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Research Article

Decision-Making Research on Tour Lines of Tourist-Dedicated Train Based on Vague Sets and Prospect Theory

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Tourist-dedicated train is the product of the combination of railway transportation and tourism, and its tour line selection includes the selection of nodes and lines. Based on the principle of decision-making, taking technical factors, tourism factors, regional economic factors, and passenger flow factors as criteria, this paper analyzes the decision-making indices affecting the tour line and establishes the decision-making index system. Subsequently, the prospect theory considering the bounded rationality and psychological factors of decision makers is combined with vague set fuzzy decision theory, and a comprehensive decision method based on vague set and prospect theory is proposed. Finally, the feasibility of the proposed decision method is verified by an example. The research shows that the established decision-making index system is representative, and the proposed decision-making method is scientific and effective for the decision making of tourist lines of tourist-dedicated train. The decision-making results can be used as a reference for the formulation of tour lines and line plans of tourist-dedicated train.

1. Introduction

Tourist-dedicated train is a new tourism product developed by railway transport enterprises for the tourism market. It is the product of the combination of railway transport industry and tourism industry. It is a tourism product developed by railway transport enterprises with transportation and tourism attributes. In the process of travel, tourists travel to the train collectively. The tourist-dedicated train of “train following people” not only provides passenger displacement services but also serves as a mobile platform for the whole process of passenger travel. That is to say, the tourist-dedicated train provides two parts of process services, namely, transportation and tourism, in which the transportation process of the tourist-dedicated train is a coordinated transportation process with railway transportation as the main body and road transportation as the connection of various modes of transportation. In a broad sense, the tourist-dedicated train line is defined as the tourism product launched by railway transport enterprises according to the tourism demand and the tourism supply they can provide. In a narrow sense, it is a tour line, which is defined as the planned and designed by railway transport enterprises for tourists, which are connected by railway lines. The tourist-dedicated train line connects the tourist source area and the area where each scenic spot is located through the railway line, which is the link between tourists and tourist destinations. The high-quality tour line is not only an important means to attract tourists and improve the operating income of railway transportation enterprises but also an important guarantee to enhance the brand power of railway tourism and the competitiveness of tourism market.

The decision making of a tour line (tour line selection) is to select high-quality line schemes from many schemes as part of the overall operation scheme. Tourism special line is an important carrier for railway transport enterprises to carry out regional tourism cooperation. It is a recombination of tourism space resources. It has the characteristics of large span, long line, and many scenic spots. The line selection process should not only analyze the scale distribution characteristics of tourism resources but also comprehensively analyze the number, type characteristics, source distribution, tourism market, and other factors of tourism resources.

At present, some experts and scholars have done some meaningful research on the problem of tour line selection. On the basis of considering tourists' preferences, Gavalas et al. [1] took effective tour time and traffic connection conditions as constraints and took tourists' maximum satisfaction as the goal to model and solve the tour line planning.

Duarte-Duarte et al. [2] proposed that the similarity between tourist attractions can be identified by clustering technology. He considered that the eight factors of natural, cultural, tourist plant, infrastructure, superstructure, accessibility, human and tourist capital, and security were the key indices affecting the line selection of tourist lines, and evaluated the tourist routes by clustering technology evaluation method. Díez-Gutiérrez and Babri [3] believed that the increase of accumulated traffic near tourist attractions, and its pollution and noise affect the tourism experience, and the decision-making of tourist traffic lines should be based on the analysis of tourists' behavior, taking into account the impact of travel time, road width and scenery along the road, outdoor activity quality, and scenic area facilities. Zhu [4] established a multi-objective mixed integer linear programming model to plan bicycle tourism routes by minimizing the total travel time, maximizing bicycle service level, and minimizing the number of intersections on bicycle routes. Some experts and scholars had made the following research on the application of prospect theory in tourism, transportation, and other. Gao et al. [5] proposed a travel behavior modeling method under uncertainty based on the combination of cumulative prospect theory and multi-attribute decision-making theory. The travel behavior of travelers was analyzed. By collecting the traveler preference data, the traveler's different emphasis on travel cost and travel time was expressed. Liao et al. [6] studied the user equilibrium of activity-travel mode under uncertainty from the perspective of prospect theory and proposed a user equilibrium model based on static activity to analyze travel behavior. Ghader et al. [7] believed that the cumulative prospect theory can reflect the impact of uncertainty of travel time on travel behavior and selects the parameters of utility function, value function, and weighting function to construct the travel behavior model. Taking the family tourism in Washington DC as an example, the validity of the model was verified. Xu et al. [8]combined the objective travel scene with the subjective decision of travelers and proposed a travel line choice model based on prospect theory to make decisions on travel line choice. Zhang and He [9] believed that the characteristics of bounded rationality and the change of line choice in the process of decision making, proposed a dynamic line choice model based on prospect theory, and then proposed a dynamic route choice method that is more suitable for thinking habits and actual travel. In view of the passenger travel decision-making behavior of the airport group, Xu et al. [10]designed the planned travel decision-making reference point and constructed the passenger travel choice model based on the cumulative prospect theory under the premise of considering the flight capacity constraints. Long et al. [11] established the decision-making model of discretionary lane-changing by using cumulative prospect theory. Zhang et al. [12] focused on the discrete robustness optimization of emergency transportation network with the consideration of timeliness and decision behavior of decision makers under limited rationality.

Some experts and scholars have made the following research on the application of vague set and TOPSIS method in comprehensive evaluation and decision making. Elzarka et al. [13] believed that vague set theory helps to eliminate uncertainty related to subjective and fuzzy information of decision makers. On the basis of assigning appropriate weights to decision makers, a vague set theory model based on multi-attribute group decision process was proposed to solve the owner decision problem in construction industry. Wang et al. [14] proposed to use the parameterized S-OWA operator for fuzzy value aggregation and combined it with vague set theory to propose a new decision support method based on vague set theory for decision makers to evaluate projects. Farhadinia [15] proposed a scoring function based on fuzzy set modeling for solving fuzzy hesitancy multi-attribute decision-making problems and considers that this method can provide a solution for multi-attribute decision-making through measure ranking. In the study of vague set decision-making method, Ye [16] proposed that an improved scoring function could be used to measure the applicability of each alternative in a set of alternatives to a set of criteria with fuzzy values. Kwok and Lau [17]believed that tourists usually have a variety of needs when choosing hotel accommodation, and travel agency websites are often unable to provide website recommendations in line with tourists' preferences. In view of this phenomenon, vague set-TOPSIS decision support algorithm is proposed to rank hotels. Taking software requirement decision making as an example, Nazim et al. [18] compared fuzzy AHP method and fuzzy TOPSIS method, and concluded that fuzzy TOPSIS method was superior to fuzzy AHP method in efficiency and accuracy. Aiming at the MCDM decision problem of autonomous vehicle, Bakiogluand and Atahan [19] proposed a decision method combining AHP and TOPSIS to apply to the information judgment and decision-making process of autonomous vehicles. Awasthi and Chauhan [20] used AHP, vague sets, and TOPSIS method to comprehensively evaluate urban logistics alternatives. In the study of supply chain vulnerability under the condition of COVID-19, Magableh and Mistarihi [21] proposed that ANP-TOPSIS with similar ideal solution framework could be used to make decision-making choices for high-quality supply chain solutions. Yan et al. [22]evaluated the railway operation safety situation by using an improved technique for order of preference by similarity to ideal solution (TOPSIS) method.

