss with a large difference between gain and loss (Scenario 2-3)

Scenario 3: gain for time and loss for money, mixed gain (Scenario 3-1), mixed loss with similar gain and loss (Scenario 3-2), and mixed loss with a large difference between gain and loss (Scenario 3-3)

Scenario 4: loss for both time and money

According to the form of the value function and the specific scenarios of gain and loss, expressions for the multiattribute utility function were obtained for different scenarios under deterministic conditions. When both time account and money account gain simultaneously, i.e., $\Delta T > 0, \Delta M > 0$, the corresponding utility function is

$$V_{DC}^{1}(T\&M) = \begin{cases} (\Delta T + VOT' * \Delta M)^{\alpha}, & \text{Integration,} \\ \Delta T^{\alpha} + (VOT' * \Delta M)^{\alpha}, & \text{Segregation.} \end{cases} \tag{6}$$

When the time account losses, money account gains and the final state is gain (the gain is greater than the loss), i.e., $\Delta T < 0, \Delta M > 0$, and $\Delta T + \mathrm{VOT}' \cdot \Delta M > 0$; the corresponding utility function is

$$V_{DC}^{2-1}(T\&M) = \begin{cases} (\Delta T + VOT' * \Delta M)^{\alpha}, & \text{Integration,} \\ -\lambda|\Delta T|^{\beta} + (VOT' * \Delta M)^{\alpha}, & \text{Segregation.} \end{cases} \tag{7}$$

When the time account losses, money account gains and the final state is loss (the loss is greater than the gain), i.e., $\Delta T < 0, \Delta M > 0$, and $\Delta T + \mathrm{VOT}' \cdot \Delta M < 0$; the corresponding utility function is

$$V_{DC}^{2-2,2-3}(T\&M) = \begin{cases} -\lambda|\Delta T + VOT' * \Delta M|^{\beta}, & \text{Integration,} \\ -\lambda|\Delta T|^{\beta} + (VOT' * \Delta M)^{\alpha}, & \text{Segregation.} \end{cases} \tag{8}$$

When the time account gains, money account losses and the final state is gain, i.e., $\Delta T > 0, \Delta M < 0$, and $\Delta T + \mathrm{VOT}' \cdot \Delta M > 0$; the corresponding utility function is

$$V_{DC}^{3-1}(T\&M) = \begin{cases} (\Delta T + VOT' * \Delta M)^{\alpha}, & \text{Integration,} \\ \Delta T^{\alpha} - \lambda|VOT' * \Delta M|^{\beta}, & \text{Segregation.} \end{cases} \tag{9}$$

When the time account gains, money account losses and the final state is loss, i.e., $\Delta T > 0, \Delta M < 0$, and $\Delta T + \mathrm{VOT}' \cdot \Delta M < 0$; the corresponding utility function is

$$V_{DC}^{3-2,3-3}(T\&M) = \begin{cases} -\lambda|\Delta T + \mathrm{VOT}' * \Delta M|^{\beta}, & \text{Integration,} \\ \Delta T^{\alpha} - \lambda|\mathrm{VOT}' * \Delta M|^{\beta}, & \text{Segregation.} \end{cases} \tag{10}$$

When both time and money accounts are loss, i.e., $\Delta T < 0, \Delta M < 0$, the corresponding utility function is

$$V_{DC}^{4}(T\&M)=\begin{cases}-\lambda\left|\Delta T+\mathrm{VOT}'*\Delta M\right|^{\beta}, & \text{Integration},\\ -\lambda|\Delta T|^{\beta}-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}, & \text{Segregation},\end{cases}\tag{11}$$

where $V_{DC}^{i}(T\&M)$ represents the joint utility function of travel time T and travel cost M in Scenario i under deterministic conditions and ΔT and ΔM represent the difference between the travel time/cost reference point and its corresponding item, respectively, where $\Delta T = T_0 - T$ and $\Delta M = M_0 - M$. When the value is greater than 0, the account is in the state of gain; otherwise, the account is in the state of loss.

In addition, the daily decision-making behavior of travelers is often influenced by factors such as weather, traffic accidents, and road conditions, which makes the traffic environment very complex and uncertain. Therefore, we consider the impact of uncertainty on travel utility based on deterministic conditions and introduce the PT weight function to formulate a multiattribute utility function under risky conditions. The expressions are assumed as follows. When both time account and money account gain simultaneously, the corresponding utility function is

$$V_{RC}^{1}(T\&M)=\begin{cases}\left(\Delta T*\pi^{+}(p)+\mathrm{VOT}'*\Delta M*\pi^{+}(q)\right)^{\alpha}, & \text{Integration},\\ \Delta T^{\alpha}*\pi^{+}(p)+\left(\mathrm{VOT}'*\Delta M\right)^{\alpha}*\pi^{+}(q), & \text{Segregation}.\end{cases}\tag{12}$$

When the time account is loss, money account is gain and the final state is gain; the corresponding utility function is

$$V_{RC}^{2-1}(T\&M)=\begin{cases}\left(\Delta T*\pi^{-}(p)+\mathrm{VOT}'*\Delta M*\pi^{+}(q)\right)^{\alpha}, & \text{Integration},\\ -\lambda|\Delta T|^{\beta}*\pi^{-}(p)+\left(\mathrm{VOT}'*\Delta M\right)^{\alpha}*\pi^{+}(q), & \text{Segregation}.\end{cases}\tag{13}$$

When the time account is loss, money account is gain and the final state is loss; the corresponding utility function is

$$V_{RC}^{2-2,2-3}(T\&M)=\begin{cases}-\lambda\left|\Delta T*\pi^{-}(p)+\mathrm{VOT}'*\Delta M*\pi^{+}(q)\right|^{\beta}, & \text{Integration},\\ -\lambda|\Delta T|^{\beta}*\pi^{-}(p)+\left(\mathrm{VOT}'*\Delta M\right)^{\alpha}*\pi^{+}(q), & \text{Segregation}.\end{cases}\tag{14}$$

When the time account is gain, money account is loss and the final state is gain; the corresponding utility function is

$$V_{RC}^{3-1}(T\&M)=\begin{cases}\left(\Delta T*\pi^{+}(p)+\mathrm{VOT}'*\Delta M*\pi^{-}(q)\right)^{\alpha}, & \text{Integration},\\ \Delta T^{\alpha}*\pi^{+}(p)-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}*\pi^{-}(q), & \text{Segregation}.\end{cases}\tag{15}$$

When the time account is gain, money account is loss and the final state is loss; the corresponding utility function is

$$V_{RC}^{3-2,3-3}(T\&M)=\begin{cases}-\lambda\left|\Delta T*\pi^{+}(p)+\mathrm{VOT}'*\Delta M*\pi^{-}(q)\right|^{\beta}, & \text{Integration},\\ \Delta T^{\alpha}*\pi^{+}(p)-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}*\pi^{-}(q) & \text{Segregation}.\end{cases} \tag{16}$$

When both time account and money account are loss simultaneously, the corresponding utility function is

$$V_{RC}^{4}(T\&M)=\begin{cases}-\lambda\left|\Delta T*\pi^{-}(p)+\mathrm{VOT}'*\Delta M*\pi^{-}(q)\right|^{\beta}, & \text{Integration},\\ -\lambda|\Delta T|^{\beta}*\pi^{-}(p)-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}*\pi^{-}(q), & \text{Segregation},\end{cases} \tag{17}$$

where $V_{RC}^{i}(T\&M)$ represents the joint utility function of travel time T and travel cost M in Scenario i under risky conditions, p and q represent the probability of occurrence of two outcomes, and $\pi^{+}(\cdot)$ and $\pi^{-}(\cdot)$ are the corresponding weight functions for the gain and loss, respectively, given by equation (2).

