Research on Travel Route Planning for Foreign Tourists Based on Comprehensive Evaluation Model and Greedy Algorithm

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Abstract. As globalization continues to deepen, China has attracted more and more international tourists with its unique culture and natural landscapes. In order to provide an efficient and in-depth travel experience, this study aims to design an optimal travel route for a foreign tourist arriving from Guangzhou to visit multiple cities in China within 144 hours. This study first determined the highest-rated attractions (BS) and their distribution by collecting and analyzing the rating data of 35,200 attractions in 352 cities. Secondly, the Analytical Hierarchy Process (AHP) and the TOPSIS method were used to comprehensively evaluate the cities and select the 50 cities that are most attractive to foreign tourists. Finally, this study applies a greedy algorithm, combined with the high-speed rail network and travel time between cities, to plan a travel route that maximizes cost-effectiveness and enriches experience. The research results not only provide tourists with an efficient travel route, but also provide data support and optimization suggestions for tourism planners and decision-makers.

Keywords: Tourism route planning; City comprehensive evaluation; Greedy algorithm; Analytic hierarchy process; TOPSIS method.

1. Introduction

As an important pillar of the global economy, tourism is experiencing rapid development of globalization [1]. With its rich cultural heritage and natural landscapes, China has become a popular tourist destination for international tourists. However, for tourists with limited time, how to plan a travel route that is both economical and full of experience within the limited stay time is an urgent problem that needs to be solved. Traditional tourism planning methods often rely on empirical judgment and lack scientific analysis and utilization of large amounts of data. With the development of big data technology, we now have the opportunity to optimize travel route design through data-driven methods. At present, tourists mainly use the positioning function and navigation function provided by online map navigation software to realize point-to-point path planning. However, with the advancement of science and technology, the planning of tourism paths should not be limited to providing map locations and point-to-point travel routes, but should also realize the comprehensive planning of the optimal path of overall tourism, but there is still no relevant research on tourism path planning [2]. This study aims to fill this gap by applying the Analytical Hierarchy Process (AHP), TOPSIS method and greedy algorithm to the tourism route optimization problem, and proposes a data-based tourism route optimization model. This article is divided into four modules: introduction of relevant methods, model establishment, conclusion, and summary. This article first describes the Analytical Hierarchy Process (AHP), TOPSIS method, greedy algorithm and Traveling Salesman Problem (TSP) and their related theories in the method introduction module. Then, in the model building module, by analyzing the attraction rating data, the highest-rated attractions among the 35,200 attractions included in 352 cities were quickly identified. The Analytical Hierarchy Process (AHP) and the TOPSIS method are used to comprehensively evaluate cities and select the most attractive cities; Apply a greedy algorithm and combine it with high-speed rail network data to plan an optimal travel route for tourists to visit multiple most attractive cities; within 144 hours. Then the conclusions obtained by the model are displayed in the conclusion module. Finally, the overall process of model establishment is analyzed and summarized in the summary module. This research

not only improves the scientific city and efficiency of tourism planning, but also brings a more personalized and rich tourism experience to tourists.

2. Method introduction

2.1. Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a subjective evaluation method proposed by American operations researcher Saaty in the early 1970s. The analytic hierarchy process decomposes the elements related to decision-making into multiple levels such as goals, criteria, and plans, and conducts qualitative and quantitative analysis on this basis. It is a systematic, simple, flexible and effective decision-making method. The principle of the analytic hierarchy process is that before analyzing a phenomenon or problem, first decompose the phenomenon or problem into relevant factors according to their nature, and classify them according to the relationship between them to form a multi-level structural model. Then, through experience or experts, we can judge and measure the relative importance of low-level factors to high-level factors, and derive a weight ranking based on the degree of importance, which can then be quantitatively analyzed and compared. The core of the AHP is to hierarchize and digitize influencing factors. It decomposes an abstract phenomenon or problem from difficult to easy, making it easy to intuitively judge and make decisions on complex problems. The application process of the analytic hierarchy process generally includes four steps: the construction of the hierarchical structure model, the construction of the judgment matrix, the single hierarchical sorting and its consistency test, the total hierarchical sorting and its consistency test.

The structure of the network analytic hierarchy process is shown in Figure 1.