At present, the research on tourist-dedicated train [23–25] mainly focused on marketing strategies, service design and management, thematic train planning, and other aspects, and lacks special research on tourist-dedicated train's tour line. If the planning and design standards of tourist-dedicated train tour lines are not formulated and the design quality is comprehensively evaluated, the design of exclusive tour lines may be empty and divorced from reality, and cannot create economic value for the exclusive operators in practical application. Therefore, it is of great theoretical research value and practical application significance to study the tour line of tourist-dedicated train combined with its operation characteristics.

The above research on tour lines and tourist-dedicated trains provides a certain reference for refining the decision-making indices of tour lines in this paper, and the research on prospect theory and fuzzy decision-making provides a theoretical reference for the research methods proposed in this paper. In this paper, based on the basic principles of tourist-dedicated train line selection and the selection criteria of decision-making indices, the decision-making indices are analyzed, and the decision-making index system of tourist-dedicated train tour lines is constructed, and a comprehensive decision-making method based on the combination of prospect theory and vague set theory is proposed to rank and compare the alternative lines. On the one hand, the decision-making process and results can provide the basis for the railway line selection, stop plan, and passenger flow organization scheme in the selection of tourist-dedicated train tour lines and the preparation of train line plan. On the other hand, they can also provide reference for the operation management of tourist-dedicated train.

2. The Line Selection Content of Tourist-Dedicated Train

As a product, tourist-dedicated train has the functions of "mobile hotel," "leisure and entertainment," "landscape platform," "shopping store," and "theme classroom." It is a combination of tourism products to meet the needs of tourists in food, accommodation, travel, travel, shopping, and entertainment.

According to the number of tourist destinations and whether the trips are on the same line, the tourism mode of tourist-dedicated train can be divided into three types: "one tourist destination on one line," "multiple tourist destinations on one line," and "multiple tourist destinations on two lines." Tourist-dedicated train is carried out through the railway line, and the station where the railway line routing scenic area is located is composed of railway lines in series. The scenic area covered by the tour line may be composed of one or more scenic spots. Taking the "multiple tourist destinations on two lines" mode as an example, the tour line of tourist-dedicated train is illustrated as shown in Figure 1.

Therefore, the line selection of tourist-dedicated train includes the railway line composed of the station where the scenic areas are located as a node, and the scenic area sightseeing line composed of multiple scenic spots as nodes and series connection.

3. Basic Principles of Selecting Decision Indices for Tour Line Selection of Tourist-Dedicated Train

3.1. Feasibility Principle. The selection of decision-making indices should follow clear feasibility criteria, take the effect evaluation of line selection scheme as the goal, be representative, and reflect the characteristics of tourism of tourist-dedicated train. Scheme decision making is to make an objective and scientific judgment on the expected effect of different tourism special tourism schemes in the planning process, and provide feedback and guidance for the revision and optimization of the scheme and the determination of the final scheme.

3.2. Principle of Demand Satisfaction. Line selection index decision-making needs to be carried out under the premise of meeting the needs of special tourists and the organizational capacity of railway transport enterprises. For the former, the selection of indices needs to be consistent with the actual tourism needs of tourists to avoid selecting indices being divorced from the actual situation of the tourism market. The latter indices' selection should consider the particularity of the railway network environment for tourist-dedicated train operation.

3.3. Principle of Reasonable Collocation. The planning and design of tourist lines should take into account the structural order of the lines and the rhythm of the tour process; that is, the nodes and lines should be planned on the premise of the gradual improvement of the tour content and the psychological and physical conditions of the tourists. Therefore, the lines of decision-making indices should consider the above content.

3.4. The Principle of Win-Win between Tourists and Railway Enterprises. The decision-making index of line selection scheme should consider the embodiment of the interests of both tourists and tourist-dedicated train operation enterprise, which are mutually beneficial relations of interests. Any party's interests are infringed, which will affect the promotion and development of tourist-dedicated train projects. The index system should take into account the interests of the both parties. The selected indices should not only reflect the satisfaction of tourist-dedicated train's passenger but also reflect the economic benefits of tourist-dedicated train operators.

4. Analysis of Decision Indices

4.1. Technical Criterion

4.1.1. Influence of Station Capacity (I_1). Station capacity mainly includes connecting train capacity of station along the scenic area and the train distribution capacity of stations. The line selection scheme needs to consider the influence of the occupancy of the railway tracks when the tourist-dedicated train stops at the station with other inbound trains, and whether the number of railway tracks of the station and its affiliated vehicles meets the stop of the tourist-dedicated train.

4.1.2. The Perfection Degree of Station Support Facilities (I_2). The tourist-dedicated train stops in the middle station of the line, tourists go out to visit, and the tourist-dedicated train

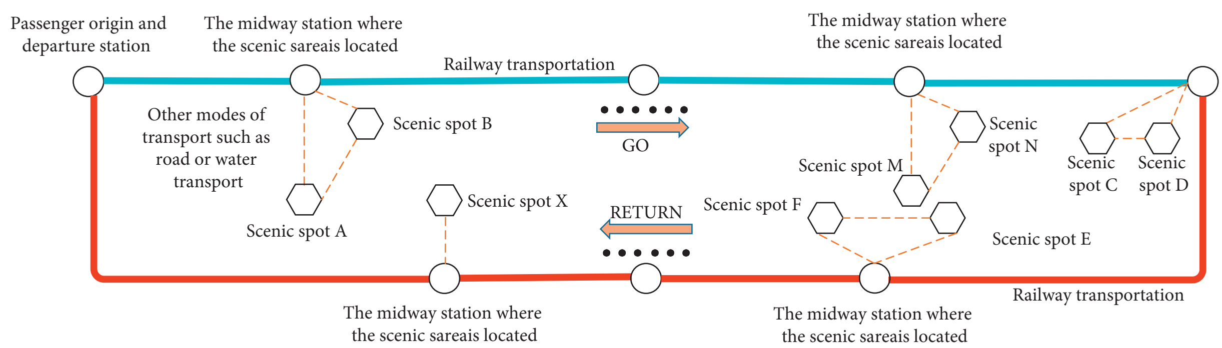

Figure 1: Chart of tour line of tourist-dedicated train.

needs to carry out technical operations such as material supplement and support at the station. The more perfect and reasonable the support facilities are, the more efficient the station's ability to supply water supply and commodities, the more suitable for the station as a line node.