From equations (12)–(17), the segregation utility formula under risky conditions is equivalent to the sum of the prospects of travel time and cost in the PT. Because the main objective of the present study is to explore whether the HE criterion for economic subjects is also applicable to travel subjects, this section has listed the possible multiattribute utility function expressions under different scenarios. That is, the utility functions under both deterministic and risky conditions include two principles of utility calculation. In the following sections, the results of the questionnaire are combined to further study the utility calculation principle that the traveler will use under different scenarios and determine the calculation principle of the mental accounting utility in the traffic environment.

4. Questionnaire Design and Results

4.1. Data Collection and Study Scenarios

4.1.1. Data Collection. An online questionnaire was designed to obtain the primary data for estimating the parameters of the proposed MA-TC model, considering that the decision variables of the model were travel time and cost. The questionnaire included questions about (a) traveler's gender, age, education, occupation, monthly income level, and total working hours of one week and (b) travelers' travel preferences for travel choice under given scenarios. The central part of the questionnaire consisted of all the combination scenarios of gain and loss under deterministic and risky conditions. Since this paper focuses on travel behavior modeling from the perspective of the mental account, the combined utility form of time and money in different scenarios and the value of model parameters (calibrated using the questionnaire data) are considered. The primary consideration is to meet the principles in Section 3.3 for setting time and money in deterministic and risky scenarios. Under each condition, there were 8 groups of decision-making scenarios: pure gains, one gain and one loss (mixed gain, mixed loss with similar gain and loss, and mixed loss with a large difference between gain and loss), and pure losses. The influence of the probability on the selection results was considered for the risky conditions, and each group of scenarios has 5 decision rungs.

As noted, in addition to the essential characteristics of individual travelers, this survey has 8 scenarios for deterministic conditional decision-making and 40 scenarios for risky conditional decision-making. To ensure the quality of the questionnaire, the questionnaire was divided into four parts: A, B, C, and D. Each part is composed of three sections: traveler's primary characteristics survey, deterministic conditions, and risky condition scenario survey. There are 20 single-choice questions in total in each part. The difference between the four parts of the questionnaire is only related to the combination of deterministic and risky conditions scenarios.

The questionnaire was distributed to subjects in different regions, occupations, and ages through the professional platform named "Wenjuanxing." In addition, repeated trap questions were set to test the effectiveness of the questionnaire. The formal survey was completed from April to May 2019, and 1249 valid questionnaires were obtained after sorting out and screening the data (each part has more than 300 questionnaires).

The questionnaire data were used to verify whether the HE criterion for economic subjects is also applicable to travel subjects. If not, the specific utility calculation principle that travelers adopt in different scenarios will be determined, and the HE criterion will be revised. To distinguish it from the utility calculation principle of mental accounting obtained of this paper, the HE criterion proposed by Thaler [23] is called herein the original HE criterion (equation (4) describes the original HE criterion). The specific scenarios are described next.

4.1.2. Scenarios of Deterministic Conditions. Scenario 1 (gain for both time and money): assuming that a traveler is making a trip now, it will take a long time for self-driving due to the severe traffic congestion. Considering the fuel cost, parking fee, and road congestion cost for self-driving, the traveler eventually gives up driving. There are two modes of transportation available for the traveler to choose from. Whatever mode the traveler uses, the travel time and cost are less than those of self-driving. The specific alternatives are as follows. Choosing Mode R can save 10 min of travel time and 40 yuan ($5.81) of travel cost, while the corresponding savings of Mode S are 20 min and 30 yuan ($4.35).

Scenarios 2-1 and 2-2 (loss for time and gain for money, mixed gain and mixed loss with similar gain and loss): suppose that the traveler usually chooses to travel by a car, the traveler's car is being repaired today. The traveler is now making a trip, and there are two modes of transportation available. Whatever mode is used, its travel time is longer, but its travel cost is less than that of self-driving (e.g., due to fuel cost and parking fee). The specific alternatives are as follows. Choosing mode R will take an extra travel time of 20/50 min, but can save a travel cost of 30/15 yuan ($4.35/$2.18), while mode S will take 10/40 min more, but can save 20/5 yuan ($2.90/$0.73), where the numbers refer to Scenario 2-1/Scenario 2-2.

Scenario 2-3 (loss for time and gain for money, mixed loss with a large difference between gain and loss): assume that a traveler needs to fly from country A to country B for a long flight distance, but all the tickets of nonstop flight have been sold out. Therefore, the traveler can only choose to transfer. There are two flights available for the traveler to choose from. No matter which flight is used, the travel time is longer than that of the nonstop flight, but the travel cost is reduced. The specific alternatives are as follows: choosing flight R will take 15 hrs more, but can save 150 yuan ($21.77) travel costs, while flight S will take 14 hrs more, but can save 100 yuan ($14.51).

Scenarios 3-1 and 3-2 (gain for time and loss for money, mixed gain and mixed loss with similar gain and loss): assuming that the traveler is making a trip now, unfortunately, the traveler has just missed a bus, and it will take a long time before the next departure, so the traveler turns to other transportation modes. There are two modes available for the traveler to choose from. Whatever mode is adopted, the travel time is shorter than that by bus, but the travel cost is increased. The specific alternatives are as follows: choosing mode R can save 40 min of travel time, but the travel cost will increase by 15/20 yuan ($2.18/$2.90), while mode S can save 15 min, but the cost will increase by 5/10 yuan ($0.73/$1.45), where the numbers refer to Scenario 3-1/Scenario 3-2.

Scenario 3-3 (gain for time and loss for money, mixed loss with a large difference between gain and loss): assume that a traveler needs to fly from Country A to Country B, and the transfer flight is cheaper, but the flight time is about twice that of the nonstop flight. After careful consideration, the traveler ultimately chose to take the nonstop flight, and there are two flights available for the traveler to choose from. No matter which flight is used, the travel time is shorter than that of transfer flight, but simultaneously, the travel cost will increase. The specific alternatives are as follows: choosing flight R can save 15 hrs of travel time, but it will cost 700 yuan ($101.60) more, while flight S can save 11 hrs, but it will cost 600 yuan ($87.08) more.

Scenario 4 (loss for both time and money): if the traveler makes a trip now, he or she chooses to take a bus to the destination. Unfortunately, the bus broke down, so the traveler must transfer to another transportation mode, and there are two transportation modes available for the traveler to choose from. Whatever mode the traveler uses, the arrival time is later than the expected arrival time and travel cost also increased. The specific alternatives are as follows: choosing mode R will make the arrival 25 min later than expected and cost 30 yuan ($4.35) more, while mode S will make the arrival time 5 min later and cost 45 yuan ($6.53) more.

The specific settings of the alternatives and choice results are shown in Table 1.

4.1.3. Scenarios of Risky Conditions. When a traveler makes a trip, there are two alternatives R and S to choose from. Because of the uncertainties of travel, $(t, p; m, q)$ is used to represent the increase/decrease in travel time and cost of the alternative, where t and m are travel time and cost, p and q are the probabilities of the event occurrence, and $1-p$ and $1-q$ are the probabilities of the event nonoccurrence, respectively. The specific settings of the alternatives are shown in Table 2.

Scenario 1 (gain for both time and money): because the traffic authorities have strengthened the road traffic management, the travel time and cost of Route R and S have been reduced.

Scenarios 2-1 and 2-2 (loss for time and gain for money, mixed gain and mixed loss with similar gain and loss): since the road that the traveler frequently chooses before is impossible to pass due to road construction, the traveler can only choose between Route R and Route S. Compared with the regular route, the travel times of these two routes increase, but the travel costs decrease.

Scenario 2-3 (loss for time and gain for money, mixed loss with a large difference between gain and loss): assuming that the traveler needs to travel from Province A to Province B, but during the Spring Festival, train tickets and air tickets are minimal. After careful consideration, the traveler finally chose to drive to Province B by himself/herself. Compared with trains and airplanes, the travel time of the two self-driving routes increases, but the travel cost decreases.

