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## Article

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## Research Article

# Construction of cultural heritage evaluation system and personalized cultural tourism path decision model: An international historical and cultural city

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## ABSTRACT

World cultural heritage (WHS) is of great significance to promoting the sustainable development of cities, and history culture is very important to achieve the goal of sustainable development. The purpose of this paper is to construct a cultural heritage evaluation system and to explore and optimize tourist routes. We take cultural heritage sites as the research object, and comprehensively use Analytic Hierarchy Process (AHP), Delphi method and fuzzy mathematics to establish a cultural heritage tourism resource evaluation system. According to the evaluation results and questionnaires, a decision-making system for cultural tourism route planning is established, and additional sites of Qin culture are found, and a complete Qin culture route is established to provide data and theoretical basis for Xi'an's perfect cultural tourism route. The traveling salesman problem is the most basic path problem. In this study, the ant colony algorithm is used to improve the model combined with the actual problem of Xi'an tourist routes, and the optimal solution of the cultural parade route is obtained. Xi'an authorities and managers can strategically use these findings to promote Xi'an as a green destination WHS.

## 1. Introduction

A city's history and culture are mostly displayed through heritage, which is a way to attract tourists to the city at the same time. International recognition by means of appointing World Heritage Sites by the United Nations Educational, Scientific and Cultural Organization (UNESCO) is a way of preserving and conserving these sites, and which also resulted in a significant increase in the number of tourists (De Simone et al., 2019). Increase: As one of the earliest world historical cities established by UNESCO, Xi'an is a famous international tourist destination city. Two cultural heritage sites have been included in the World Heritage List: the Mausoleum of Qin Shi Huang and the Terracotta Warriors and Horses. For such world heritage cities, more attention should be paid to the activation and renewal of urban context while promoting the rapid economic development. Although there are many historical and cultural scenic spots and scenic spots in Xi'an, the number is huge, but at present there is no clear tourism planning route.

Research has shown that visitor demand is an important component to be considered in sustainable tourism planning and that in order for tourism to be considered sustainable, it needs visitors support in order to be as successful as possible (Megeirhi et al., 2020). It is very useful to understand the preconceived ideas of tourists before they visit the city. These data can be used to continuously improve

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the tourism experience (Nguyen & Cheung, 2014). It is very important for the successful management of a certain area to understand the tourists' emotions, activities and movement rules, as well as the factors to consider when choosing a certain area: traffic, culture, environment, people flow, etc (Abuamoud et al., 2014). Increase: it is very important for the development of tourism to understand visitors' city impression perception (Ramkissoonupa/Sup & Nunkoosubp/Supsup\*/Sup, 2011). Understanding the perceived behavior of tourists is about finding authenticity (Ramkissoon & Uysal, 2011).

The Traveling Salesman Problem (TSP) is a well-known problem that attempts to find the least-cost trip among all nodes in a graph that start and end at the same place (Worboys, 1986). In this problem, a single traveling merchant needs to visit several cities. Given the distance between each city, how to choose a route so that the traveling merchant can visit each city exactly once and return to the departure city with the shortest distance. This is a NP problem in combinatorial optimization, which plays an important role in operations research and theoretical computer science. It has strong practical significance and has attracted a large number of scholars' exploration for a long time (Yu, 2018). Abdoun et al. studied the genetic algorithm for solving the traveling salesman problem, discussed the basic conceptual characteristics and specific characteristics of various crossover operators in the context of the traveling salesman problem (TSP), and compared the accuracy of different adaptive crossover operators for solving the traveling salesman problem (Abdoun & Abouchabaka, 2012). Jati et al. introduced a new learning mechanism that makes it easier to search for the global optimal solution of the traveling salesman problem, and has better convergence performance than the original firefly optimization algorithm (Jati, 2011). The ant colony algorithm used in this paper is an intelligent population algorithm abstracted from the natural phenomenon of ants searching for the optimal path. The ant colony algorithm originated from the natural ant foraging process, which was first proposed by the Italian scholar Dorigo and continuously improved. Based on the pheromone communication of ants, this algorithm simulates the pheromone volatilized mechanism and state transition strategy of real ants, forming an overall positive pheromone feedback mechanism, which enables the algorithm to quickly conduct global search (Abdoun & Abouchabaka, 2012). Compared with other traditional mathematical programming methods, the ant colony algorithm has strong stability, strong robustness, fast convergence, and has the advantages of distributed parallel computing structure, feedback information and heuristic search, and can dynamically respond and feedback The external influence in the process of path selection (Yu, 2018).

Establishing a database and constructing a heritage evaluation system is beneficial to the sustainable development of the city. The International Cultural Diversity Network developed a Cultural Impact Assessment (CIA) framework to address the negative impact assessment of cultural variables (Sagna, 2004). ICOMOS has developed guidelines for the assessment of world cultural heritage, in which cultural heritage is considered as a distinct feature that needs to be separated from environmental assessments (ICOMOS, 2011). On March 8, 2021, the Ministry of Natural Resources of China issued the "Guiding Opinions of the State Administration of Cultural Heritage on Strengthening the Protection and Management of Historical and Cultural Heritage in the Preparation and Implementation of National Land and Space Planning". Among them, the integration of historical and cultural heritage spatial information into the basic land spatial information platform is an important link to collect cultural heritage resource data. Although some literature has proposed methods, it seems that further research is required to develop a more systematic and comprehensive approach.

Cultural heritage plays an important role in promoting the development of urban tourism and the sustainable development of cities. Research shows that WHS as a "brand" offers new opportunities for historic cities (De la Calle Vaquero & Hernández, 1998). Research has demonstrated how Canada's cultural and heritage tourism resources facilitate sustainable access to attractions (Boyd, 2002). The study revised sustainable marketing agreements for 24 heritage tourism agencies, noting that these agreements mainly focused on short-term planning and current survival (Chhabra, 2009). Shockingly, at the time of conducting the English Heritage study, managers were not addressing issues related to congestion carrying capacity management or issues related to traffic (Fyall & Garrod, 1998). Despite a significant increase in the number of tourists to the WHS, there is still very little information on such tourists (Nguyen & Cheung, 2014). Tourism route planning seems to play a decisive role in its sustainability, so more research is needed.

Routes-based tourism is essential for the sustainable development of cultural Spaces in historic areas. The research shows that Ni Sheng et al. used the concept of route tourism to guide tourists to walk along the cultural relics route, which alleviated the overflow of hot spots and improved the overall carrying capacity of the city (Sheng & Tang, 2015). According to Bjeljic et al., the process of forming cultural routes as tourism products is considered as a new principle of cultural heritage protection, revitalization, utilization and display, which promotes tourism promotion in Serbia (Bjeljac et al., 2015). The place attachment generated by tourists in the process of tourism in cultural heritage sites can promote tourists' mental health and stimulate tourists' protection behavior of cultural heritage (Ramkissoon et al., 2013). Cultural tourism promotes happiness, and the social dynamics generated in cultural tourism experiences are of great significance to people (Sanagustín-Fons et al., 2020). More and more people attach importance to cultural tourism (Ramkissoon, 2015). Unfortunately, there is very little literature on the construction of personalized dynamic cultural tourism route selection models, and this study to some extent fills the gap in this field.