4.1.3. The Perfection Degree of Station Distribution Facilities (I_3). This index is the reference basis for the station to be selected as a node. Generally, the higher perfection of the distribution facilities is, the stronger the ability of the station to collect and distribute special passenger is, and the more suitable it is to effectively organize the connection and ride and surrender of tourist-dedicated train passengers in the peak period.

4.1.4. Line Capacity Impact (I_4). Due to the influence of the operation speed of the tourist-dedicated train, the line occupied by the tourist-dedicated train will affect the interval operation of other passenger trains and freight trains. The line selection should consider the influence of the train on the interval carrying capacity and try to choose the railway line with rich transportation capacity.

4.2. Tourism Factor Criterion

4.2.1. Tourism Market Basis (I_5). The basis of tourism market refers to the scale of tourism market in the planning area of tourist-dedicated trains. The planning of special tour lines should consider the overall market scale involved in the line, and the influence of market volume occupied by other tourism modes similar to the planning line. Usually, hot lines face strong competition in the same industry, and too cold lines are not easy to attract passengers.

4.2.2. Tourism Resource Quality (I_6). Tourism resources are the basic factors in the design process of special line of tourism, including the types, combinations, development status, and the number and spatial distribution of tourism resources available for special line of tourism. The higher the quality of tourism resources, the more favorable to the design of high-quality line selection scheme.

4.2.3. Fitting Degree of Line and Tourist-Dedicated Train Theme (I_7). The theme of tourist-dedicated train is the brand of tourist-dedicated train launched by railway transport enterprises, which is an important factor to attract passengers. The selected scenic spots should be consistent with the theme of the tourist-dedicated train. For example, the tourist-dedicated train with historical tourism theme should choose the combination of scenic areas with historical relics as the main cultural attractions.

4.2.4. Combination of Line Scenic Areas (I_8). The tour line of tourist-dedicated train should connect the stations where different types of scenic areas are located. There may be some well-developed and well-known attractions and some newly developed tourist spots in the line. After reasonable combination and collocation of different types of spots, different emphases of tourist-dedicated train line can be balanced. Therefore, for the vast majority of tourists who do not have the purpose of exploring tourism, the reasonable collocation and cross-appearance of cultural landscape, natural landscape, shopping attractions, and leisure experience attractions are also the embodiment of the rationality of the dedicated trains tour line planning. This index reflects the reasonable and coordinated combination and collocation of the line selection scheme for scenic spots.

4.2.5. The Situation of Coverage of Scenic Areas (I_9). As the node of the tourist-dedicated train line, scenic areas constitute a "point-line" relationship with the tourist-dedicated train line. The coverage of line selection scheme refers to the coverage of representative and characteristic scenic spots along the line. This index reflects the scheme's depth of understanding of regional tourism.

4.2.6. The Reception Capacity of Scenic (I_{10}). Tourist-dedicated train can bring a large number of tourists to the scenic area. In the peak season of tourism, the reception capacity of the scenic area is also an important index of line selection. Exceeding the reception capacity of the scenic area will cause congestion in the scenic area, decrease the satisfaction of tourists, and also lead to traffic delay due to congestion, which will cause inconvenience to the punctual departure of the train.

4.2.7. The Situation of Hardware Facilities in Scenic Areas (I_{11}). The influence of scenic areas in hardware facilities on line selection scheme are mainly reflected in the influence of tourist experience. The scenic areas with old hardware facilities have poor tourist experience, which are not suitable to be the node of line selection scheme. When planning the line selection scheme, it is necessary to evaluate the hardware facilities of the scenic area.

4.2.8. Fitting Degree of Season (I_{12}). The determination of tourist-dedicated train visiting scenic areas and tour lines needs to consider the influence of seasonal factors on tourism experience, especially the natural scenic spots with the best viewing period. When planning them as line nodes, it is necessary to evaluate whether the scenic spots on the line are the best viewing period.

4.2.9. Environment and Management Level of Scenic Areas (I_{13}). The environmental quality of scenic spots affects tourists' satisfaction, which is the factor that scenic spots as nodes consider. The management level of scenic areas indirectly affects the efficiency of tourist-dedicated train tourists' sightseeing, which needs comprehensive consideration in the selection of scenic areas nodes.

4.2.10. Environmental Characteristics along the Way (I_{14}). From the perspective of the tour line, the travel process is also a process for tourists to enjoy the scenery along the way. The scenery along the way is the advantage of railway tourism. According to the scenery along the way, the line can choose the tourist-dedicated train railway line suitable for scenery appreciation, which helps to improve the experience of tourists' railway tourism and the satisfaction of tourist-dedicated train tourism.

4.2.11. Line Node Shopping Environment (I_{15}). The selection of line nodes should also consider the shopping environment, including market order, consumption level, and other factors, which have a certain impact on tourism consumption experience.

4.2.12. Experience Environment of the Line (I_{16}). The selected lines should be exploratory and interactive. The high-quality solutions have a good sense of travel experience, which can improve the satisfaction of passengers in the process of sightseeing, increase the novelty experience, and improve the tourism interest.

4.2.13. Competitive Factors in Tourism Market (I_{17}). Tour line is the combination of six elements of tourism products, and its competitiveness is the core of regional tourism competitiveness. The line selection scheme should consider the influence of competition factors with other transportation modes and other tourism modes. The competition factor is an important factor that affects whether the selected line achieves profitability and long-term operation. For high-quality line, selection scheme has the advantages of complement each other, distinctive design features.

4.3. Regional Economic Factors Criterion. The relationship between tourism project industry and regional economy is mutual influence. For tourist-dedicated train projects, the line selection scheme is affected by regional economic factors in the area where the line scheme is located, including the influence of economic level on passenger flow, and the influence of tourism consumption environment on the experience of tourist-dedicated train.

(1) Regional economic level (I_{18})

The regional economic level is one of the important factors that affect the tourism industry. The region includes the tourist source and scenic area location. This index reflects regional and tourism development vitality, which is also a reflection of tourism consumption and tourism human resources.