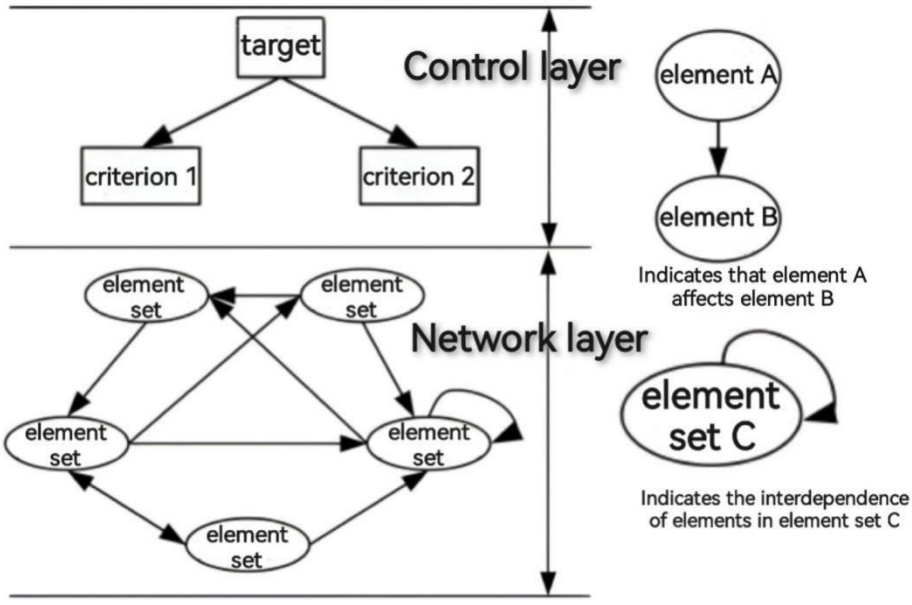


Figure 1. Analytic Hierarchy Structure Diagram.

This article uses the Analytical Hierarchy Process (AHP) to conduct the basic process of comprehensive urban assessment:

Standardize data of different dimensions to ensure that all indicators are of the same magnitude. The corresponding rating levels of each factor are shown in Table 1:

$$x_{ij}^{*} = \frac{x_{ij} - min(x_j)}{max(x_j) - min(x_j)} \quad (1)$$

Table.1. Concentration of each factor

scale.	scale definition
1	m element is equally important as n element m
3	m element is slightly more important than n element
5	m element is more important than n element
7	m element is very important than n element
9	m element is absolutely important than n element.
2,4,6,8	The intermediate value of the above adjacent evaluation, the reciprocal of the absolute importance of m elements compared to n elements.

Construct the AHP judgment matrix:

$$A = (a_{ij})_{m\times n} = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \tag{2}$$

Conduct consistency check on the judgment matrix. The maximum eigenvalue of the judgment matrix is λ_{max} , and the number of indicators in the judgment matrix is n:

$$C.I. = \frac{\lambda_{max}-n}{n-1} \tag{3}$$

Calculate the consistency index ratio, where R. I. is the random consistency index, and the specific values are shown in Table 2:

$$C.R. = \frac{C.I.}{R.I.} \tag{4}$$

Table.2. Random consistency index value.

n	R. I.
1	0.00
2	0.00
3	0.52
4	0.89
5	1.12
6	1.26
7	1.36
8	1.41

By comprehensively considering all indicators and excluding substitutable and unclear indicators, the corresponding evaluation results can be obtained.

2.2. TOPSIS method

TOPSIS method, also known as the distance method between superior and inferior solutions. The TOPSIS method is a commonly used comprehensive evaluation method that can make full use of the information of original data and accurately reflect the gaps between various evaluation plans. The basic process is to first unify the original data matrix to the indicator type (general forward processing) to obtain a forwarded matrix, and then standardize the forwarded matrix to eliminate the influence of each indicator dimension and find the best plan and the worst plan, and then calculate the distance between each evaluation object and the best plan and the worst plan respectively, and obtain the relative closeness of each evaluation object to the best plan, which is used as the basis for evaluating the merits. This method has no strict restrictions on data distribution and sample content, and data calculation is simple and easy.

On the basis of using the analytic hierarchy process, this paper uses the superior and inferior solution distance method to forward process the intermediate indicators, transform them into

extremely large indicators, and carry out the same trend of the indicators to establish the same trend matrix. Then, each indicator is normalized to eliminate the dimensional influence and obtain the normalized matrix. Finally, according to the values of various indicators in the normalized matrix, the optimal vector and the worst vector are calculated, and the optimal and worst evaluation objects are determined. By calculating the distance between each indicator and the optimal plan and the worst plan, and integrating the evaluation results of each indicator, a comprehensive evaluation model is established. Based on this model, cities are sorted and cities with higher comprehensive evaluation indexes are selected as the city's most desirable to foreign tourists.