The route a tourist chooses affects their satisfaction with the tourist city (Martin et al., 2021). The most basic problem of routing is the traveling salesman problem. In this work, we studied the generalization of the well-known traveling salesman problem in routing. The Traveling Salesman Problem (TSP) is a well-known problem that attempts to find the least-cost trip among all nodes in a graph that start and end at the same place (Worboys, 1986). In this problem, the salesperson needs to visit  $n$  cities in the shortest possible time, each city only once. For the traveling salesman problem, the ant colony algorithm used in this study is an intelligent population algorithm abstracted from the natural phenomenon of ants finding the optimal path. The algorithm is based on the pheromone communication of ants, simulates the pheromone volatilization mechanism and state transition strategy of real ants, and forms an overall pheromone positive feedback mechanism, which enables the algorithm to quickly perform a global search (Abdoun & Abouchabaka, 2012). For previous studies, it refers only to the effect of time and distance on route choice (Gavalas & Kenteris, 2011; Jati, 2011; Scheiner, 2010; Wu et al., 2012). However, here we emphasize the influence of culture on route choice.

Our views will be verified through the selection of Xi'an cultural tourism simulation routes. As a case study, we focus on the dynamic

routing of tourism. In addition, this study will also provide an interesting visualization system for cultural path selection to enhance the sustainable or green image of Xi'an cultural space with characteristic cultural tourism routes. The study of these characteristics is the first of its kind and has important implications for a better understanding of a city's WHS. Therefore, the purpose of this study is to:

(1) The evaluation system of cultural heritage tourism resources is established, and the evaluation system is used to select the research site. Based on the questionnaire survey to understand the real will of tourists, the ant colony algorithm is used to solve the TSP problem and build a personalized decision-making model of cultural tourism path. (2) Through the tourism route visualization system, it is of great value to formulate future tourism routes and better manage WHS. (3) Discover cultural heritages that need to be protected, and then protect and transform them, which plays an important role in the sustainable development of culture.

From the perspective of tourists, this paper fully considers the distance, time, culture and other factors that tourists consider when planning the route in the process of tourism, and puts forward the cultural heritage tourism path decision that satisfies tourists, which can provide a new research direction for the theoretical research of cultural heritage tourism in the future. This paper built a personalized dynamic cultural tourism path decision model, found the need to protect but not the development of cultural sites, improve the structure of xi'an cultural heritage, and better promote the sustainable development of urban cultural heritage, also for other cities today how to solve the lack of the cultural heritage protective development and how to reasonable planning tourist routes of realistic problem to provide more specific countermeasures and suggestions.

## 2. Constructing an evaluation system for cultural heritage

### 2.1. Selection of research object

Xi'an material cultural heritage site, 80 places in total.

### 2.2. Constructing an evaluation system

Carry out analysis and word cloud analysis on user comments and other texts on Ctrip and other tourism apps, extract keyword words, and summarize the people's concerns about tourism cultural resources. Summarize the main factors affecting the development of cultural tourism, and bring the frequent indicators into the evaluation system (Figs. 1-2).

### 2.3. Research method

For the above subjects, comprehensively use Analytic Hierarchy Process (Saaty, 1994), Delphi method and fuzzy mathematics to establish the evaluation system of cultural heritage tourism resources.

#### 2.3.1. Constructing pairwise discriminant matrix

For the constructed evaluation system, the importance of each index at the same level with respect to an index in the previous level is compared, and the pairwise discrimination matrix is constructed as follows. The judgment matrix is an important basis for the comparison of relative importance (Saaty, 1990). It describes the importance of indicators respectively and quantifies them with numbers:

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nn} \end{pmatrix}$$

Importance discrimination matrix of D-level index about C-level index and importance discrimination matrix of C-level index about B-level index (Appendix A, Table s1–4).

#### 2.3.2. Hierarchical sorting

Hierarchical sorting: determines the weight value of the importance order of each element associated with this hierarchy. The eigenvalue and eigenvector of the judgment matrix are calculated by determining the square root method. The judgment matrix R corresponds to the maximum eigenvalue  $\lambda$ . After normalization, it is the ranking weight of the relative importance of an index at the same level. Ranking weight of relative importance of D-level indicators to C-level indicators and ranking weight of relative importance of C-level indicators to B-level indicators (Appendix A, (1)–(4)) (Table 1).

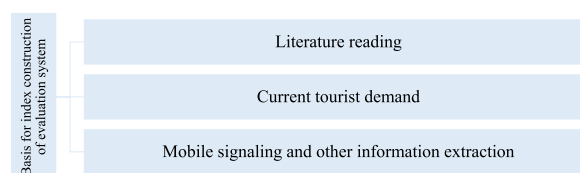


Fig. 1. Basis for index construction of evaluation system.

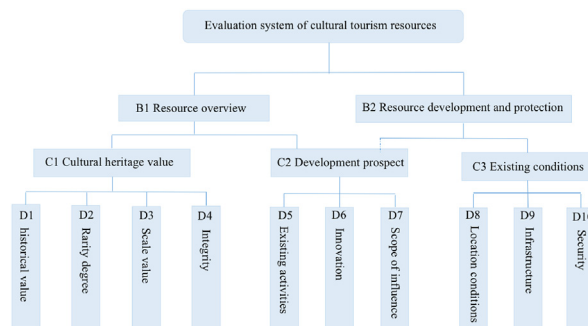


Fig. 2. System of cultural tourism resources.

### 2.3.3. Consistency test

After calculating the maximum eigenvalue and its corresponding eigenvector, the consistency test is carried out. In order to test the consistency of the judgment matrix, its consistency index CI needs to be calculated (Al-Harbi, 2001). When  $CI = 0$ , the judgment matrix has complete consistency. The larger the CI, the worse the consistency. Table 5 presents parts of values of the RI with different matrix sizes (Hong et al., 2002). When  $CR \leq 0.1$ , it is considered that the judgment matrix has satisfactory consistency, otherwise experts need to readjust the weight (Appendix A, Table 5). D-level and C-level index consistency test passed (Appendix A, (5)–(8)) (Table 2).

### 2.3.4. Determination of quantitative evaluation parameters

Through the comprehensive application of analytic hierarchy process and Delphi method, the  $w$  vector of the above consistency test (C relative to level B and D relative to level C) is multiplied to form the final quantitative analysis parameters of the cultural heritage resource evaluation system (Table 2).

## 2.4. Research result

This section presents the evaluation clustering results of the research attractions in this study. Among them, Section 2.4.1 gives the evaluation scoring methods of 10 evaluation levels and the evaluation results of learning points, and Section 2.4.2 conducts principal component analysis on the evaluation level. Section 2.4.3 clusters the evaluation results and selects 19 main research points.

### 2.4.1. Evaluation scoring method

Corresponding the evaluation factors in the above evaluation system with the basic data generated by analysis software such as GIS to form a scoring reference (Table 3).

When evaluating and scoring each element, the evaluation grade classification of each element is established, and the discrimination level in each element is divided into five grades, and a five-point system is adopted (Table 4).