Scenarios 3-1 and 3-2 (gain for time and loss for money, mixed gain and mixed loss with similar gain and loss): since the road that the traveler frequently chooses before is impossible to pass due to road construction, the traveler can only choose between Route R and Route S. Compared with the regular route, the travel time of these two routes is reduced, but the travel cost is increased.

Scenario 3-3 (gain for time and loss for money, mixed loss with a large difference between gain and loss): if the traveler needs to travel from Province A to Province B, traveling by train is cheap, but the travel time is long. After careful consideration, the traveler finally chose to fly. Compared to taking a train, two flights available for travel have a shorter travel time, but the travel costs have increased.

Scenario 4 (loss for both time and money): due to traffic congestion, both routes' travel time and cost have increased.

Due to the large number of scenarios under risky conditions, this paper only takes Rung 1 in Scenario 1 as an

Table 1: Travel choice results under deterministic conditions.

Scenario	Alternative *R*		Alternative *S*	
	t, *m*	No. of choices/proportion	*t*, *m*	No. of choices/proportion
1	+10 ; +40	148/46.3%	+20 ; +30	172/53.7%
2-1	−20 ; +30	127/39.7%	−10 ; +20	193/60.3%
2-2	−50 ; +15	173/55.3%	−40 ; +5	140/44.7%
2-3	−900 ; +150	139/45.0%	−850 ; +100	170/55.0%
3-1	+40 ; −15	128/41.7%	+15 ; −5	179/58.3%
3-2	+40 ; −20	180/58.3%	+15 ; −10	129/41.7%
3-3	+900 ; −700	190/61.9%	+650 ; −600	117/38.1%
4	−25 ; −30	71/22.7%	−5 ; −45	242/77.3%

t and *m* represent travel time and cost, respectively, and the corresponding units are minutes and yuan. The symbol "+" indicates that the travel time/cost of the alternative is gain relative to the reference point (i.e., the travel time/cost decreases), while the symbol "–" indicates that the travel time/cost of the alternative is loss relative to the reference point (i.e., the travel time/cost increases).

Table 2: Travel choice results of different scenarios under risky conditions.

Rung	Alternative *R*		Alternative *S*	
	t, *p*; *m*, *q*	No. of choices/proportion	*t*, *p*; *m*, *q*	No. of choices/proportion
		(a) Scenario 1		
1	+10 , 30% ; +20 , 20%	185/57.8%	+30 , 10% ; +10 , 40%	135/42.2%
2	+10 , 60% ; +20 , 40%	157/49.1%	+30 , 20% ; +10 , 80%	163/50.9%
3	+10 , 20% ; +40 , 30%	168/52.5%	+20 , 10% ; +30 , 40%	152/47.5%
4	+10 , 40% ; +40 , 60%	153/47.8%	+20 , 20% ; +30 , 80%	167/52.2%
5	+10 , 20% ; +50 , 40%	171/53.4%	+20 , 10% ; +40 , 50%	149/46.6%
		(b) Scenario 2-1		
6	−30 , 10% ; +20 , 20%	125/39.1%	−10 , 30% ; +10 , 40%	195/60.9%
7	−30 , 20% ; +20 , 40%	94/29.4%	−10 , 60% ; +10 , 80%	226/70.6%
8	−20 , 10% ; +30 , 20%	118/36.9%	−10 , 20% ; +20 , 30%	202/63.1%
9	−20 , 20% ; +30 , 40%	106/33.1%	−10 , 40% ; +20 , 60%	214/66.9%
10	−20 , 30% ; +40 , 20%	120/37.5%	−10 , 60% ; +20 , 40%	200/62.5%
		(c) Scenario 2-2		
11	−30 , 20% ; +10 , 20%	122/39.0%	−20 , 30% ; +5 , 40%	191/61.0%
12	−30 , 40% ; +10 , 30%	113/36.1%	−20 , 60% ; +5 , 60%	200/63.9%
13	−30 , 30% ; +10 , 20%	111/35.5%	−20 , 45% ; +5 , 40%	202/64.5%
14	−50 , 40% ; +15 , 20%	109/34.8%	−40 , 50% ; +5 , 60%	204/65.2%
15	−60 , 50% ; +15 , 30%	111/35.5%	−50 , 60% ; +5 , 90%	202/64.5%
		(d) Scenario 2-3		
16	−600 , 80% ; +100 , 100%	246/79.6%	−800 , 60% ; +200 , 50%	63/20.4%
17	−700 , 65% ; +100 , 40%	113/36.6%	−650 , 70% ; +50 , 80%	196/63.4%
18	−700 , 60% ; +150 , 30%	92/29.8%	−600 , 70% ; +50 , 90%	217/70.2%
19	−700 , 80% ; +100 , 90%	220/71.2%	−800 , 70% ; +150 , 60%	89/28.8%
20	−900 , 40% ; +200 , 20%	110/35.6%	−800 , 45% ; +50 , 80%	199/64.4%
		(e) Scenario 3-1		
21	+30 , 20% ; −10 , 10%	114/37.1%	+15 , 40% ; −5 , 20%	193/62.9%
22	+30 , 30% ; −10 , 20%	116/37.8%	+15 , 60% ; −5 , 40%	191/62.2%
23	+30 , 40% ; −10 , 30%	107/34.8%	+15 , 80% ; −5 , 60%	200/65.2%
24	+40 , 20% ; −10 , 10%	115/37.5%	+20 , 40% ; −5 , 20%	192/62.5%
25	+40 , 30% ; −10 , 20%	114/37.1%	+20 , 60% ; −5 , 40%	193/62.9%
		(f) Scenario 3-2		
26	+30 , 20% ; −15 , 20%	167/54.1%	+15 , 40% ; −10 , 30%	142/45.9%
27	+30 , 50% ; −15 , 40%	123/39.8%	+15 , 100% ; −10 , 60%	186/60.2%
28	+30 , 20% ; −25 , 40%	137/44.3%	+15 , 40% ; −20 , 50%	172/55.7%
29	+40 , 30% ; −30 , 20%	135/43.7%	+15 , 80% ; −20 , 30%	174/56.3%
30	+40 , 25% ; −25 , 20%	150/48.5%	+25 , 40% ; −20 , 25%	159/51.5%
		(g) Scenario 3-3		
31	+450 , 70% ; −500 , 60%	163/53.1%	+700 , 45% ; −600 , 50%	144/46.9%
32	+500 , 80% ; −500 , 60%	166/54.1%	+800 , 50% ; −600 , 50%	141/45.9%
33	+550 , 80% ; −600 , 70%	175/57.0%	+800 , 55% ; −700 , 60%	132/43.0%
34	+600 , 90% ; −600 , 70%	175/57.0%	+900 , 60% ; −700 , 60%	132/43.0%
35	+650 , 90% ; −700 , 80%	185/60.3%	+900 , 65% ; −800 , 70%	122/39.7%

Table 2: Continued.

Rung	Alternative R t, p; m, q	No. of choices/proportion	Alternative S t, p; m, q	No. of choices/proportion
		(h) Scenario 4		
36	−30 , 10% ; −10 , 40%	134/42.8%	−10 , 30% ; −20 , 20%	179/57.2%
37	−30 , 15% ; −10 , 60%	125/39.9%	−10 , 45% ; −20 , 30%	188/60.1%
38	−30 , 20% ; −10 , 80%	136/43.5%	−10 , 60% ; −20 , 40%	177/56.5%
39	−30 , 10% ; −40 , 50%	129/41.2%	−15 , 20% ; −50 , 40%	184/58.8%
40	−30 , 30% ; −40 , 75%	137/43.8%	−15 , 60% ; −50 , 60%	176/56.2%

$(t, p; m, q)$ indicates the decrease/increase in travel time and cost of the alternative, where t and m represent travel time and cost, respectively, and p and q represent the probabilities of the event occurrence. The plus and minus signs indicate that the travel time/cost of the alternative is gain and loss, respectively, relative to the reference point.

example to introduce in detail the scenario settings in the questionnaire survey, and the other scenarios are similar. The scenario of Rung 1 in the questionnaire is as follows.