Based on the analytic hierarchy process, this paper uses the TOPSIS method to establish the basic process of a comprehensive evaluation model:

Use the superior and inferior solution distance method to forward the intermediate indicators, that is, transform them into extremely large indicators, and the sequence $\{X_1, X_2\}$ is forwarded:

$$X_j^* = 1 - \frac{|X_j - X_{best}^*|}{max|X_j - X_{best}^*|} (j = 1,2,3) \tag{5}$$

The indicators are trending together. That is to convert very small indicators into very large indicators:

$$X_j^* = \frac{1}{X_j} (j = 7,8,9,10,11) \tag{6}$$

Normalize each indicator to eliminate the influence of indicator dimensions and obtain the normalized matrix:

$$Z_{ij} = X_{ij} / \sqrt{\sum_{j=1}^{11} (X_{ij})^2} (i = 1,2,3) \tag{7}$$

According to the Z_{ij} value of each indicator in the matrix, the optimal vector Z^+ and the worst value vector Z^- are obtained, that is, the optimal object Z^+ and the worst object Z^- among the limited evaluation objects:

$$\begin{cases} Z^+ = (Z_{i1}^+, Z_{i2}^+, \cdots, Z_{ij}^+) \\ Z^- = (Z_{i1}^-, Z_{i2}^-, \cdots, Z_{ij}^-) \\ i = 1,2,3; j = 1,2,3 \end{cases} \tag{8}$$

Calculate the distances D_i^+ and D_i^- between the Z_{ij} value of each indicator and the optimal solution and the worst solution of the corresponding indicator:

$$\begin{cases} D^+ = \sqrt{\sum_{j=1}^{11} (Z^+ - Z_{ij})^2} \\ D^- = \sqrt{\sum_{j=1}^{11} (Z^- - Z_{ij})^2} \\ i = 1,2,\cdots,16; j = 1,2,\cdots,11 \end{cases} \tag{9}$$

Based on the distances D_i^+ and D_i^- between each indicator and the optimal plan and the worst plan of the corresponding indicators, a comprehensive evaluation model is established, the cities are sorted according to the comprehensive evaluation index, and the city's most desirable to foreign tourists are selected.

2.3. Greedy Algorithm and Traveling Salesman Problem (TSP)

The greedy algorithm (also known as the greedy algorithm) means that when solving a problem, always make the best choice at the moment. In other words, without considering the overall optimality, the algorithm obtains a local optimal solution in a certain sense.

The greedy algorithm is a step-by-step optimization strategy. Its process can be summarized into four basic steps: First, build a mathematical model to accurately describe the problem. The

optimization problem faced; secondly, decompose this large problem into multiple manageable sub-problems; then, seek the local optimal solution for each sub-problem, that is, the best choice in the current step; finally, combine all sub-problems The local optimal solutions are combined to form a complete solution, in order to obtain the global optimal or approximately optimal solution to the original problem. Through this series of logical steps, the greedy algorithm pursues the optimal local choice at each step, thereby achieving a satisfactory solution as a whole.

The Traveling Salesman Problem (TSP) is a classic combinatorial optimization problem. In this problem, a traveling salesman needs to start from a certain city, pass through a series of other cities, and visit each city only once, and finally return to the starting point. The goal is to find the shortest possible path that minimizes the total distance traveled by the traveling salesman. The greedy algorithm is a heuristic algorithm that takes the currently optimal choice at each step in the hope that the result will be globally optimal. In the Traveling Salesman Problem (TSP), the greedy algorithm finds an approximately optimal path through a series of decision steps. The execution of the algorithm begins with a starting point, and subsequently at each step, the algorithm selects the nearest unvisited city to the current city as the next destination. Once this city is selected, the algorithm updates the current route to include this new city and marks this city as visited, thereby removing it from the set of cities to be visited. This process is repeated until all cities are included in the path. Ultimately, the algorithm ensures that the traveling salesman can return to the original starting point after completing visits to all cities, forming a closed-loop path.

The TSP problem is different from the tourism route optimization problem studied in this article in terms of whether to consider returning to the starting point. However, the TSP problem is similar to the tourism route optimization problem studied in this article in terms of the use of greedy algorithms and the model building process, which provides certain insights for this study. reference value.