Data visualization of assessment results for 80 site selections in GIS (Fig. 3).

### 2.4.2. Evaluation factor classification

Using the final score of 10 evaluation factors of 80 heritage sites, carry out principal component analysis, and conclude that the main component is the historical factor (Fig. 4).

### 2.4.3. Evaluation factor clustering

The final scoring results of the 10 evaluation factors of the 80 sites were clustered and divided into four main categories (Fig. 5). The highest score in the first level is Terracotta Army and Huaqing Palace. The second highest score is Daming Palace National Heritage Park, Huaqing Palace, Small Wild Goose Pagoda, Dayan Pagoda, Seoul Lake Park, Wenjing Park, Mausoleum of the First Qin Emperor. The third level has higher scores for Wooden Pagoda Ruins Park, Taiye pool, Wenjing Park, Qin II Ruins Park, Tang Paradise, Qu Jiang Pool

**Table 1**  
Pairwise comparison scale for AHP preferences.

Numerical rating	Definition
1	Indicates that two elements are of equal importance compared to each other.
3	Indicates that the former is moderately more important than the latter.
5	Indicates that the former is obviously more important than the latter.
7	Indicates that the former is strongly more important than the latter.
9	Indicates that the former is extremely important than the latter.
2, 4, 6, 8	Represents the intermediate value of adjacent judgment.
Reciprocal	If the importance of element $i$ and element $j$ is $r_{ij}$ , the importance of element $j$ and element $i$ is $r_{ji} = 1/r_{ij}$

The R matrix has these properties:  $r_{ij} > 0$ ;  $r_{ij} = 1$  ( $i, j = 1, 2, \dots, n$ ),  $r_{ij} = 1/r_{ji}$  ( $i \neq j$ ).

**Table 2**

Determination of quantitative evaluation parameters.

	D1	Factor evaluation layer
B1 Resource overview (0.70)	C1 Cultural heritage value (0.42)	D1historical value (0.21) D2Rarity degree (0.14) D3Scale value (0.03) D4Integrity (0.04)
	C2 Development prospect (0.28)	D5 Existing activities (0.20) D6 Innovation (0.06) D7 Scope of influence (0.02)
B2 Resource development and protection (0.26)	C3 Existing conditions (0.3)	D8 Location conditions (0.10) D9 Infrastructure (0.12) D10 Security (0.08)

**Table 3**

The reference relationship of the evaluation index.

Index factor	Corresponding data
D1historical value	Historical era.
D2Rarity degree	Nationally assessed heritage class.
D3Scale value	The size of the cultural heritage site.
D4Integrity	Integrity of cultural heritage sites under existing conservation conditions and future conservation plans.
D5 Existing activities	The popularity of the existing cultural heritage sites, refer to Baidu map.
D6 Innovation	Scenic level.
D7 Scope of influence	Recommendation index for different apps.
D8 Location conditions	Location.
D9 Infrastructure	Amount of infrastructure within the service radius.
D10 Security	Traffic.

and Xingqing Palace. The forth level has higher scores for the Site of Weiyang Palace in Chang'an City of Western Handynasty, Seoul Lake Park and the Xi'an Circumvallation.

### 3. Questionnaire surveys

Questionnaires are distributed online and offline, with a total of 462 valid data (Appendix A). The survey questions are based on existing research. This survey is divided into four categories. The first category is the personal information of each respondent, including age, gender, place of residence and means of transportation.

Part II of the questionnaire explored the respondents' familiarity with the heritage site culture, the most important points and considerations for choosing a heritage site sightseeing. Specifically, the respondents' familiarity was represented by know well, general understanding, do not know much, do not care. The most important points recorded on cost, time, landscape, culture, other. Specifically, considerations are represented by human factors, technological factors, natural factors, other (Appendix A).

Part III of the questionnaire surveyed the quality of travel services, specific evaluation of travel transportation, evaluation of the landscape quality of the scenic spot and the overall value of Xi'an cultural scenic spots. Frequency was represented by a List of 5-level scales (many (1); more (2); general (3); less (4); few (5)) (Appendix A).

Part IIII of the questionnaire surveyed respondents on the ranking and reasons for the 17 sites. And surveyed respondents' satisfaction with Xi'an cultural tourism and obtained some suggestions for the improvement of the scenic spot. Specifically, suggestions are represented by development of new projects, new attractions, buildings, improve tourism service facilities, improve traffic conditions, maintenance and renovation of old attractions, increase participatory activities, excavate historical and cultural connotations and increase cultural charm and other (Appendix A)

#### 3.1. Respondent attributes

A total of 154 effective questionnaires were collected. As is shown in Table X, amount of female respondents (261, 56.49%) are significantly more than male (201, 43.15%), seniors (7, 4.55%, >55 years old), and the vast majority are younger than 34(378, 88.32%) and from outside the Shaanxi province (570, 58.44%). In terms of transportation options, most of respondents choose to use public transportation (subway, 366, 79.22%; bus, 222, 48.05%). About 3/4 of the respondents have a high ("general understanding" and "know well") level of understanding of Xi'an culture, and over 70% of them tend to take natural and humanity factors of scenic spots. In trials, majority of the respondents reported their preference for Xi'an historical and cultural tourist attractions and the comprehensive quality evaluation of the scenic spots. At the same time, the respondents' suggestions for the renovation and improvement of each scenic spot were collected (Appendix B).

**Table 4**

Another two discriminant matrices of each index under the constraint layer of cultural tourism resources.

Index factor	Evaluation grade					EvaluationMethod
	5 points	4 points	3 points	2 points	1 points	
D1historical value	Xia, Shang, Zhou Dynasty and before	Spring and Autumn, Southern and Northern Dynasties	Sui and Tang Dynasties five Dynasties Liao and Jin Dynasties	Song, Yuan, Ming and Qing Dynasties	Republic of China to present	historical research method
D2Rarity degree	National key protection	Provincial cultural relics protection unit	Municipal cultural relics protection unit	County-level cultural relics protection unit	no level	expert scoring method
D3Scale value	extra large	Big	middle	Small and medium	little	size
D4Integrity	wonderful	very good	good	not bad	bad	research statistics
D5 Existing activities	>500	300–500	200–300	100–200	<100	expert scoring method
D6 Innovation	AAAAA level	AAAA level	AAA level	AA level	A level	scenic spot classification
D7 Scope of influence	>10,000	1000–10000	500–1000	50–500	<50	number of app entries
D8 Location conditions	1 km from the city center	5 km from the city center	10 km from the city center	20 km from the city center	>20 km from the city center	geographical location
D9 Infrastructure	>200	100–200	50–100	30–50	<50	amount of infrastructure
D10 Security	wonderful	very good	good	not bad	bad	traffic condition



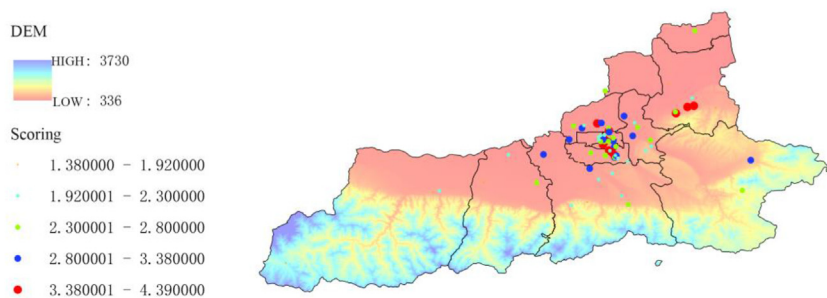


Fig. 3. 80 site selections in GIS.