Suppose you are facing a trip now and there are two routes for you to choose. Due to the strengthening of road traffic management by the transportation authorities, the travel time and cost on both routes are reduced. If you choose Route *R*, the possibility of your travel time reduction by 10 min is 30% (the possibility of time invariance is 70%), and the possibility of your cost reduction by 20 yuan ($2.90) is 20% (the possibility of cost invariance is 80%). If you choose Route *S*, the possibility of your travel time reduction by 30 min is 10% (the possibility of time invariance is 90%), and the possibility of your cost reduction by 10 yuan ($1.45) is 40% (the possibility of cost invariance is 60%). Which route would you choose?

The risk or uncertainty associated with travel is the numerical probability. For example, Rung 1 under Scenario 1 of risk condition, the alternative path S (+30, 10%; +10, 40%) has a 10% chance of reducing 30 min and a 40% chance of reducing 10 yuan ($1.45). According to the statistical results, the number of travelers choosing *S* is 135. If the probability increases from 10% or 40% to 50%, the number of travelers who chose the route will increase.

4.2. Analysis of Questionnaire Data

4.2.1. Traveler Characteristics. This section first analyzes the distribution of the obtained data for age, education, occupation, monthly income level, and total working hours of one week. The specific distributions are as follows:

(a) Age: the age distribution of subjects is concentrated between 20 and 40 years old, accounting for 90% of the total number of subjects.

(b) Educational level: the subjects' average educational level is high, and the number of subjects with an undergraduate degree or above accounts for 85% of the total. The high level of education means that the subjects can easily understand the situation designed in the questionnaire, which is conducive to this study.

(c) Occupation: company employees (75%), public institutions (14%), and civil servants (3%) account for the top three proportions. These occupations have relatively strict commuting time requirements so that the working hours of subjects do not fluctuate as much as those of self-employed or freelancers. Moreover, the salaries of these occupations are relatively stable, which helps calculate the travel time value of the subjects.

(d) Monthly income level: the level of monthly income is concentrated in the three sections of 3000-5000 yuan ($435.41-$725.69), 5000-7000 yuan ($725.59-$1015.97), and 7000-10000 yuan ($1015.97-$1451.38), accounting for 23.2%, 32.9%, and 28.1%, respectively.

(e) Total working hours per week: the number of people with 40 to 49 hrs is the largest, accounting for 60%, followed by 30 to 39 hrs (22%) and 50 to 59 hrs (12%). After calculating the average value, the average working hours of the subjects are 8 hrs a day. This value is close to the average working hours of the wage laborers published in the National Time Use Survey Bulletin of 2018 (7.7 hrs, the data from the official website of [39]). Therefore, this shows that the sample data collected in this survey are representative and reflect the actual situation.

In addition, the income-benefit method is used to calculate the VOT of travelers [40] as follows:

$$\overline{\mathrm{VOT}} = \frac{1}{N}\sum_{i=1}^{N}\frac{\mathrm{INC}}{4T}, \tag{18}$$

where INC is the monthly income of the subjects, T is the total weekly working time of the subjects, and N is the sample size. After calculation, the average travel time value of the subjects in this survey is 38.74 yuan/hr ($5.62/hr). That is, VOT' is 1.55 min/yuan (0.22 min/$). Thus, the results are not much different from those of Wang [41] and Hou [42]. The VOTs in these studies are 27.5-44.1 yuan/hr ($3.99-$6.40/hr) and 34.35 yuan/hr ($4.99/hr), respectively.

4.2.2. Choice Results of Situational Decision-Making. Decision scenarios under deterministic and risky conditions include pure gain, one gain and one loss (mixed gain, mixed loss with similar gain and loss, and mixed loss with large difference in gain and loss), and pure loss. The only difference between deterministic and risky conditions is that the risky conditions consider the influence of probability on the choice results, and each scenario includes 5 decision rungs. The choice results under the deterministic and risky conditions are shown in Tables 1 and 2.

5. Estimation and Analysis of the Proposed MA-TC Model

5.1. Parameter Estimation. We used the parameter estimation method adopted by Wu and Gonzalez [43] and Xu et al. [44], which is based on minimizing the sum-square error (SSE) using the least-squares fitting method. The respective formulas are given by

$$\Pr(R_i > S_i) = \frac{1}{1 + \exp(V(S_i) - V(R_i))},$$
$$SSE_{DC}(\alpha, \beta, \lambda) = \sum_{i=1}^{8} (r_i - \Pr(R_i > S_i))^2, \quad (19)$$
$$SSE_{RC}(\alpha, \beta, \lambda, \gamma, \delta) = \sum_{i=1}^{40} (r_i - \Pr(R_i > S_i))^2.$$

where $V(S_i)$ and $V(R_i)$ denote the utility values of alternatives S and R under scenario i, respectively, and the specific formulas are equations (6)–(17), r_i denotes the proportion of subjects who actually choose the alternative R under scenario i, $\Pr(R_i > S_i)$ denotes the probability that the utility value of alternative R is greater than that of alternative S under scenario i, and DC and RC denote deterministic and risky conditions, respectively.

Before model calibration, we listed all possible combinations of the value calculation methods under 8 decision scenarios. Since each scenario has two methods (integration and segregation), there were 256 combinations in total. We chose the utility calculation principle corresponding to the minimum SSE as the best combination of utility calculation methods for different scenarios under deterministic and risky conditions. As noted, the sum-squared error formula is a nonlinear function, and its solution process belongs to nonlinear least-squares optimization. Therefore, we intended to use the Levenberg–Marquard (LM) algorithm, the particle swarm optimization (PSO) algorithm, and the improved particle swarm optimization (BreedPSO) algorithm to solve the problem [45] and finally selected the parameters with the best fitting effect. The estimated values of model parameters under deterministic and risky conditions obtained by the three methods are summarized in Table 3.

From Table 3, the minimum SSE values under deterministic and risky conditions are 0.0198 and 0.1605, respectively, and the fitting effect is the best. Therefore, the parameters corresponding to the SSE value are selected as the final results of the model parameter calibration. The parameter estimates are $\{\alpha = 0.39,\ \beta = 0.36,\ \lambda = 1.48\}$ and $\{\alpha = 0.13,\ \beta = 0.48,\ \lambda = 1.31,\ \gamma = 0.68,\ \delta = 0.22\}$, for deterministic and risky conditions, respectively.

According to the calibration results, under deterministic conditions, the risk attitude coefficients are similar ($\alpha = 0.39$ and $\beta = 0.36$). This indicates that travelers have similar sensitivity to the change of gain/loss of travel time and cost under deterministic conditions. The loss aversion coefficient $\lambda = 1.48$ is slightly less than the calibration value of 1.51 [44], but it still conforms to the conclusion that travelers are more sensitive to loss than to gain. Under risky conditions, the risk attitude coefficients are pretty different, $\alpha = 0.13$, $\beta = 0.48$, and $\alpha < \beta$. It indicates that travelers are more sensitive to the change of loss of travel time and cost and less sensitive to the change of gain. The loss aversion coefficient $\lambda = 1.31$ is slightly smaller than the value under deterministic conditions, indicating that the loss aversion phenomenon under risky conditions is less obvious than that of deterministic conditions. The parameters of the weight function corresponding to the gain and loss are $\gamma = 0.68$ and $\delta = 0.22$, respectively, which are pretty different. This shows that the tendency of the traveler to overestimate the small probability event and underestimate the high probability event is more obvious when losing than when gaining.

5.2. Principle of Utility Calculation. According to some actual economic phenomena and scenario experiments, the original HE criterion is an ideal decision-making evaluation principle proposed by Thaler [23, 35]. The criterion can be used to explain economic phenomena such as sunk cost effect. However, whether the criterion still has a good explanatory ability under different decision-making backgrounds (e.g., different research purposes, behavior subjects, and fields) is worth further study.