(2) Disposable income level of residents in tourist source areas (I_{19})

The index can reflect the tourism consumption ability of the residents in the source area. The higher the disposable income level is, the larger the proportion of tourism consumption is, and the more conducive to the line selection scheme as a tourist-dedicated train starting point.

(3) Population of residents in tourist source areas (I_{20})

As the main body of tourism activities, the larger the population base is, the higher the corresponding tourism population is. The population of the source area is the source base of the number of tourists. The number of tourist-dedicated train tourists is mainly determined by the number of tourists in the source area (the departure place of the tourist-dedicated train) and the number of tourists coming to the main source area for taking the tourist-dedicated train, which is an important index in selecting the departure place of the tourist-dedicated train in the line scheme.

(4) Tourism consumption level and consumption environment in scenic area location (I_{21})

The consumption of tourists on the tourist-dedicated train includes two parts, that is, tourism consumption on the tourist-dedicated train, such as entertainment and catering activities on the train, and tourism consumption in the scenic area after leaving the tourist-dedicated train. The tourism consumption level of the scenic area should not be too different from the consumption level of the tourist-dedicated train tourists, resulting in poor consumption perception.

In addition, the shopping consumption environment of scenic spots in the line is also the focus of the line selection scheme, tourism consumption belongs to "one-time consumption" to a certain extent, and whether commercial environment of the selected shopping place is healthy, and whether there is a "consumption fraud" phenomenon, which is an important factor affecting tourism satisfaction. Based on the above two points, high-quality line selection scheme will examine the environment of the selected place, which has the characteristics of reasonable consumption level and good consumption environment.

4.4. Background Factor Criterion of Passenger Flow. With the acceleration of the information age, the tourism demand industry is more diversified, which makes it necessary to design different tourism lines to meet the diversified needs of tourists. The analysis of passenger flow background is an important step to understand the overall characteristics of passenger flow and design tourist-dedicated train lines that meet the demand of passenger flow.

(1) Conformity with tourism motivation of tourist (I_{22})

The formation of tourists' travel behavior includes subjective conditions and objective conditions. Subjective conditions are tourism motivation. Tourists' choice behavior of tourist lines often varies greatly due to their different feelings of lines. Therefore, the customized tourist-dedicated train line selection scheme needs to be designed according to the tourism motivation and intention.

(2) The consistency with tourists' age and occupational characteristics (I_{23})

Tourists of different ages and occupations also have great differences in the selection of tour lines due to their different working and living characteristics and experience. In view of these differences, diversified line selection schemes are needed. High-quality line selection schemes should fully investigate the age and occupation distribution of potential tourists to meet the travel demand as much as possible.

(3) Adaptability to educational background (I_{24})

The view of tourism believes that the educational level of tourists will affect the choice of tourism lines. Usually, there are large differences in the choice of tourism lines between highly educated postgraduates and junior high school and below, while undergraduate and college groups have more common choices. Therefore, when formulating the line selection scheme, it is necessary to consider the adaptability between the characteristics of the tourist-dedicated train line and the dedicated train tourists, so as to select the tourist-dedicated train for the energy-absorbing tourists.

4.5. Decision Index System of Tourist-Dedicated Train Tour Lines. According to the analysis of the above decision-making indices, the tour lines consist of the starting node, the middle node, and the tour line. The decision-making indices "$I_1, I_2, I_3, I_{19}, I_{20}$," "$I_1, I_2, I_3, I_9, I_{10}, I_{11}, I_{13}, I_{15}, I_{21}$," and "$I_4$, I_6, I_7, I_8, I_{12}, I_{14}, I_{16}" are the reflection of the line plan of the three components of the three components. And according to the analysis of the above decision-making indices, the three-level decision-making index system of tourist-dedicated train lines can be established according to the target layer, criterion layer, and index layer, as shown in Figure 2.

5. TOPSIS Comprehensive Decision Method Based on Vague Sets and Prospect Theory

5.1. Overview of Vague Sets and Prospect Theory. Prospect theory is a behavioral economics theory combining psychology and economics, which is used to judge decision-making theory under uncertainty, and is one of the important research results of behavioral economics. Based on the rational person hypothesis, this paper studies the influence of irrational psychological factors on decision making, reflecting the subjective risk preference of decision makers. Prospect theory holds that there will be different attitudes toward foreseeable risk based on different reference points chosen by decision makers and that the outcome of decision depends on the gap between the envisaged reference point and the outcome. The prospect theory can be used to make an empirical study on the relationship between risk and income. Before making the decision of the line selection scheme, the decision maker will produce an expected expectation value for the selection scheme, which is the expected reference value in the prospect theory.

Vague set theory is an extension of fuzzy sets and an important theory for dealing with fuzzy mathematics problems. Its related theories have been applied to auxiliary decision making, information pattern recognition, reliability research, target point recognition, and other fields [26].

According to the characteristics of tourist-dedicated train line selection, the decision index has certain uncertainty. This problem has good applicability and application value.

The description of vague set is as follows: suppose there exists a universe U, and a vague set in U includes a pair of membership functions $t_A(x)$ and $f_A(x)$, which represent the true and false membership functions, respectively, and represent the lower bound of x positive and negative membership degrees [26]. The membership degree of x is limited in the subinterval $[t_A(x), 1 - f_A(x)]$ of [0, 1], and $[t_A, 1 - f_A] = [t_A, t_A^*]$. If taking the voting as an example, five people voted, three agreed, one opposed, and one abstained, then the vague value is expressed as [0.6, 0.2].

TOPSIS method is a multi-objective attribute decision-making method, which is close to the ideal solution. By calculating the measurement distance between each scheme index and the optimal and worst scheme, the relative accessible degree is taken as the evaluation basis.

Based on the practical characteristics of the above two theoretical methods, this paper adopts the vague set theory and prospect theory to process the decision-making indices and calculates the prospect value under the premise of considering the internal reference point and risk preference of the decision maker, so as to avoid the problem of complete rationality of the decision maker, and obtain the accessible degree between the actual vague and the ideal vague, and then sort the line selection scheme of the tourist-dedicated train, so as to make the decision result more scientific and objective.