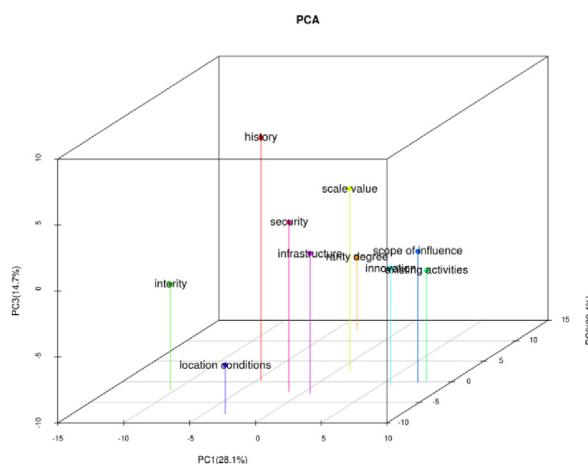


Fig. 4. Evaluation factor principal component analysis diagram.

### 3.2. Evaluation of tourism service quality and tourism traffic

Regarding the traffic safety and convenience, the number and characteristics of scenic spots, tourism experience and public facilities in Xi'an historical and cultural scenic spots, 21.31% of the respondents were very satisfied with the quality of tourism services, 42.27% of the respondents were satisfied, and 34.77% of the respondents believed that in general, only 1.65% of the respondents were dissatisfied, among which the negative comments on the convenience of transportation and public restroom services were relatively high, indicating that the comprehensive service quality of Xi'an historical and cultural tourist attractions is acceptable.

19.48% of the respondents were very satisfied, 46.66% of the respondents were satisfied, 31.91% of the respondents were very satisfied with the convenience of transportation around and inside Xi'an, the improvement of urban transportation facilities, and the management and services of urban public transportation information. Respondents believed that in general, 1.95% of the respondents were dissatisfied, and the satisfaction with transportation facilities was relatively low, indicating that while ensuring transportation convenience, Xi'an should appropriately increase transportation facilities, such as sufficient parking spaces (Appendix C).

### 3.3. Respondents' satisfaction with the site

The gender and age of the respondents were significantly correlated with transportation convenience, entertainment security, perfect traffic information, landscape richness, vegetation coverage, landscape sketch. The gender and age of the respondents were significantly correlated with transportation convenience, project point experience, public toilet conditions, overall service impression, general layout, plant diversity. The location of the respondents is significantly related to complete transportation, historical expression. The respondents' transportation mode is significantly related to taxi service, subtotal, air quality. The respondents' familiarity with culture is significantly related to the quality of tourism services and scenic spots (Appendix D).

Respondents made a simple ranking of the most important Chengdu cultural attractions in Xi'an mainly based on their personal preferences (74.68%) and attractiveness of attractions (47.4%). The ranking results are as follows: Terracotta Warriors > Datang Furong Garden > Big and small wild goose pagoda > Huaqing Pool > City wall > Qujiangchi > Daming Palace National Heritage Park > Muta Temple Ecological Site Park > The ruins of Weiyang Palace in Chang'an City of Han Dynasty > Taiye Pond > Qinglong Temple > Kunming Lake > Seoul lake > Qin II Ruins Park > Xingqing Palace > Wenjing Park > Ancestral tribe. Respondents' ranking and reasons



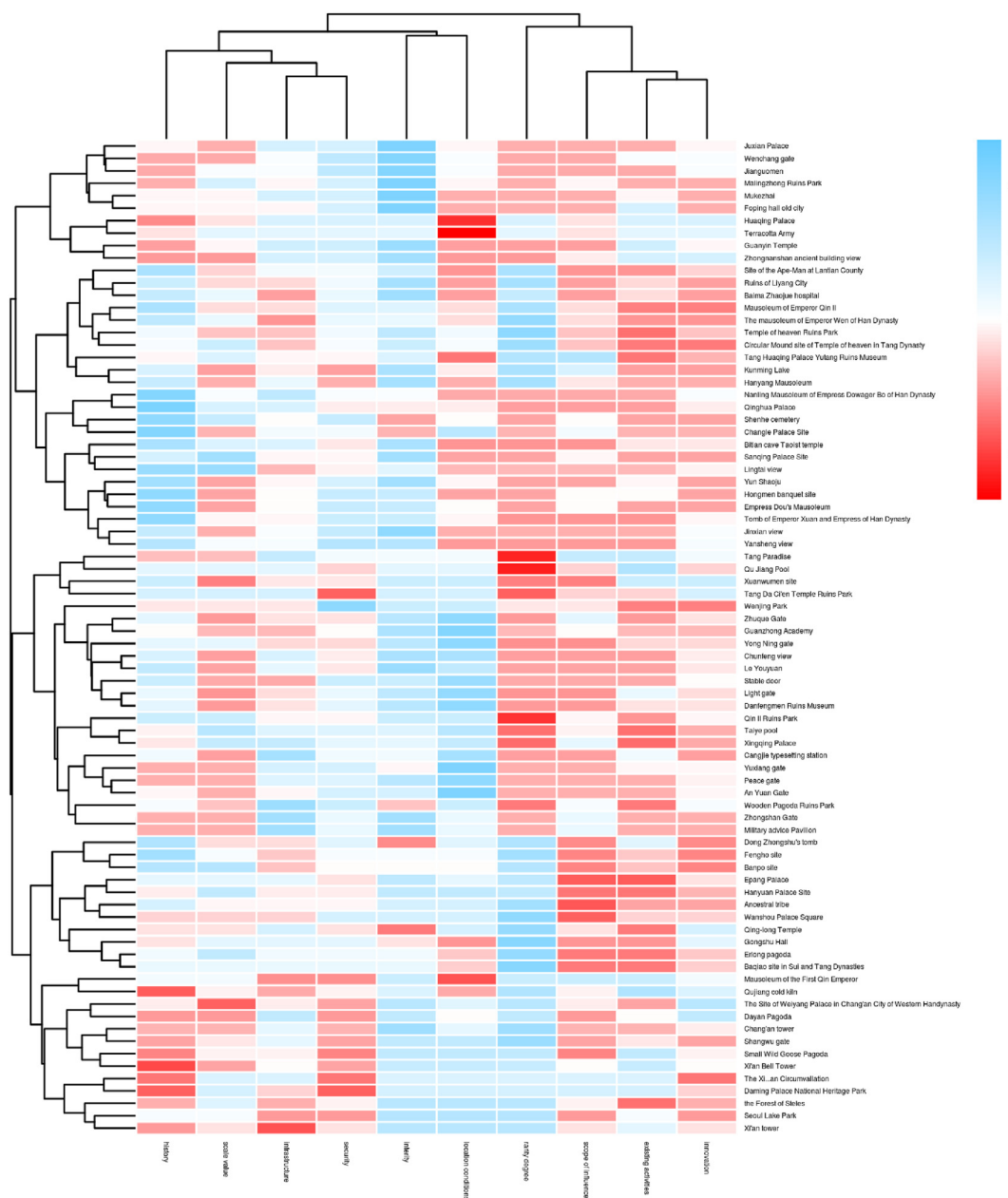


Fig. 5. Cluster heatmap.

for 17 heritage sites were obtained through principal component analysis, and personal preference and attraction of attractions were the most important reasons. Qin culture-related heritage points are clustered in the first quadrant, respondents pay more attention to Qin culture (Figs. 6-7).