We chose the utility calculation principle corresponding to the minimum SSE as the best combination of utility functions for different scenarios under deterministic and risky conditions. According to the questionnaire data and fitting results, the utility calculation principle corresponding to eight groups of scenarios under deterministic and risky conditions can be obtained. They are {Segregation, Segregation, Integration, Integration, Segregation, Segregation, Segregation, Segregation} and {Integration, Segregation, Segregation, Segregation, Segregation, Segregation, Segregation, Segregation}, respectively. From the calculation results, only Scenario 2-2 and Scenario 2-3 adopt the integrated calculation principle under deterministic conditions. Travelers prefer the integrated principle when the time account is loss, the money account is gain, and the final state is mixed loss. In this way, they can try to integrate the gain to reduce the pain caused by the loss. While travelers prefer to separate in another scenario, where the time account is gain, the money account is loss and the final state is mixed loss (Scenario 3-2 and Scenario 3-3). In the same case of one account loss and another account gain, the traveler's choice results of time loss and money loss are pretty different. This result once again confirms that travelers have different attitudes towards time and money, which is consistent with the research conclusions of Leclerc et al. and Yang et al. [30, 34]. Under the risky conditions, travelers prefer segregation in all scenarios except Scenario 1, which indicates that when risk is considered in utility measurement system, travelers' preference will be reversed.

Table 3: Calibration results of MA-TC model parameters under deterministic and risky conditions.

Solution Algorithm	Estimated parameter α^{a}	β^{a}	λ^{b}	γ^{c}	δ^{c}	SSE
(a) Deterministic conditions						
LM	0.39	0.36	1.48	—[d]	—	0.0198
PSO	0.34	0.26	1.75	—	—	0.0232
BreedPSO	0.31	0.20	2.40	—	—	0.0232
(b) Risky conditions						
LM	0.25	0.33	1.12	0.87	0.48	0.2290
PSO	0.19	0.29	2.21	0.88	0.35	0.1995
BreedPSO	0.13	0.48	1.31	0.68	0.22	0.1605

[a] α and β are risk attitude coefficients, which measure the degree of diminishing sensitivity of the decision makers to risk changes. The greater the value is, the more sensitive the decision makers are to risk. [b] λ is the loss aversion coefficient, which indicates that individuals are more sensitive to losses than to gains. The greater the value is, the more sensitive the decision makers are to losses. [c] γ and δ are parameters denoting the curvature of the weight function. A smaller value of the parameters indicates that the tendency of the decision makers to overestimate small probability events and underestimate high probability events is more obvious. [d] denotes not applicable.

The utility calculation principle based on the proposed mental accounting deviates from the original HE criterion, and the specific comparison schemes are shown in Table 4. This table shows the value calculation principle (integration or segregation), which the decision maker prefers in the eight decision scenarios. If the integration principle is adopted, the formula can be expressed as $V_{MA}(T+M)$; otherwise, it is $V_{MA}(T)+V_{MA}(M)$. For example, according to the original HE criterion, decision makers prefer to use the segregation principle to calculate the utility of the joint outcomes in Scenario 1, so the corresponding formula is $V_{MA}(T)+V_{MA}(M)$. The formula of the original HE criterion is shown in equation (4), and the formulas of the deterministic and risky conditions are shown in equations (5)–(17). The possible reason for the difference mentioned above is that the scenarios designed in this paper have strong traffic characteristics and consider both time and money attributes, which are different from traditional economic scenarios. Different hypothetical scenarios and subjects lead to different prediction results. Furthermore, researchers still know little about the utility measurement system of MAT and only have a general utility calculation principle, namely, the original HE criterion. Thereby, the early theoretical research of MAT usually only involves decision-making problems under deterministic conditions. However, this paper aims to explore the travelers' decision-making under both deterministic and risky conditions, so the different problems involved in the research may also be one of the reasons for the difference between the two prediction results.

To sum up, there may be some differences in the HE criterion under different environments. Therefore, in practice, the original HE criterion should be appropriately corrected according to the research background, objects, and purposes, to make the criterion close to the actual choice behavior of the subjects.

5.3. New Utility Expressions. Based on the preceding results of parameter estimation and the principle of utility calculation (Table 4), the expressions of the multiattribute utility function of Section 4.3 can be refined and integrated. Then, the utility expression of the travel choice behavior model based on mental accounting can be obtained. The specific expressions are as follows:

$$V_{DC}(T\&M)=\begin{cases}\Delta T^{\alpha}+(\mathrm{VOT}'*\Delta M)^{\alpha}, & \text{if } \Delta T>0 \text{ and } \Delta M>0,\\ -\lambda|\Delta T|^{\beta}+(\mathrm{VOT}'*\Delta M)^{\alpha}, & \text{if } \Delta T<0, \Delta M>0 \text{ and } \Delta T+\mathrm{VOT}'*\Delta M>0,\\ -\lambda\left|\Delta T+\mathrm{VOT}'*\Delta M\right|^{\beta}, & \text{if } \Delta T<0, \Delta M>0 \text{ and } \Delta T+\mathrm{VOT}'*\Delta M<0,\\ \Delta T^{\alpha}-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}, & \text{if } \Delta T>0 \text{ and } \Delta M<0,\\ -\lambda|\Delta T|^{\beta}-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}, & \text{if } \Delta T<0 \text{ and } \Delta M<0,\end{cases} \tag{20}$$

$$V_{RC}(T\&M)=\begin{cases}\left(\Delta T*\pi^{+}(p)+\mathrm{VOT}'*\Delta M*\pi^{+}(q)\right)^{\alpha}, & \text{if } \Delta T>0 \text{ and } \Delta M>0,\\ -\lambda|\Delta T|^{\beta}*\pi^{-}(p)+(\mathrm{VOT}'*\Delta M)^{\alpha}*\pi^{+}(q), & \text{if } \Delta T<0 \text{ and } \Delta M>0,\\ \Delta T^{\alpha}*\pi^{+}(p)-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}*\pi^{-}(q), & \text{if } \Delta T>0 \text{ and } \Delta M<0,\\ -\lambda|\Delta T|^{\beta}*\pi^{-}(p)-\lambda\left|\mathrm{VOT}'*\Delta M\right|^{\beta}*\pi^{-}(q), & \text{if } \Delta T<0 \text{ and } \Delta M<0,\end{cases}$$

Table 4: Comparison of the utility calculation principle for different scenarios under deterministic and risky conditions.

Conditions	Calculation principle							
	Sce.1	Sce.2-1	Sce.2-2	Sce.2-3	Sce.3-1	Sce.3-2	Sce.3-3	Sce.4
Prediction results based on OHEC	Sep.	Int.	Int.	Sep.	Int.	Int.	Sep.	Int.
Solution results of the DC model	Sep.	Sep.	Int.	Int.	Sep.	Sep.	Sep.	Sep.
Solution results of the RC model	Int.	Sep.	Sep.	Sep.	Sep.	Sep.	Sep.	Sep.

OHEC, original HE criterion; DC, deterministic conditions; RC, risky conditions; Sce., scenario; Sep., segregation; Int., integration.

where $V(T\&M)$ is the joint utility function of travel time T and travel cost M, DC and RC refer to deterministic and risky conditions, respectively, and VOT' is the travel time value coefficient, where the unit is minute/yuan. The values of the parameters α, β, λ, γ, and δ are as presented in Section 6.1.

6. Model Validation

The proposed MA-TC model was validated by comparing it with two other formulated models: (1) the PT model that considers both travel time and cost (PT-TC) and (2) the mental accounting model based on the original HE criterion (MA-HE, see equation (4)). Two indicators were used for comparison: nonlinear correlation coefficient (RNL) and hit rate (HitR). There are two reasons for selecting these two models. First, PT is the most commonly used tool for analyzing and modeling of bounded rational travel behavior [16, 46, 47]. Transportation scholars have widely recognized the tool with rich research results and broad applications. The proposed model is based on mental accounting considering travel time and cost and it seems intuitive to use the PT-TC model as a comparison model. Second, there are some differences between the utility calculation principle and the original HE criterion. Using the mental accounting model based on the original HE criterion (MA-HE model) as a comparison model, one can further verify that the original HE criterion should be appropriately corrected in actual applications.