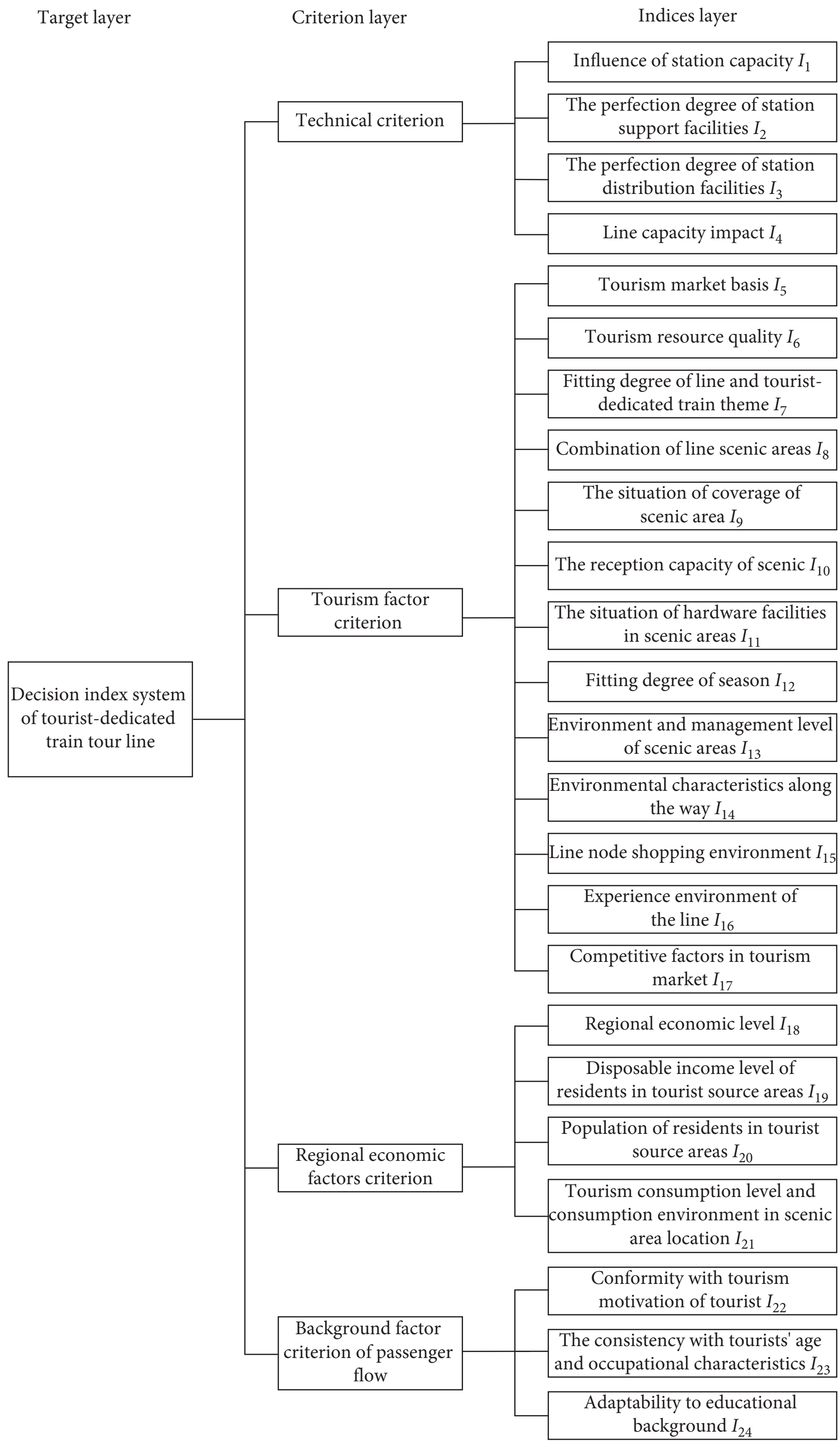

Figure 2: The decision-making index system of tourist-dedicated train lines.

5.2. PT-Vague Comprehensive Decision Method. In this paper, vague sets, prospect theory, and TOPSIS method are combined to propose PT-Vague comprehensive decision method. The calculation steps are as follows:

Step 1: Determine the scoring matrix. First of all, get the language score of each index of the line selection of tourist-dedicated train by expert evaluation scoring, as follows:

It is assumed that there are s different grades in the expert group ($s \leq 3$), and the weights are gradually weighted 0.5 from 1. For example, there are experts with three grades A, B, and C, and their weights are 2, 1.5, and 1, respectively. For the determination of evaluation language, first of all, through the questionnaire statistical expert selection, combined with the weight of expert group members, the highest cumulative weighted value of evaluation language selection as a language score. After obtaining the language score, the language score of each index is transformed into the corresponding typical vague value as the quantitative score according to the corresponding relationship shown in Table 1, where the language score is the seven-level language score. Then, the vague value scoring matrix X of each decision index of each line selection scheme is obtained as shown in formula (1), where the matrix X is a matrix of $m \times n$ size, m represents the number of line selection schemes for tourism special trains, and n represents the number of decision indices.

$$X = \left[x_{ij}\right]_{m\times n}, \tag{1}$$

where x_{ij} is vague value, $x_{ij} = [t_{ij}, 1 - f_{ij}^{*}] = [t_{ij}, t_{ij}^{*}]$.

Step 2: Determine the expected value matrix, and the decision makers score the expected value of each line selection scheme using Table 1 language. Convert to the expected value matrix E as shown in Step 1, as shown in formula.

$$E = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1n} \\ e_{21} & e_{22} & \cdots & e_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ e_{m1} & e_{m2} & \cdots & e_{mn} \end{bmatrix}, \tag{2}$$

where e_j is the decision maker's psychological expectation of index j, which is the lower bound of the decision maker's expectation based on the actual situation, that is, the evaluation level to which the scheme should reach at least.

Step 3: Calculation of the payoff matrix. By comparing the evaluation index value with the expected value of the index, the payoff matrix $R = [r_{ij}]_{m\times n}$ can be obtained, as shown in the following formula:.

$$r_{ij} = x_{ij} - e_{ij}. \tag{3}$$

Wwhere r_{ij} represents the payoff value of the index j of scheme i. For example, $x_{ij} = [0.5, 0.5]$, $e_{ij} = [0.8, 0.9]$, and then, $r_{ij} = [-0.3, -0.4]$ is obtained.

Step 4: Calculate the prospect vague value according to the payoff value, the calculation method is shown in the following formula:

$$v_{ij} = \begin{cases} \left(r_{ij}\right)^{\alpha}, & r_{ij} \geq 0, \\ -\lambda\left(-r_{ij}\right)^{\beta}, & r_{ij} < 0, \end{cases} \tag{4}$$

where v_{ij} represents the prospect value of index j of scheme i; α and β are risk sensitive coefficients, which represent the concave and convex degree of decision maker's psychological payoff and loss value function.