### 3.4. Environmental modification

Respondents' satisfaction with Xi'an tourism cultural value is normally distributed, and the satisfaction is not good. More than half of the respondents suggested that Xi'an scenic spots should improve tourism service facilities (52.6%) and be able to tap the historical and cultural connotation of scenic spots to increase cultural charm (55.19%). The respondents' suggestions for scenic spots are mainly in development of new projects, new attractions, buildings, improve tourism service facilities, improve traffic conditions, maintenance and renovation of old attractions, increase participatory activities, excavate historical and cultural connotations and increase cultural charm.

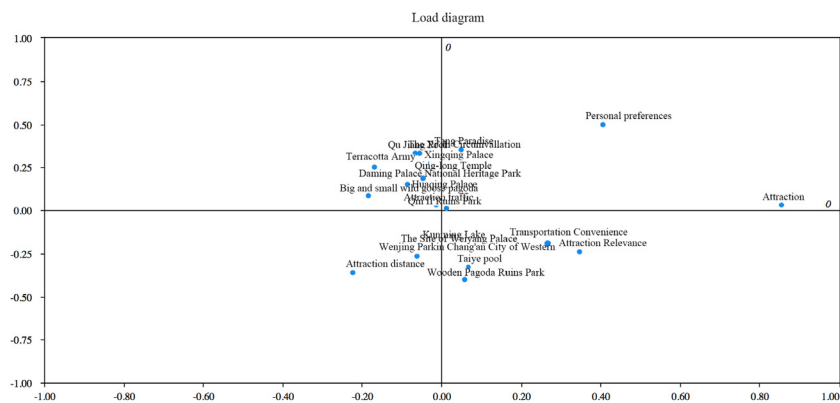


Fig. 6. Principal component analysis of tourist preference.

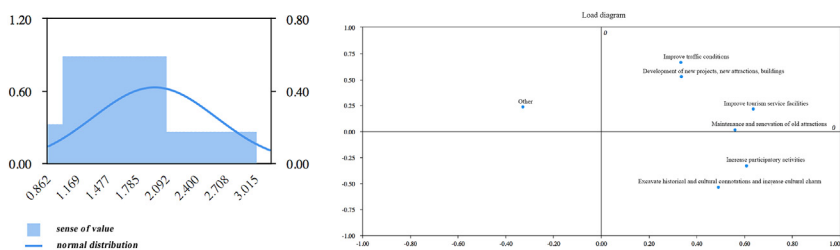


Fig. 7. Principal component analysis of tourist preference.

#### 4. Route selection model of urban cultural tourism

##### 4.1. Question hypothesis

Based on the generalized TSP model research: by putting forward a reasonable tourism route and a tour, or experiencing a Hamilton circuit in tourist attractions of Xi'an, you can visit every scenic spot just once, and finally return to the starting point (Table 6). The purpose of this trip planning is how to make the tourists get the highest experience. In order to solve the problem conveniently, the optimization plan is described as in Eqs (1)–(5)

$$x = [x_1, x_2, \dots, x_n]^T, \quad (1)$$

$$\min y = f(x) = \{f_1(x), f_2(x), \dots, f_m(x)\}, \quad (2)$$

$$s.t. x \in S = \{x | g_i(x) \leq 0, i = 1, 2, \dots, p\}, \quad (3)$$

$$\min y = (x) = \{f_1(x), f_2(x), \dots, f_m(x)\}, \quad (4)$$

$$f_1(x) = \sum d_{ij}x_{ij}, f_2(x) = \sum t_{ij}x_{ij}, f_3(x) = \sum c_{ij}x_{ij}$$

**Table 5**  
Determination of quantitative evaluation parameters.

$x$	the decision vector
$y$	the objective vector
$g_i(x)$	the $i$ constraint
$S$	the feasible solution region of the decision variable
$d_{ij}$	distance from the $i$ scenic spot to the $j$ scenic spot
$t_{ij}$	time spent from $i$ to $j$ attractions
$c_{ij}$	$c_{ij}$ the cultural connection from the $i$ scenic spot to the $j$ scenic spot.
$x_{ij} = 1$	the path from scenic spot $i$ to scenic spot $j$

**Table 6**  
Determination of quantitative evaluation parameters.

i, j	starting point and the ending point
$\eta_{ij} = 1/c_{ij}$	Visibility, reciprocal of distance between two points i and j
$\tau_0 = 1/c_{ij}$	$c_{ij}$ – The average of all edge distances in the graph
$\alpha, \beta$	Pheromone, Weighted value of visibility

$$s.t. x_{ij} = \begin{cases} 1(i,j) & \text{on the way back} \\ 0 & \text{other} \end{cases} \quad (5)$$

In this paper, we consider three indicators: distance, time and culture when we make the optimal decision.

#### 4.2. Problem solving

TSP is usually solved by dynamic program, branch and bound method, genetic algorithm and so on. This study uses ant colony algorithm to solve the problem. The solution algorithm of TSP model can be summarized as the following steps: 1. Initialize ant information (represented by agents below); 2. Construct a complete path for each agent; 3. Update pheromone; 4. Iteration to save the optimal solution. The two core steps of ant colony algorithm are path construction and pheromone update.

##### 4.2.1. Path construction

Each ant randomly selects a scenic spot as its starting place, and maintains a path memory vector to store the scenic spots that the ant passes through in turn. In each step of constructing the path, the ant selects the next scenic spot according to a random proportion rule. The random probability is calculated according to the following formula:

$$P_{ij}^k(t) = \begin{cases} \frac{\tau_{ij}^\beta \eta_{ij}^\alpha}{\sum_{z \in J_k(i)} \tau_{iz}^\beta \eta_{iz}^\alpha} w_1 + \frac{\frac{1}{|t_i - a_j|} + \frac{1}{|t_i - b_j|}}{\sum_{z \in J_k(i)} \frac{1}{|t_i - a_j|} + \frac{1}{|t_i - b_j|}} w_2 & \text{if } j \in J_k(i) \\ 0 & \text{others} \end{cases} \quad (6)$$

##### 4.2.2. Pheromone update

After each round, the pheromones on all paths of problem space will evaporate. Then, all ants release pheromones on the edges and they pass through according to the path length constructed by themselves. The formula is shown as in Eqs (7) and (8).

$$\tau_{ij}(t) = (1 - \rho)\tau_{ij} + \sum_{k=1}^m \Delta\tau_{ij}^k \quad (7)$$

$$\Delta\tau_{ij}^k = \begin{cases} (C_k)^{-1} & \text{if the } k^{\text{th}} \text{ ant traverses } (i, j) \\ 0 & \text{others} \end{cases} \quad (8)$$