6.1. Evaluation Indicators. Two indicators were used for model evaluation: nonlinear correlation coefficient RNL and hit rate HitR. The RNL is usually used as the goodness-of-fit indicator, and its significance is similar to R^2 in linear regression analysis. The closer the goodness-of-fit value is to 1, the better the prediction effect of the model is. The specific calculation is as follows:

$$\text{RNL} = 1 - \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{\sum y_i^2}}, \tag{21}$$

where y_i and $\hat{y}_i$ represent the actual value and the predicted value, respectively, that is, the actual choice probability and the ideal choice probability calculated by the model.

The hit rate is an indicator to evaluate whether the actual choice results are consistent with the prediction results of the model. The higher the value is, the higher the accuracy of the prediction results of the model is and the stronger the prediction ability of the traveler's travel choice behavior is. For Scenario i, if the choice probability calculated by the model is greater than or equal to 50%, it is regarded as the selection result of travelers in the scenario, and then, the choice result SR_i is predicted as

$$SR_i = \begin{cases} 1, & \text{if } Pr \geq 50\%, \\ 0, & \text{if } P < 50\%. \end{cases} \tag{22}$$

If the prediction result SR_i of the model is consistent with the actual choice result, let σ_i be 1, otherwise 0. Therefore, the HitR can be calculated by

$$\text{HitR} = \frac{\sum_{i=1}^{N} \sigma_i}{N} \times 100\%, \tag{23}$$

where N is the number of scenarios. The number of deterministic and risky conditions are 8 and 40, respectively.

6.2. Parameter Calibration of Comparison Models

6.2.1. PT-TC Model. Based on the prospect theory, this section presents a travel choice behavior model that considers both travel time and cost. The value and weight functions of the model are represented in the classical forms (see [22]). The reference point is the same as that of the proposed model, based on the actual or expected travel time/cost in the previous trip. The idea of calculating the multiattribute utility function of the comparison PT-TC model is as follows. The value and weight functions are first used to calculate the prospects of the time and cost attributes, respectively. Then, these prospects are summed up to obtain the multiattribute utility function. The expression is as follows:

$$U_{PT} = v(T)\pi(p) + v(M)\pi(q), \tag{24}$$

where U_{PT} denotes the utility function of PT, T and M denote travel time and cost, p and q denote the probability of events occurrence, $v(\cdot)$ denotes the value function as equation (1), and $\pi(\cdot)$ denotes the weight function of equation (2). It is worth noting that, under deterministic conditions the values of $\pi(p)$ and $\pi(q)$ equal 1. The same parameter calibration method and solution algorithm were used to estimate the parameters of the PT-TC model based on the questionnaire data. The specific calibration results are shown in Table 5.

Table 5 shows that, in the traffic environment, the parameter estimates of the PT-TC model considering the travel time and cost are different from those of the previous studies [22], especially the calibration values under deterministic

Table 5: Parameter calibration results of the PT-TC, MA-HE, and proposed models.

Conditions	Estimated parameter value					SSE
	α	β	λ	γ	δ	
(a) PT-TC model						
Deterministic	0.21	0.18	2.04	—[a]	—	0.0459
Risky	0.42	0.53	1.19	0.75	0.70	0.3835
(b) MA-HE model						
Deterministic	0.15	0.15	1.65	—	—	0.2013
Risky	0.11	0.61	2.52	0.95	0.15	0.4000
(c) Proposed MA-TC model						
Deterministic	0.39	0.36	1.48	—	—	0.0198
Risky	0.13	0.48	1.31	0.68	0.22	0.1605

a, not applicable.

conditions, where the risk attitude coefficient α and β are relatively small. This indicates that travelers are not sensitive to the change of travel time and cost under deterministic conditions. The loss aversion coefficient $\lambda = 2.04$ is slightly less than the calibration value of 2.25 [22], but it is consistent with the conclusion that travelers are more sensitive to loss than gain. Under risky conditions, the value function parameters are $\alpha = 0.42$, $\beta = 0.53$, and $\lambda = 1.19$; α and β are larger than those of the deterministic conditions, while λ is the opposite. These calibration results show that travelers are more sensitive to the change of travel time and cost when considering uncertainty, but the degree of loss aversion is smaller than deterministic conditions. The parameters γ and δ of the weight function have little difference from the calibration values of the existing PT studies. Note that δ for PT is 3 to 4 times larger than that δ for the MA models. The parameter δ denotes the curvature of the weight function, and a smaller value indicates that the tendency of the decision makers to overestimate small probability events and underestimate high probability events is more obvious. Such a difference between the value of PT and that of the MA model means that the tendency is more obvious when the travelers have mental accounts.

6.2.2. MA-HE Model. Similar to the PT-TC model, the MA-HE model presented in this section still uses the actual travel time/cost or expected travel time/cost as the reference point. Its utility calculation principle fully follows the original HE criterion [23]. That is, the combination of the eight scenarios' utility calculation principles under both deterministic and risky conditions is {Segregation, Integration, Integration, Segregation, Integration. Integration, Segregation, Integration}. On this basis, we used the same method to calibrate the parameters of the MA-HE model based on the questionnaire data.

The specific calibration results are shown in Table 5. As noted, under deterministic conditions, the risk attitude coefficients α and β of the MA-HE model are relatively small and almost equal. This indicates that travelers are not sensitive to the travel time and cost changes, and the sensitivity to changes is similar. Loss aversion coefficient $\lambda = 1.65$ is smaller than the values calibrated by Tversky and Kahneman [22], indicating that travelers from the perspective of MA are more sensitive to loss than gain, but less sensitive than PT. Under risky conditions, the risk attitude coefficients α and β are 0.11 and 0.61, respectively, and the difference between them is large. In addition, the loss aversion coefficient $\lambda = 2.52$ is larger than that of Tversky and Kahneman [22]. The values of these three parameters indicate that travelers are very sensitive to the travel time and cost changes, and the phenomenon of loss aversion is evident. The weighting function $\gamma = 0.95$ is very close to 1 in gain, but the parameter is exactly the opposite in loss, $\delta = 0.15$. This shows that travelers have slight tendency to overestimate small probability and underestimate probability in gain, but it is pronounced in loss.

6.3. Comparison of Model Fitting Accuracy. RNL and HitR of the three models were calculated for the deterministic and risky conditions (Table 6). For the deterministic conditions, RNL of the travel choice behavior model based on the proposed MA-TC model is 0.90, which is larger than that of the PT-TC and MA-HE models (0.84 and 0.62, respectively). This result shows that the fitting effect of the proposed model is the best. The hit rates of the proposed MA-TC, PT-TC, and MA-HE models are 87.5%, 75.0%, and 37.5%, respectively. The accuracy of the first two models is relatively high, and the proposed model is obviously superior to the two comparison models. The results also show that the original HE criterion has poor explanatory ability in the traffic environment, which further verifies the conclusion that there are differences in the HE criterion under different research backgrounds.

For the risky conditions, after considering the uncertainty in travel, RNL of the proposed and PT-TC models are less than those of the deterministic conditions, but the extent of the reduction is different. The value of the proposed model decreases from 0.90 to 0.86 and remains at a high level (above 0.85), while the value of the PT-TC model decreases from 0.84 to 0.79, with a relatively poor-fitting effect. It is interesting to note that the MA-HE model is different from the other two models. After considering risk, RNL of this model increases (rather than decreases) from 0.62 to 0.78, but the fitting effect is still not as good as that of the proposed model. Although there are many hypothetical scenarios under risky conditions, the hit rates of the three models are

Table 6: Contrastive analysis of models.