The basic process of greedy algorithm:

Greedy selection: At each step k, the greedy algorithm selects a local optimal solution, denoted as x_k, which is the lowest-cost solution among all currently available solutions:

$$x_k = argmin_X\{c(x)\} \tag{10}$$

Problem decomposition: Decompose the original problem into sub-problems, and only consider part of the decision for each sub-problem. For example, in TSP, each subproblem may only involve selecting the next city;

Path update: In TSP, each time a new city is selected, the current path P is updated:

$$P_{new} = P \cup \{next\ city\} \tag{11}$$

Constraints: Ensure that each selected city is unvisited until all cities are included, where $c_{i,j}$ represents the connection cost from city i to city j, and n is the total number of cities:

$$\wedge_{i=1}^{n-1}\left(c_{i,i+1} \in P\right) \wedge \left(c_{i,i} = 0\right) \tag{12}$$

Closed loop formation: After all cities have been visited, select a path to return to the starting point to complete the closed loop:

$$P_{final} = P \cup \{return\ to\ start\} \tag{13}$$

Total cost calculation: Calculate the total cost of the final path, which is the ultimate goal of the greedy algorithm:

$$C_{total} = \sum_{x \in P_{final}} c(x) \tag{14}$$

The application of the greedy algorithm and the detailed process of establishing the optimal route will be described in the model establishment module of this article.

3. Model establishment

3.1. Data preprocessing

In the data preprocessing stage, this study first collected rating data of 35,200 attractions in 352 cities (Data source: https://www.saikr.com/vse/chinamcm/2024). Next, find the highest rated value (BS) among them. Then, count the number of attractions across the country that achieve this top rating and identify the cities with the highest number of attractions that have received the highest ratings for attractions. Then, a comprehensive evaluation model is established using the analytic hierarchy process and the TOPSIS method. The model should consider factors such as city size, environmental protection, cultural heritage, transportation convenience, climate and food. These factors need to be quantified and standardized, and then combined to calculate an overall score for each city. Sort according to the total score and select the city with the higher score.

The specific process of data preprocessing:

Find the highest score among all attractions. The highest score is defined as BS. Calculate the highest score (BS):

$$\begin{cases} S = \{s_1, s_2, \dots, s_\{35200\}\} \\ B\ S = \backslash max\ (S) = \backslash max\ (s_1, s_2, \cdots, s_{\{35200\}}) \end{cases} \tag{15}$$

Suppose the highest-rated attractions set is $C\{BS\}$, which contains all attractions rated BS. Calculate the number of attractions in C_{BS} and record it as n_{BS}:

$$n_{\{B\ S\}} = \left|C_{\{B\ S\}}\right| = \backslash sum_{\{i=1\}}^{\{35200\}\backslash mathbb\{I\}(s_i = B\ S)} \tag{16}$$

Let Cj represent the scenic spot rating data set of the j-th city, $j = 1,2, \dots ,352$, and the number of scenic spots with the highest score (BS) according to city statistics:

$$n_{BS,j} = \sum_{i \in C_j} \mathbb{I}(s_i = BS) \tag{17}$$

Data of different dimensions are standardized to ensure that all indicators are of the same magnitude. This article uses maximum and minimum standardization (processed by the method of dispersion annotation), which is a linear transformation of the original data, so that the result value is mapped to between [0,1]:

$$x_{ij}^* = \frac{x_{ij} - min(x_j)}{max(x_j) - min(x_j)} \tag{18}$$

Conduct consistency check on the judgment matrix. If the judgment matrix meets the consistency requirements, the consistency ratio CR will be less than 0.1. Suppose the maximum eigenvalue of the judgment matrix is λ_{max}, and the number of indicators in the judgment matrix is n:

$$C.I. = \frac{\lambda_{max} - n}{n-1} \tag{19}$$

Use the distance method of superior and inferior solutions to forward the intermediate indicators, that is, convert them into extremely large indicators, and forward the intermediate indicator sequence $\{X_1, X_2\}$:

$$X_j^* = 1 - \frac{|X_j - X_{best}^*|}{max|X_j - X_{best}^*|} (j = 1,2,3) \tag{20}$$

The indicators are trending together. That is to convert very small indicators into very large indicators:

$$X_j^* = \frac{1}{X_j} (j = 7,8,9,10,11) \tag{21}$$

Normalize each indicator to eliminate the influence of indicator dimensions and obtain the normalized matrix:

$$Z_{ij} = X_{ij} / \sqrt{\sum_{j=1}^{11} \left(X_{ij}\right)^2} \ (i = 1,2,3) \tag{22}$$