##### 4.2.3. Iteration and stop

The conditions for stopping the iteration can be stopped after selecting the appropriate number of iterations and outputting the optimal path. Also can see whether the specified optimal conditions are met and stop after finding the satisfied solution. In each iteration, pheromone will volatilize and increase. The volatilization formula consists of fixed parameters:

$$\tau_{ij} = \tau_{ij} * (1 - \alpha) \quad (9)$$

$$\tau_{ij} = \tau_{ij} + \frac{1}{\text{now\_best\_cost}} * (1 + \text{delta}) \quad (10)$$

$$\text{delta} = \frac{\text{best\_cost} - \text{now\_best\_cost}}{\text{now\_best\_cost}} \text{ if } \text{best\_cost} > \text{now\_best\_cost} \quad (11)$$

The pheromone increase formula determines the total distance of the strongest ant sent each time, that is, the current optimal solution. The penalty value delta is added to the calculation formula to reward super elite ants that exceed the global optimal solution. The part composed of heuristic value and pheromone points to the edge with short path. The part of time window and total time points to the edge conforming to time constraints. Then W1 and W2 parameters comprehensively consider the two objectives, where  $W1 + W2 = 1$ .

### 4.3. Data description

#### 4.3.1. Data content and type

The data used in this study mainly include the basic information, path information of 17 cultural sites and the data adjustment parameters of ant colony algorithm. The data source is mainly Baidu map API, which obtains data by calling the relevant interfaces of Baidu Map Web Service API. The specific interfaces are: geocoding service interface, which provides the function of converting structured address data (such as No.10, Shangdi 10th Street, Haidian District, Beijing) into corresponding coordinate points (longitude and latitude) and route planning service interface, which provides driving, cycling, walking and public transportation, then planning the travel route distance and time consumption according to the starting and ending coordinates. The data type is tabular data, which is stored in MySQL database under program control, and returned to the front end in json format through back-end interface call for data display.

Data selection and its role: First, the longitude and latitude information of 17 cultural sites is used to display and identify the information of each site on the map. Second, the commuting time and distance between 17 cultural sites are used for path planning of ant colony algorithm. Third, the data parameters of ant colony algorithm, such as iteration times, parameters of data formula, maximum path/maximum time, etc., are used to accurately the final path information results and facilitate data processing.

#### 4.3.2. Data preprocessing technology and achievements

Preprocessing process: planning the format of page data, mainly planning the format data required for the display content. Using MySQL database to establish relevant tables, namely region table and regionTable table. Region table is used for longitude and latitude information of all site selection and start and end requirements of each region. It is also used to store the distance and time between addresses.

Key technologies: Baidu map JavaScript API GL v1.0 is a set of application program interfaces written in JavaScript language, which can help you build rich and interactive map applications in the website, support browser based map application development on PC and mobile terminals, and also support map development with HTML5 features. MySQL database stores the data of Baidu map API interface, which is displayed through Java back-end program development (Table 7).

Using data to record the itinerary of all tourists in Xi'an, including the travel distance and travel time between various attractions. At the same time, users can choose the places they want to go, set their own interests and preferences, and establish the priority order of tourist attractions. Then, according to various considerations, a completely undirected graph with weights is reasonably established to find a Hamiltonian circuit with the smallest sum of weights. The pseudocode for this routing algorithm is shown in Table 8.

## 5. Case analysis

Build a front-end web interface, and design a simple menu bar on the left, including data statistics and route planning. Users can view information about scenic spots at any time, and generate the best trip they want by setting the distance and travel time of the scenic spots route. Changing the iteration parameters, time and distance will produce different results, and different routes can also be selected according to cultural preferences.

### 5.1. Model application demonstration and result interpretation (time or distance parameter settings)

The result of adjusting the parameters with the distance option: the tourists only want to visit the main city attractions, the shortest distance is the priority, and the number of iterations is set to 20 (Fig. 8a). The result of adjusting parameters with the distance option: Tour all the selected attractions, the shortest distance is the priority, and the number of iterations is set to 10 (Fig. 9b). The result of adjusting the parameters with the time option: Suppose the tourists want to spend 4 days in Xi'an, and the iteration parameter is set to 1000 (Fig. 9c). The result of adjusting the parameters with the time option: Suppose that tourists want to spend 3 days in the main city of Xi'an, and the iteration parameter is set to 1500 (Fig. 9d).

### 5.2. Model application demonstration and result interpretation (culture factor parameter settings)

Urban roads largely determine the division and layout of urban space. According to the tourist routes generated by the model, some urban spaces close to cultural attractions are divided. Through the results of road route selection with the theme of Qin culture, it is found that the sites are distributed far away and cannot be well connected, and the narrative of urban cultural stories cannot be completed.

Therefore, we added 3 Qin sites that have not yet been developed on the basis of the route selection, namely the Qin Dongling, the

**Table 7**  
Determination of quantitative evaluation parameters.

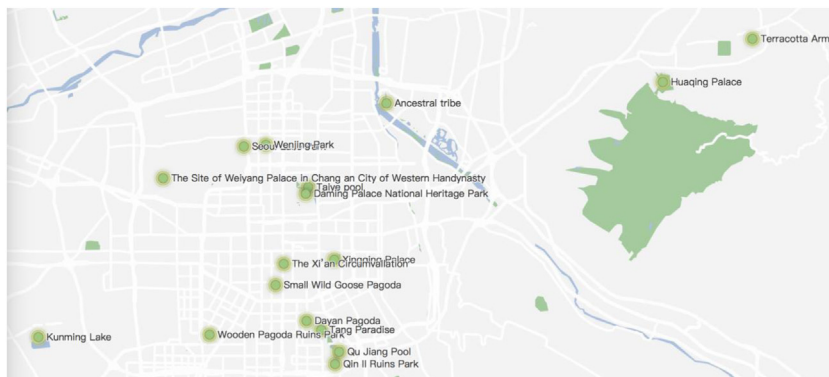
$m$	the number of ants
$0 < \rho = 1$	Evaporation rate of pheromone, normally set to 0.5
$\Delta \tau_{ij}^k$	Pheromone left by the kth ant from path I to path J
$C_k$	The total path length of the kth ant after taking the whole path

**Table 8**  
Pseudocode.

```

1: public void path(Map pr, nr){
2:   var start, next;
3:   // The cycle establishes the starting point until the whole journey is completed
4:   while (start != next){
5:     for { // Loop to calculate the probability of all possible next targets
6:       pNow(start->next) = pr.get(start->next) * nr.get(start->next);
7:     }
8:     // The starting point becomes the next target point
9:     start = next;
10:    // Route added
11:    allRoad.add(start);
12:  }
13:  // Update all pheromones circularly
14:  for (allRoad){
15:    // Update the pheromone concentration of all target points according to the existing pheromone
16:    concentration and the whole road route
17:    pr.set(startPoint -> endPoint) = (1-p)nr.get(startPoint -> endPoint) + (1/roadIn(startPoint ->
endPoint));
18:  }
19:  // Continue to optimize the route repeatedly according to the new probability until the route meets the
20:  requirements and returns the demand results
21:  return path(pr, nr) only have allRoad = needRoad;
22: }

```



**Fig. 8.** Distribution map of cultural sites.

ruins of Burning Shuru and the tomb of King Zhuangxiang of Qin. Qin Dongling is the tomb of the ancestors of Qin Shihuang, the tomb of King Zhuangxiang of Qin is buried by Qin Shihuang's father, and the ruins of burning books are the place where Qin Shihuang burned classical documents and killed Confucian scholars. The three additional sites have rationalized the distribution distance of the sites, enriched the Qin culture story to a certain extent, made the Qin culture tourism route more complete, and told the whole process of the ancient Qin Empire from its rise to its decline (Fig. 10).