λ is the loss aversion coefficient, which reflects the psychological characteristics of decision makers. Previous research results [27] show that if $\alpha = 0.89$, $\beta = 0.92$, and $\lambda = 2.25$, that calculation results of the prospect value are closest to the results caused by the psychological conditions of the actual decision makers' payoff and losses. This paper refers to the research results.

Step 5: By calculating the prospect vague values, the prospect value matrix can be obtained as shown in the following formula:

$$V = \left[v_{ij}\right]_{m\times n} = \begin{bmatrix} \left[t_{11}^{v}, t_{11}^{v,*}\right] & \left[t_{11}^{v}, t_{11}^{v,*}\right] & \cdots & \left[t_{1n}^{v}, t_{1n}^{v,*}\right] \\ \left[t_{21}^{v}, t_{21}^{v,*}\right] & \left[t_{22}^{v}, t_{22}^{v,*}\right] & \cdots & \left[t_{2n}^{v}, t_{2n}^{v,*}\right] \\ \vdots & \vdots & \ddots & \vdots \\ \left[t_{m1}^{v}, t_{m1}^{v,*}\right] & \left[t_{m2}^{v}, t_{m2}^{v,*}\right] & \cdots & \left[t_{mn}^{v}, t_{mn}^{v,*}\right] \end{bmatrix}. \tag{5}$$

Step 6: A positive and negative ideal solution scheme is proposed for the vague values of the prospect values calculated by each scheme index. The positive and negative ideal solutions are composed of PVPIS and PVPIS values. The detailed steps are as follows: PVPIS and PVPIS are determined by comparing the vague prospect values of each index. PVPIS represents the optimal value of the vague prospect value of the index, and the PVPIS value of all indices is expressed by matrix F^{+}, as shown in formula (6). PVNIS represents the worst of vague prospect value, and PVNIS values of all indices are expressed by matrix F^{-}, as shown in formula (7) as follows:

$$F^{+} = \left(v_1^{+}, v_2^{+}, \ldots, v_n^{+}\right), \tag{6}$$

$$F^{-} = \left(v_1^{-}, v_2^{-}, \ldots, v_n^{-}\right). \tag{7}$$

Step 7: The index weight is calculated. The commonly used weight determination methods such as entropy weight method and analytic hierarchy process (AHP) can be used to calculate the index weight, and the 10-degree scoring algorithm can also be used. In this paper, the 10-degree scoring algorithm is taken as an example, and the weight calculation is shown in the following formula:

$$\omega_j = \frac{g_j}{\sum_{j=1}^{n} g_j}, \tag{8}$$

where ω_j is the weight of index j, and g_j is the weight fraction of scale 1–10 assigned to the index j.

Step 8: The weighted TOPSIS measure is calculated. On the basis of considering the weight ω_j of each index, according to the similarity measure of vague value [26]

Table 1: Vague values for seven-level language scores.

Evaluation language	Abbreviation of evaluation language	Vague value range	Typical vague values
Absolutely good	AG	[0.9, 1]	[1, 1]
Good	G	[0.75, 0.9]	[0.75, 0.85]
Fairly good	FG	[0.6, 0.75]	[0.6, 0.7]
Medium	M	[0.45, 0.6]	[0.5, 0.5]
Fairly poor	FP	[0.3, 0.45]	[0.3, 0.4]
Poor	P	[0.15, 0.3]	[0.15, 0.25]
Absolutely poor	AP	[0, 0.15]	[0, 0]

Table 2: Language scores for each scheme indices.

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}	I_{20}	I_{21}	I_{22}	I_{23}	I_{24}
F_1	FG	M	FG	FP	G	FG	FG	FG	M	G	G	AG	FG	M	FG	G	M	G	FG	G	FG	G	G	G
F_2	M	M	FG	P	G	FG	G	FG	FG	FP	FG	FG	M	FG	FG	FG	P	FG	FG	G	FG	FG	FG	FG
F_3	G	G	AG	FG	AG	AG	AG	G	FG	AG	G	AG	G	FG	G	AG	FP	G	G	AG	G	AG	G	AG
F_4	FG	G	G	M	AG	G	AG	FG	M	M	AG	AG	FG	G	M	G	P	FG	G	AG	FG	FG	FG	M

Formula (9), the measurement distance between each scheme and PVPIS and PVNIS is calculated first, so as to obtain the weighted measurement distance between PVPIS and PVNIS of each scheme, as shown in formulas (10) and (11) as follows.

$$M_{\omega}(x, y) = 1 - \frac{\left|t_x - t_y - \left(f_x - f_y\right)\right|}{8} - \frac{\left|t_x - t_y + f_x - f_y\right|}{4} - \frac{\left|t_x - t_y\right|\left|f_x - f_y\right|}{8}, \tag{9}$$

$$S_i^{+} = \sum_{j=1}^{n} \omega_j M_{\omega}\left(\left[t_{ij}, t_{ij}^{*}\right], \text{PVPIS}\right), \tag{10}$$

$$S_i^{-} = \sum_{j=1}^{n} \omega_j M_{\omega}\left(\left[t_{ij}, t_{ij}^{*}\right], \text{PVNIS}\right). \tag{11}$$

Step 9: Calculate the accessible degree $\sigma(F_i)$ of each scheme. If the value of $\sigma(F_i)$ is larger, it means that F_i is closer to the positive ideal solution F^+ and farther away from the negative ideal solution F^-. The calculation method of accessible degree $\sigma(F_i)$ is shown in the following formula:

$$\sigma(F_i) = \frac{S_i^{+}}{S_i^{+} + S_i^{-}}. \tag{12}$$

Step 10: Rank each scheme according to the level of closeness accessible degree and get the optimal scheme.

6. Case Application Analysis

A railway group company plans to launch two special tour lines, and the planned line schemes are F_1, F_2, F_3, and F_4. Two high-quality line schemes need to be selected as the brand lines launched by the railway bureau. The members of the group of experts shall consist of experts in the areas of tourism and transport. In this case, the expert group consists of five experts: the expert group level is divided into two levels, including three tourism industry experts and two railway operation and management experts, including two high weight tourism industry experts and one railway operation and management expert. Firstly, according to Step 1, experts make linguistic scores on each decision index of the four schemes, and the scores of each scheme indices are shown in Table 2.

According to Step 1, the vague value corresponding to each index language score can be represented to obtain the decision-making score matrix, and the table form is shown in Table 3.

Similarly, according to Step 2, the expected matrix E, as shown in Table 4.

The payoff matrix is calculated by Step 3, and the prospect value matrix is calculated by Step 4 according to the payoff matrix, which is expressed in tabular form as shown in Table 5.