According to the Z_{ij} value of each indicator in the matrix, the optimal vector $Z^+$and the worst value vector $Z^-$are obtained, that is, the optimal object $Z^+$and the worst object Z^-among the limited evaluation objects:

$$\begin{cases} Z^+ = \left(Z_{i1}^+, Z_{i2}^+, \cdots, Z_{ij}^+\right) \\ Z^- = \left(Z_{i1}^-, Z_{i2}^-, \cdots, Z_{ij}^-\right) \\ i = 1,2,3; j = 1,2,3 \end{cases} \tag{23}$$

Calculate the distances D_i^+ and D_i^- between the Z_{ij} value of each indicator and the optimal solution and the worst solution of the corresponding indicator:

$$\begin{cases} D^+ = \sqrt{\sum_{j=1}^{11} \left(Z^+ - Z_{ij}\right)^2} \\ D^- = \sqrt{\sum_{j=1}^{11} \left(Z^- - Z_{ij}\right)^2} \\ i = 1,2,\cdots,16; j = 1,2,\cdots,11 \end{cases} \tag{24}$$

3.2. Create optimal route

On the basis of data preprocessing, through greedy algorithm and dynamic programming optimization algorithm, combined with high-speed rail network and travel time between cities, path planning is established to establish the optimal route model, and plan a travel route that maximizes cost-effectiveness and rich experience.

Attraction information: Collect information on the cities most desired by foreign tourists, including the number of major attractions in each city, the visit time and ticket fees for each attraction. Suppose the information of the i-th city is: the number of attractions n_i, the average visit time of each attraction $t_{\{s_i\}}$, and the ticket cost of each attraction $p_{\{s_i\}}$.

High-speed rail information: Collect high-speed rail information between these cities, including high-speed rail time and high-speed rail costs between cities. Suppose the high-speed rail time between city i and city j is $t_{\{t_{\{ij\}}\}}$ and the high-speed rail cost is $p_{\{t_{\{ij\}}\}}$.

The specific process of path planning based on scenic spot information and high-speed rail information:

Time constraint: The total time includes high-speed rail time and attraction time, no more than 144 hours, where m is the number of cities visited by tourists:

$$\sum_{k=1}^{m-1} t_{t_{i_k i_{k+1}}} + \sum_{k=1}^{m} n_{i_k} t_{s_{i_k}} \leq 144 \tag{25}$$

Cost constraints: The total cost includes high-speed rail fees and ticket fees:

$$\sum_{k=1}^{m-1} p_{t_{i_k i_{k+1}}} + \sum_{k=1}^{m} n_{i_k} p_{s_{i_k}} \tag{26}$$

Calculate the total time: Calculate the sum of the high-speed rail time and attraction time between the selected cities:

$$T_{\text{total}} = \sum_{k=1}^{m-1} t_{t_{i_k i_{k+1}}} + \sum_{k=1}^{m} n_{i_k} t_{s_{i_k}} \tag{27}$$

Calculate the total cost: Calculate the total cost of high-speed rail and attraction ticket costs between the selected cities:

$$P_{\text{total}} = \sum_{k=1}^{m-1} p_{t_{i_k i_{k+1}}} + \sum_{k=1}^{m} n_{i_k} p_{s_{i_k}} \tag{28}$$

Using a heuristic algorithm, consider that the total time spent in this article does not exceed 144 hours. The heuristic algorithm requires that each time a selection is made, it checks whether the time limit is met and records the visited cities and related costs.

The algorithm modeling in this article takes Guangzhou as the starting point. It first initializes variables including the visited city list, remaining city pool, total time and total cost. Then at each decision point, the nearest unvisited city is selected as the next stop and the current city status is updated, while the visited city is removed from the remaining city pool. This process is repeated until the 144-hour time budget is used up or all cities are visited. Ultimately, the algorithm calculates and provides the total travel time and total cost within a given period of time, as well as the total number of attractions the visitor was able to visit.