### 5.3. Place making of cultural spaces

We have planned and designed the landscape space of three Qin cultural sites. The site area of the site of the tomb of King Qinzhuangxiang is small, and it adopts a regular layout, which symbolizes the short but glorious life of King Qinzhuangxiang. The distance between the Qin Dongling and Qinkeng Rugu sites is relatively short, so they are connected by a landscape avenue, and the layout is basically similar. The whole garden is laid out in a compositional form of surrounding nature and intermediate rules, which not only reflects the charm of Chinese gardens, but also shows the fortitude and strength of the Qin people, intending to restore the history of the rise and fall of the Qin state. The main axis of the landscape adopts the layout form of straight lines to create a grand and atmospheric historical atmosphere, which vividly hints at the historical background of Qin Shihuang's ancestors working hard and gradually becoming

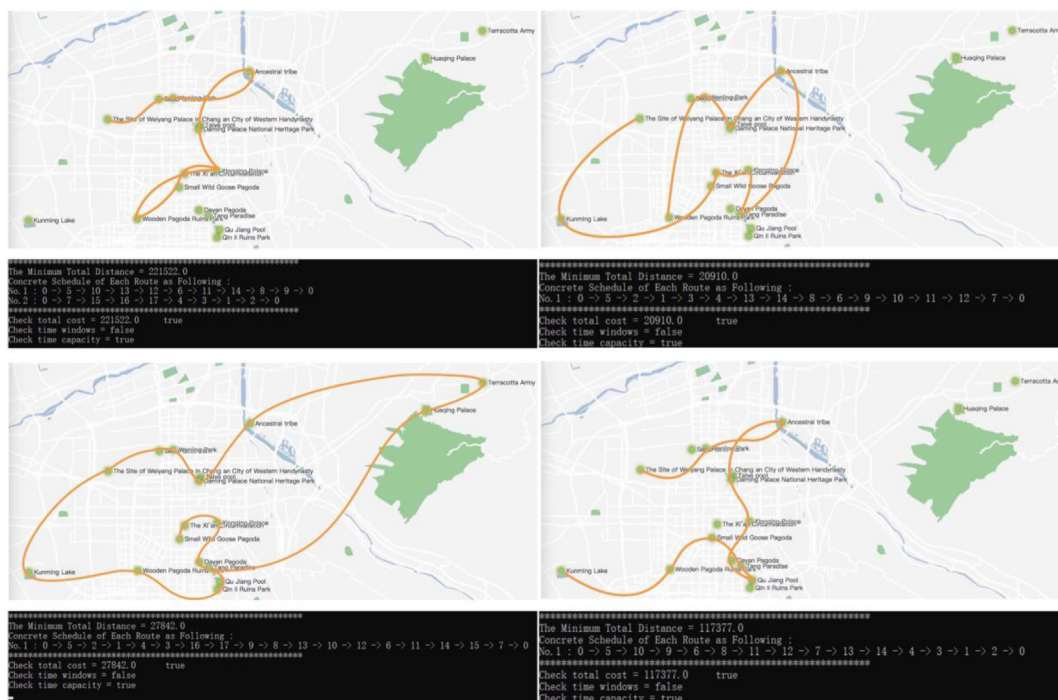


Fig. 9. Time or distance factor route map.

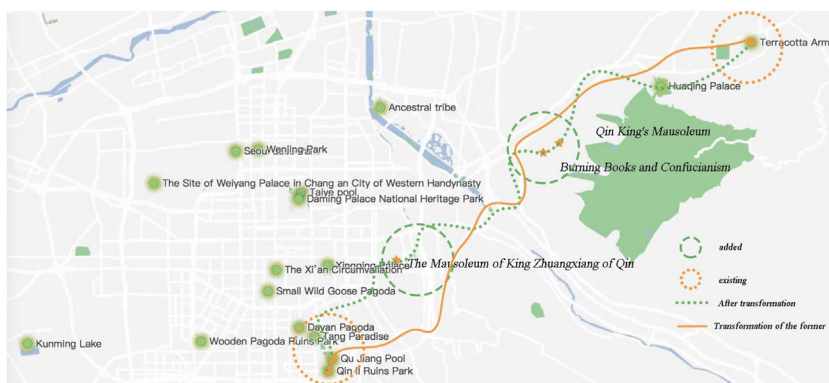


Fig. 10. Culture factor route map.

stronger. The open lawn seen after entering from the main entrance symbolizes the weak and helpless state of Qin at the beginning of the country. The two squares that have grown from small to large symbolize the development process of Qin's gradual strengthening. The cohesive water system construction symbolizes the world. The unified Great Qin Empire, the last scattered farmland symbolizes the disintegration of the Qin state after its decline (Fig. 11).

## 6. Discussion and conclusion

### 6.1. Discussion

#### 6.1.1. Construction of evaluation system

The evaluation system constructed in this study is more comprehensive and scientific, and provides profound insights for the evaluation of cultural sites. The research adopts the analysis process and evaluation methods such as frequency statistics method, theoretical analysis method, and expert consultation method to construct an evaluation system (J. Li, 2019). The research uses the Delphi-AHP method to construct a value evaluation system for intangible cultural heritage resources (Minfeng, 2017). According to the data collected by the previous questionnaire, and then analyzed it, the key evaluation indicators in its evaluation system were