Conditions	PT-TC model		MA-HE model		Proposed MA-TC model	
	RNL	HitR	RNL	HitR	RNL	HitR
Deterministic	0.84	75.0%	0.62	37.5%	0.90	87.5%
Risky	0.79	90.0%	0.78	62.5%	0.86	97.5%

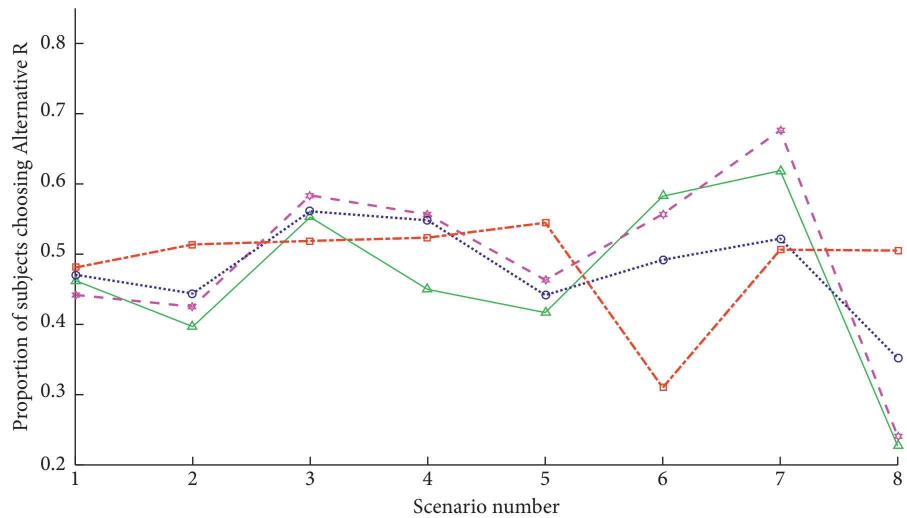

Figure 4: Fitting curve under deterministic conditions.

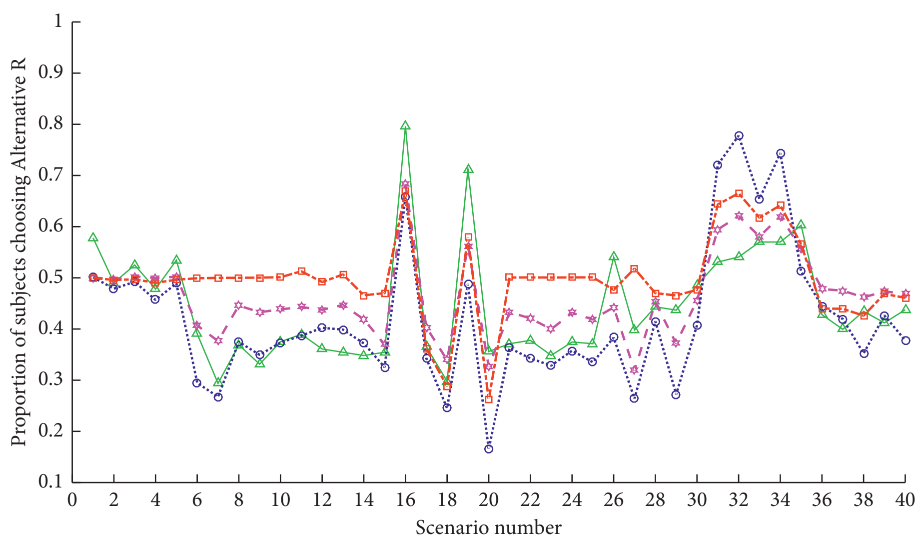

Figure 5: Fitting curve under risky conditions.

increasing. The hit rate of the proposed model is as high as 97.5%, which is better than that of the two comparison models (90.0% and 62.5%).

In addition, model fitting curves were developed so that the fitting differences of the three models can be seen more intuitively. The curves under deterministic and risky conditions are shown in Figures 4 and 5, respectively. The solid green lines represent actual questionnaire results. The magenta dashed lines, the blue dotted lines, and the red dash-dotted lines represent the predicted results based on the

Table 7: Prediction accuracy of models.

Conditions	PT-TC model		MA-HE model		Proposed MA-TC model	
	RNL	HitR	RNL	HitR	RNL	HitR
Deterministic	0.84	75.0%	0.75	37.5%	0.81	87.5%
Risky	0.80	80.0%	0.76	52.5%	0.82	87.5%

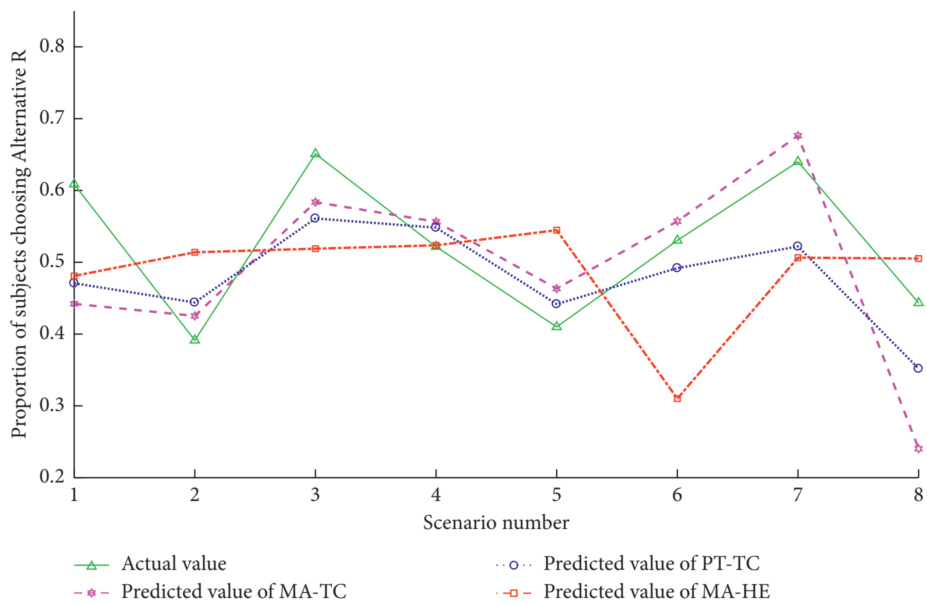

Figure 6: Forecast curve under deterministic conditions.

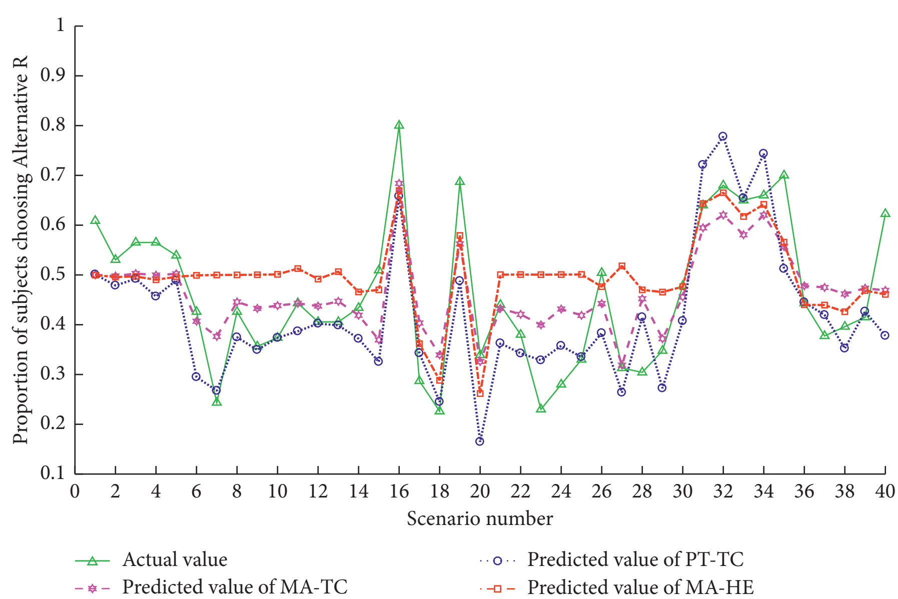

Figure 7: Forecast curve under risky conditions.

proposed MA-TC, PT-TC, and MA-HE models, respectively. The numbers of scenarios for the deterministic and risky conditions are 8 and 40, respectively. The fitting curves show that the fitting effect of the proposed model in this paper is better than that of the PT-TC model under deterministic conditions, especially Scenarios 6 to 8. In contrast, the MA-HE model has a poor-fitting effect, and only Scenario 3 is closer to the actual choice result. Under risky conditions, the fitting results of the proposed and PT-TC models have their advantages and disadvantages.