Calculated total time, total cost and total number of attractions that can be visited within 144 hours:

$$\begin{cases} T_{\text{total}} = 144h \\ P_{\text{total}} = total\ cost \\ \&\text{Total number of attractions} = \sum_{k=1}^{m} n_{i_k} \end{cases} \tag{29}$$

The research plan of this article is based on the "Principle of Touring the Best Scenic Spots in the City", and tries to visit cities with higher scenic spot ratings within 144 hours. This paper considers travel time and cost, and use a greedy algorithm to select cities with short high-speed rail times and low costs. Finally, it was calculated that tourists entered the country from Guangzhou and visited Chongqing, Chengdu, Shanghai, Suzhou and other cities in sequence, with a total travel time of 144 hours, a total expenditure of 8,108 yuan, and a total of 29 scenic spots visited. The city quality and economic cost of travel are optimized within a limited time, and efficient travel routes are provided for tourists.

The travel time and cost in each city are shown in Table 3.

Table.3. Travel time and cost in each city.

city	play time	cost
Guangzhou	42h	¥2723
Chongqing	39h	¥1630
Chengdu	29h	¥1127
Shanghai	23h	¥1039
Suzhou	11h	¥1589

4. Results

This study used python to organize and analyze the data in the data preprocessing stage, and quickly found the highest-rated attractions and the cities with the most high-rated attractions. Through the Analytical Hierarchy Process (AHP) and the TOPSIS method, multiple evaluation indicators were comprehensively considered, making the evaluation results more comprehensive and objective. Figure 2 shows the scatter distribution and histogram between different variables, including factors such as city size, environmental protection, and transportation convenience. Scatter matrix plots can help observe the correlation and distribution between various variables. For example, there may be a certain linear relationship between some variables, while the relationship between other variables is more complex or there is no obvious relationship.

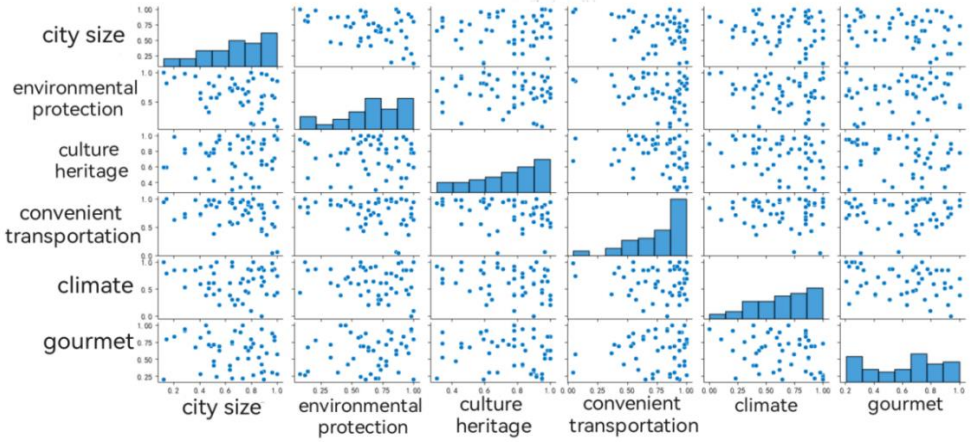


Figure 2. Variable scatter matrix plot of AHP method

The specific travel route obtained through the greedy algorithm starts from Guangzhou, passes through Chongqing, Chengdu, Shanghai, and finally reaches Suzhou. The specific tour route is shown in Figure 3.

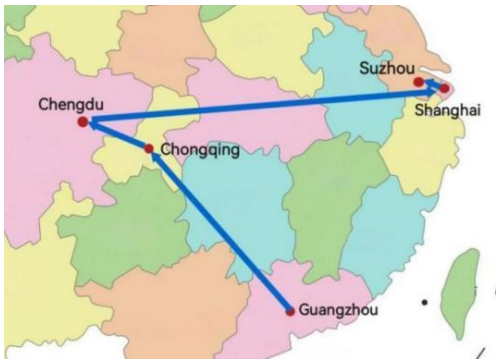


Figure 3. Tour route map

5. Conclusions

This study comprehensively uses the Analytical Hierarchy Process (AHP), TOPSIS method and greedy algorithm to create a 144-hour efficient travel route tailored for international tourists in China. The study accurately analyzed the rating data of 35,200 attractions to identify the highest-rated attractions; and then selected the most attractive cities to ensure the cultural connotation and tourism value of the route. In the end, the greedy algorithm optimization based on high-speed rail network and time efficiency achieved the best balance between cost and experience. This research result not only provides tourists with an efficient, economical and in-depth travel route, but also provides scientific data analysis and practical optimization strategies for the planning and decision-making of the tourism industry, which has important practical significance and application prospects.

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