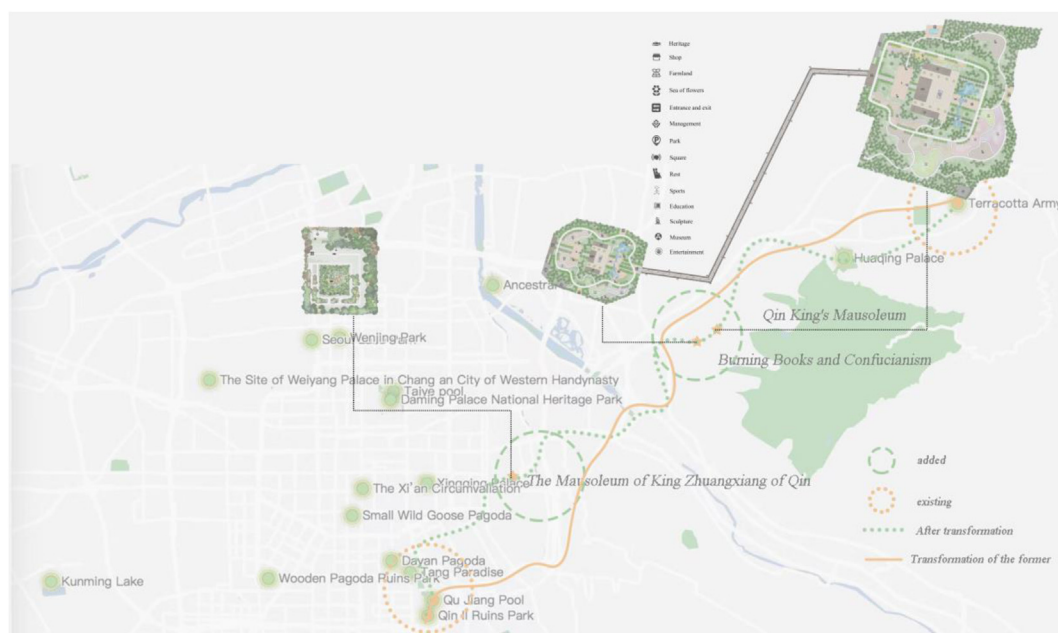


Fig. 11. Cultural route renovation design drawing.

determined (Liu et al., 2017). This study comprehensively used AHP, Delphi method and fuzzy mathematics to establish a cultural heritage tourism resource evaluation system. Based on the previous tourism big data, the evaluation system summarizes the evaluation indicators in the form of web crawlers, and uses big data to quantitatively evaluate the historical and cultural attractions of Xi'an on the meso-micro scale. The comprehensive evaluation of historical and cultural attractions will help urban managers better manage and update the city.

#### 6.1.2. Application of ant colony algorithm in path selection

In this study, principal component analysis and cluster analysis were carried out according to the evaluation results, and 17 representative historical and cultural sites were obtained, and the ant colony algorithm was used to study the tourist routes. Ant colony algorithm is robust, adaptable, easy to combine with other algorithms, and has applications in data mining and cluster analysis (Zhang, 2019). Based on the natural phenomenon that ants do not cycle infinitely when foraging, the positive and negative feedback of the ant colony algorithm can ensure the retention of effective information, and also promote the diversity of data and the utilization of various data, reflecting the authority of the ant colony algorithm sex. The previous research took “one-day tour” as an example to study the optimization of tourism traffic routes, and improved the objective function of the travel route optimization problem through ant colony algorithm and principal component analysis (Mao, 2019). This study uses ants to simulate the trajectories of tourists, and combines the preferences and characteristics of tourists to generate reasonable and personalized tourist routes. Data such as scenic distance, point passenger flow distribution, and real-time road traffic conditions are obtained through Baidu Maps, and dynamic information processing (analytical method) is used to obtain dynamic paths for users with different preferences to tourist attractions. The previous research is based on the tourism data of a travel agency, used the statistical idea of hierarchical clustering and random sampling to process the acquired data, and obtained simulation examples in other articles. For this model, a knowledge-based hybrid ant is designed (S. Li et al., 2022). Different from this study, we study the use of web crawling data and integrate the data into the database, and cooperate with the front end to enrich the overall model content. It will help optimize and upgrade the urban tourism transportation system, better promote the steady development of tourism economy, provide tourists with more travel road options and possibilities, and help urban economic construction while meeting the growing spiritual and cultural needs of people in society, producing certain social benefits.

In our study, based on the personalization of user needs, a shortest travel route selection model under the influence of different traffic and tourism-related factors (time, distance, cultural influence, etc.) is established. The terminal travel path planning of ant colony algorithm under Android platform is studied and analyzed, and an optimal guidance path planning model based on ant colony algorithm is proposed. By giving the time constraints of the tour guide path planning and the total length of the tour guide path, the objective function is solved to complete the tour guide path planning for the best group in the tourist area (Mei, 2018). Our model adds the parameter of historical culture. The travel route selection model realizes the dynamic selection scheme of the shortest travel route for visiting multiple scenic spots in different scenarios.

#### 6.1.3. Cultural path selection

The research results of cultural tourism optimization routes contribute to the sustainable development of Xi'an. The traditional travel route planning is time-consuming and labor-intensive, and the user experience is poor, which needs to be improved urgently. In the



development of smart cities, route optimization has become a growing problem in the field of transportation and logistics (Gomes et al., 2021). At present, there are many papers on tourism route optimization, but they are not comprehensive enough. One study obtained and analyzed some information about the scenic spots and the needs of tourists, as well as the tourist behavior characteristics such as the frequency of visiting and the number of tourist attractions. Based on the transmission data, they proposed the optimal tourist route with the maximum satisfaction of tourists and the shortest tour distance design (Han et al., 2014). This research relies on the application model of big data smart tourism route, combined with the personalized needs of users, develops a dynamic planning scheme, and proposes a tourism route for Qin cultural sites that tourists are more interested in. The cultural route phenomenon is mainly due to its innovative organization, which is different from the institutionalized and formalized heritage management structures adopted in the past, nor does it conform to the contemporary discourse around cultural heritage, which is one of the foundations of current sustainable development (Bogacz-Wojtanowska et al., 2019). Tourism based on cultural heritage routes is conducive to improving the level of urban tourism services, better promoting the stable development of the tourism economy, providing tourists with convenient and diverse travel options, and meeting the cultural consumption needs of different groups. Compared with previous studies, this study has more research significance for urban sustainable development.

## 6.2. Conclusion

In this study, 80 research objects with historical and cultural sites in Xi'an were used to build a historical and cultural evaluation system. Personalized travel route selection is realized according to different traffic and tourism related factors (time, distance, culture, etc.).

- (1) An evaluation system for heritage sites was constructed, and principal component analysis was performed on the evaluation values of 80 sites, and it was concluded that the most important principal component was historical factors. Through cluster analysis, three levels were obtained, and different sites were selected for each level, and 17 selected points were finally obtained. A questionnaire survey was conducted on the past tourists, and it was found that the tourists paid the most attention to the historical and cultural sites, especially the Qin culture.
- (2) Combining ant colony algorithm with TSP problem solving method, a personalized travel route selection model based on user demand is proposed. The model optimizes the shortest path between two scenic spots and the tour order of scenic spots, and realizes the shortest path selection of travel distance for visiting multiple scenic spots in different scenarios. At the same time, the cultural parameters were added to obtain the Qin cultural route.
- (3) Combed the cultural structure of xi 'an, this study through the questionnaire, the study found people for the travel line selection is still more to their own preferences, understanding of the cultural space is less, so we simulate lines on different culture through the system, on the basis of the existing increased the Qin culture line, increasing the Qin culture heritage and enrich the transmission route of Qin culture.

## CRedit authorship contribution statement

Zhang Shuangyu: Investigation, Data curation, Writing -Original draft preparation. Lin Jiayi: Survey, Resources, Visualization Charts. Feng Zhaoxin: Investigation, Visualization Charts. Wu Yang: Investigation. Zhao Qianyi: Data collation. Liu Shen: Investigation, Visualization Charts. Ren Yanshen: Investigation, data collation. Li Houhua: Conceptualization, Methodology, Writing review and editing, Supervision.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jum.2022.10.001>.

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