Decision-making index weights based on Step 7 as shown in Table 6.

PVPIS and PVNIS are extracted according to Step 6, and the accessible degree of each scheme is calculated by Steps 8–10. The calculation results are shown in Table 7.

According to the results of accessible degree shown in Table 6 and Figure 3, the order of design quality of four tourist-dedicated train tour line schemes is $F_3 > F_4 > F_1 > F_2$, schemes F_3 and F_4 should be selected as the priority scheme of the tourist-dedicated train tour line launched by the Railway Administration Group Company. From the decision-making process, it can be found that for different indices, due to the influence of objective factors, it is impossible for all indices to take the optimal score value as the expectation. Decision makers have different expectations

Table 3: Tabular form of vague value decision score matrix.

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{18}	I_{11}
F_1	[0.6, 0.7]	[0.5, 0.5]	[0.6, 0.7]	[0.3, 0.4]	[0.75, 0.85]	[0.6, 0.7]	[0.6, 0.7]	[0.6, 0.7]	[0.5, 0.5]	[0.75, 0.85]	[0.75, 0.85]	[0.75, 0.85]
F_2	[0.5, 0.5]	[0.5, 0.5]	[0.6, 0.7]	[0.15, 0.25]	[0.75, 0.85]	[0.6, 0.7]	[0.75, 0.85]	[0.6, 0.7]	[0.6, 0.7]	FP	[0.6, 0.7]	[0.6, 0.7]
F_3	[0.75, 0.85]	[0.75, 0.85]	[1, 1]	[0.6, 0.7]	[1, 1]	[1, 1]	[1, 1]	[0.75, 0.85]	[0.6, 0.7]	[1, 1]	[0.75, 0.85]	[0.75, 0.85]
F_4	[0.6, 0.7]	[0.75, 0.85]	[0.75, 0.85]	[0.5, 0.5]	[1, 1]	[0.75, 0.85]	[1, 1]	[0.6, 0.7]	[0.5, 0.5]	[0.5, 0.5]	[0.6, 0.7]	[1, 1]

	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{19}	I_{20}	I_{21}	I_{22}	I_{23}	I_{24}
F_1	[1, 1]	[0.6, 0.7]	[0.5, 0.5]	[0.6, 0.7]	[0.75, 0.85]	[0.5, 0.5]	[0.6, 0.7]	[0.75, 0.85]	[0.6, 0.7]	[0.75, 0.85]	[0.75, 0.85]	[0.75, 0.85]
F_2	[0.6, 0.7]	[0.5, 0.5]	[0.6, 0.7]	[0.6, 0.7]	[0.6, 0.7]	[0.15, 0.25]	[0.6, 0.7]	[0.75, 0.85]	[0.6, 0.7]	[0.6, 0.7]	[0.6, 0.7]	[0.6, 0.7]
F_3	[1, 1]	[0.75, 0.85]	[0.6, 0.7]	[0.75, 0.85]	[1, 1]	[0.3, 0.4]	[0.75, 0.85]	[1, 1]	[0.75, 0.85]	[1, 1]	[0.75, 0.85]	[1, 1]
F_4	[1, 1]	[0.6, 0.7]	[0.75, 0.85]	[0.5, 0.5]	[0.75, 0.85]	[0.15, 0.25]	[0.75, 0.85]	[1, 1]	[0.6, 0.7]	[0.6, 0.7]	[0.6, 0.7]	[0.5, 0.5]

Table 4: Tabular form of expectation matrix.

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}	I_{20}	I_{21}	I_{22}	I_{23}	I_{24}
F_1	[1,1]	[0.75,0.85]	[1,1]	[0.75,0.85]	[1,1]	[0.75,0.85]	[0.75,0.85]	[1,1]	[0.6,0.7]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0.75,0.85]	[0.6,0.7]	[0.75,0.85]	[0.75,0.85]	[1,1]	[1,1]	[0.75,0.85]	[0.75,0.85]
F_2	[0.75,0.85]	[0.6,0.7]	[1,1]	[0.75,0.85]	[1,1]	[0.75,0.85]	[1,1]	[1,1]	[0.75,0.85]	[0.75,0.85]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0.75,0.85]	[1,1]	[0.75,0.85]	[0.6,0.7]	[0.5,0.5]	[1,1]	[0.75,0.85]	[1,1]
F_3	[1,1]	[1,1]	[0.75,0.85]	[0.6,0.7]	[0.75,0.85]	[1,1]	[0.75,0.85]	[0.75,0.85]	[0.75,0.85]	[1,1]	[1,1]	[0.6,0.7]	[0.5,0.5]	[0.75,0.85]	[1,1]	[1,1]	[1,1]	[1,1]	[0.75,0.85]	[1,1]	[1,1]	[1,1]	[0.75,0.85]	[1,1]
F_4	[1,1]	[0.75,0.85]	[1,1]	[1,1]	[0.75,0.85]	[0.6,0.7]	[1,1]	[1,1]	[0.75,0.85]	[1,1]	[1,1]	[0.6,0.7]	[1,1]	[1,1]	[0.75,0.85]	[1,1]	[0.6,0.7]	[0.5,0.5]	[0.75,0.85]	[1,1]	[0.6,0.7]	[0.75,0.85]	[1,1]	[0.75,0.85]

Table 5: Prospect values of decision-making indices of each scheme.