Although the PT-TC model is slightly closer to the actual choice curve in some scenarios than the proposed model, it performs poorly in Scenarios 20, 26, and 29 to 34, and the prediction results are pretty different from the actual observations. In this model, among all the predicted values, there are 7 scenarios where the choice probability deviation ranges from 15% to 24%. In contrast, the deviation of the proposed model is less than 15% in all scenarios. From the overall trend, the fitting effect of the model in this paper is still better, so the proposed model has stronger explanatory power and can describe the actual travel choice behavior of the traveler more accurately. In addition, Figure 5 shows that the prediction accuracy of the MA-HE model is poor, almost 50% of the scenario prediction deviations exceed 10%, and the fitting effect is inferior to the proposed model. Compared with the HE criterion of the mental account and the linear utility combination of the PT theory, the MA-TC model considers the different utility combinations of travelers for time and money to improve the fitting accuracy.

6.4. Validation of the Proposed Model. Because all the collected data from April to May 2019 were used to calibrate model parameters, we conducted another survey in December 2021 and collected a total of 436 valid questionnaires. To verify the effectiveness of the MA-TC model, the proposed and comparison models were used to predict the choice of travelers. RNL and HitR of the three models were calculated for the deterministic and risky conditions (Table 7).

For the deterministic conditions, RNL of the MA-TC model is 0.81, which is slightly lower than that of the PT-TC model and higher than that of the MA-HE model (0.84 and 0.62, respectively). However, HitR of the MA-TC and PT-TC models are 87.5% and 75%, respectively, while HitR of the MA-HE comparison model is only 37.5%. So, HitR of the proposed model is the best although RNL is the second best.

For the risky conditions, RNL of the MA-TC and MA-HE models increases, but RNL of the PT-TC model decreases by 4%. The MA-TC model has the highest RNL of 0.82, which has the best prediction accuracy. In terms of HitR, the MA-TC model is also the best. Therefore, from the two aspects of nonlinear correlation coefficient and hit rate, the proposed MA-TC model has the best prediction effect under risky conditions and can better explain the travel choice behavior of the travelers.

In addition, the prediction curves in the two cases are shown in Figures 6 and 7. As noted in Figure 6, the prediction accuracy of the MA-TC model is less than that of the PT-TC model in deterministic scenarios, which is mainly due to the large gap between the predicted and actual values of Scenarios 1 and 8, which are 15% and 20%, respectively. However, the prediction errors of the other scenarios are less than 5%, except that Scenario 3 is 6.7% and Scenario 5 is 5.3%. This indicates that a smaller nonlinear correlation coefficient is mainly contributed by Scenarios 1 and 8. In these two scenarios, the number of travelers choosing route R increases since they focus more on money than time account. They pay more attention to increasing money gain and reducing money loss, which may be caused by the prevalence of COVID-19 and other reasons. However, for the MA-HE model, only the prediction error of Scenario 4 is less than 10%, but the error of other scenarios is more than 10%, so its prediction effect is poor. In the risky case, the proposed model has high prediction accuracy. Only the prediction error of Scenarios 23, 24, and 40 is more than 15%, and the maximum prediction error is 16.97%. For the PT-TC model, the prediction error of five scenarios is more than 15%, and the maximum prediction error of the model is 24.48%. For the MA-HE comparison model, the prediction error of Scenarios 7, 23, 24, and 27 is more than 20%. Therefore, the MA-TC model is more suitable for risk decision to describe the travelers' travel choice behavior. In addition, the prediction accuracy of the MA-HE model is lower than that of MA-TC model in two scenarios, which indicates that the calculation principle of mental accounts should be adjusted appropriately in the traffic background.

7. Conclusions

The research on bounded rational travel choice behavior is a complex and challenging topic. How to use bounded rationality theory to propose a travel behavior model that is more in line with the actual travel behavior of travelers is the focus of scholars in transportation. Based on the mental accounting theory in behavioral economics, we conducted an in-depth analysis of its utility measurement system concerning account setting, value function form, and calculation principle and proposed a travel choice behavior model considering both travel time and cost under deterministic and risky conditions. The following research results are offered:

(1) According to the survey data, the parameters of the travel choice behavior model were calibrated. There are great differences in model parameters under deterministic and risky conditions. In deterministic conditions, travelers have similar sensitivity to the change [23, 35] of gain/loss of travel time and cost. Under risky conditions, they are more sensitive to the change in loss and less sensitive to the change in gain. Simultaneously, the tendency of overestimating small probability events and underestimating high probability events is more obvious when travelers lose in risky environments. The parameter estimates are $\{\alpha = 0.39, \ \beta = 0.36, \ \lambda = 1.48\}$ and $\{\alpha = 0.13, \ \beta = 0.48, \ \lambda = 1.31, \ \gamma = 0.68, \ \delta = 0.22\}$, for deterministic and risky conditions, respectively.

(2) The original HE criterion is an ideal decision-making evaluation principle proposed by Thaler, which can be used to explain how individuals use mental accounts to evaluate and make decisions on economic activities. However, this study has focused on whether the criterion still has a good explanatory ability under different decision-making backgrounds, such as different research purposes, behavior subjects, and fields. Based on this idea, this paper used a questionnaire to explore how travelers use time and money accounts to make travel choice decisions and then verified whether the original HE

criterion for economic subjects is also applicable to travel subjects. The results showed that the original HE criterion deviates from the actual survey results, so we revised the criterion and proposed a utility calculation principle in the traffic context. The proposed principle is closer to the traveler's choice behavior in natural traffic environments. The combination of the utility calculation principle under deterministic and risky conditions presented in this paper are {Segregation, Segregation, Integration, Integration, Segregation, Segregation, Segregation, Segregation} and {Integration, Segregation, Segregation, Segregation, Segregation, Segregation, Segregation, Segregation, Segregation}, respectively. The "Integration" and "Segregation" mentioned above represent the value function calculation method preferred by travelers in each decision-making scenario.

(3) Taking the nonlinear correlation coefficient and the hit rate as evaluation indicators, the proposed model was compared with the prospective theory and mental accounting models for fitting accuracy and prediction. The prospect theory model considers both travel time and cost (PT-TC model) and the mental accounting model is based on the original HE criterion (MA-HE model). The results of data fitting accuracy show that the values of the two indicators of the proposed model are larger than those of the two comparison models. Therefore, the proposed model has stronger explanatory power and can describe the actual travel choice behavior of the traveler more accurately. For model prediction, under deterministic scenarios, although the nonlinear correlation coefficient of the MA-TC model is slightly smaller than that of PT-TC, the nonlinear correlation coefficient of the proposed model is larger than that of MA-HE. Under risk scenarios, the MA-TC model's nonlinear correlation coefficient and the hit rate are larger than those of the two comparison models. Therefore, the proposed model can well predict the travel choices in most cases.

(4) Future research may focus on the relationship between time and money from the perspective of mental accounts. From the perspective of mental account, the purpose of travel, time constraints, and other factors affecting travelers' travel choice can be explored. In addition, this study adopts the stated preference survey method, but there may not be any relevant situation in reality that completely conforms to the design of this questionnaire. Therefore, the change range of time and money in travel choice can be investigated when travelers encounter traffic management and other situations and then make the choice scheme according to the actual situation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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