	F_1	F_2	F_3	F_4
I_1	[−0.9685, −0.7432]	[−0.6285, −0.8565]	[−0.6285,−0.3928]	[−0.9685, −0.7432]
I_2	[−0.6285, −0.8565]	[−0.2705,−0.5118]	[−0.6285, −0.3928]	[0,0]
I_3	[−0.9685, −0.7432]	[−0.9685, −0.7432]	[0.2912, 0.1848]	[−0.6285, −0.3928]
I_4	[−1.0793, −1.0793]	[−1.4063,−1.4063]	[0,0]	[−1.1891,−1.1891]
I_5	[−0.6285, −0.3928]	[−0.3928,−0.3928]	[0.2912,0.1848]	[0.2912,0.1848]
I_6	[−0.3928, −0.3928]	[−0.3928,−0.3928]	[0,0]	[0.1848,0.1848]
I_7	[−0.3928, −0.3928]	[−0.6285,−0.3928]	[0.2912,0.1848]	[0,0]
I_8	[−0.9685, −0.7432]	[−0.9685,−0.7432]	[0, 0]	[−0.9685,−0.7432]
I_9	[−0.2705, −0.5118]	[−0.3928,−0.3928]	[−0.3928,−0.3928]	[−0.6285,−0.8565]
I_{10}	[−0.6285, −0.3928]	[−1.0793,−1.0793]	[0,0]	[−1.1891,−1.1891]
I_{11}	[0.1848, 0.1848]	[−0.9685,−0.7432]	[−0.6285,−0.3928]	[0,0]
I_{12}	[0,0]	[−0.9685,−0.7432]	[0.4424,0.3425]	[0.4424,0.3425]
I_{13}	[−0.9685, −0.7432]	[−1.1891,−1.1891]	[0.2912,0.3928]	[−0.9685,−0.7432]
I_{14}	[−1.1891, −1.1891]	[−0.9685,−0.7432]	[−0.3928,−0.3928]	[−0.6285,−0.3928]
I_{15}	[−0.9685, −0.7432]	[−0.9685,−0.7432]	[−0.6285,−0.3928]	[−0.6285,−0.8565]
I_{16}	[−0.6285, −0.3928]	[−0.9685,−0.7432]	[0,0]	[−0.6285,−0.3928]
I_{17}	[-0.6285, −0.8565]	[−1.4063,−1.4063]	[−1.6206,−1.4063]	[−1.0793,−1.0793]
I_{18}	[0.1848, 0.1848]	[−0.9685,−0.7432]	[−0.6285,−0.3928]	[0.1288, 0.2387]
I_{19}	[−0.3928, −0.3928]	[−0.3928,−0.3928]	[0,0]	[0,0]
I_{20}	[0,0]	[0.1848,0.1848]	[0,0]	[0,0]
I_{21}	[−0.9685,−0.7432]	[0.1288,0.2387]	[−0.6285, −0.3928]	[0,0]
I_{22}	[−0.6285,−0.3928]	[−0.9685,−0.7432]	[0,0]	[−0.3928,−0.3928]
I_{23}	[0,0]	[−0.3928,−0.3928]	[0,0]	[−0.9685, −0.7432]
I_{24}	[0,0]	[−0.9685, −0.7432]	[0,0]	[−0.6285, −0.8565]

Table 6: Weights of each decision index.

ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8	ω_9	ω_{10}
0.0643	0.05	0.05	0.0643	0.0571	0.05	0.0429	0.0571	0.0429	0.05
ω_{11}	ω_{12}	ω_{13}	ω_{14}	ω_{15}	ω_{16}	ω_{17}	ω_{18}	ω_{19}	ω_{20}
0.0286	0.0429	0.0214	0.0286	0.0214	0.05	0.0357	0.0286	0.0286	0.0429
ω_{21}	ω_{22}	ω_{23}	ω_{24}						
0.0357	0.05	0.0357	0.0214						

Table 7: Distance measure and accessible degree of positive and negative weighting measures for each scheme.

	F_1	F_2	F_3	F_4
S_i^+	0.7012	0.5993	0.9174	0.7624
S_i^-	0.8355	0.9217	0.6171	0.7686
$\sigma(F_i)$	0.4563	0.3940	0.5978	0.4980

for different indices. Under this premise, the better the vague prospect value of the index, the more satisfied the expectation. Through the analysis of the decision-making process, it can be found that the vague prospect values of the decision-making indices I_7, I_{11}, I_{12}, I_{19}, and I_{20} of schemes F_3 and F_4 are better, and the weights of indices I_7, I_{19}, and I_{20} are also higher, which has a high impact on the weighted measurement distance and closeness of schemes.

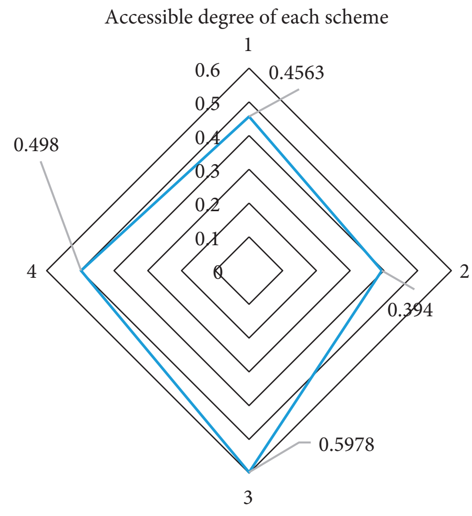

Figure 3: Accessible degree of each scheme.

7. Conclusion

In this paper, through the analysis of the principles and decision-making indices of the selection of tourist-dedicated train tour lines, the corresponding line selection decision-making index system is constructed. Through the proposed comprehensive decision-making method based on prospect theory and vague set theory, the applicability of the method to the decision-making of tour lines is verified by an example. The conclusions are as follows:

(1) The tour line of tourist-dedicated train is the key to attract tourists, ensure high-quality tour, and improve the experience and satisfaction of tourists. In this paper, the selection of high-quality tour line of tourist-dedicated train as the goal, on technical factors, tourism factors, regional economic factors, passenger flow factors as the criterion, the influence of line selection under the criterion of decision-making index analysis, and build a tour line selection for tourism of tourist-dedicated train decision index system.

(2) A comprehensive decision-making method based on prospect theory and vague set is proposed for the first time. The vague set is used to solve the characteristics of fuzzy evaluation, and the prospect theory considers the characteristics of limited rationality and psychological factors of decision makers. Vague set is used to quantify the linguistic score of experts, and the concept of prospect vague value is proposed. Through the weighted calculation of its value matrix, the TOPSIS measurement and accessible degree are obtained.

(3) The effectiveness of the decision-making method proposed in this paper can be obtained through the verification of examples. For the decision-making problems in the operation activities of tourist-dedicated trains, this method can be applied not only to the line selection decision of tourist-dedicated trains but also to the quality evaluation of line planning of tourist-dedicated trains, the evaluation of the economic effect of tourist-dedicated trains, and the evaluation of the implementation effect of the train diagram under the condition of tourist-dedicated trains. In addition, as a new decision-making idea and method, this method quantitatively calculates the decision indices under the condition of considering the psychological expectations of decision makers. As a theoretical supplement to the multi-attribute decision-making method and the fuzzy decision-making method, it can be used as a decision-making method for the scheme decision-making that needs to consider the psychological expectations of decision makers. It provides a new theoretical reference for the multi-objective attribute decision-making solution problem and can also be applied to other decision-making management research processes.

(4) It should be pointed out that tourist-dedicated train is a tourism product launched by railway transport enterprises, and the decision-making selection of its tour lines has a certain degree of complexity. In the follow-up study, it is necessary to conduct more in-depth research on the correlation between various indices, so as to make the decision results more accurate.

Data Availability

The data used to support the findings of this study are available from the corresponding author on request through email 0118001@stu.lzjtu.edu.cn.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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