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Research on the Simulated Decision-Making of Spatio-Temporal Diversion Route Planning for Tourists in Heritage Sites during the Peak Tourism Seasons Based on a Case Study of Maiji Mountain

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Abstract:

With the enhancement of national cultural consciousness and protection awareness, the world heritage sites are more and more favored by the public, which brings a spurt of tourists during the tourism peak seasons, but also a great pressure and challenges to the management of heritage sites. To solve the problem of serious overload of tourists at heritage sites and unbalanced spatial and temporal distribution of tourists in scenic spots during the peak seasons, in this paper, based on the case study of Maiji Mountain, three cross-peak tour route plans were firstly selected, and simulated and tested in combination with the actual conditions during the tourism peak seasons; next, they were optimized under the evaluation criteria of tourists' satisfaction and variance of scenic spots' load rate, and the effects of each route and the overall spatial and temporal distribution were compared; and finally, the targeted management decisions were put forward. The study has practical reference value for heritage site management decision makers to realize proactive distribution management.

Keywords: *tourist diversion; route planning; heritage sites; simulation; tourism peak seasons*

I. INTRODUCTION

In recent years, holiday tourism has taken on an unprecedented upsurge.According to the statistics of the China National Tourism Administration, the number of tourists nationwide during the first "National Day Golden Week" in 1999 was 40 million, which increased to 782 million by 2019, an increase of nearly 20 times in 20 years.The huge tourist flow has brought many problems, such as difficult access to scenic spots, serious congestion, low satisfaction of tourists' experience, serious destruction of scenic resources and so on. Therefore, the regulation of tourists in scenic spots during the peak seasons has become an urgent problem to be solved[1].Popular heritage sites, under the pressure of huge tourist crowds, not only need to ensure the high-quality recreational needs of the general public, but also ensure the sustainable development of the heritage[2], which involves many factors such as resource limitations of scenic spots, unscientific management planning, uncontrollable potential safety hazards, fairness of scenic spots and so on[3]. The domestic and foreign research on tourism flow[4] and tourist management theory and model[5][6]will provide sufficient theoretical support and research breakthrough point for the regulation of tourist diversion, and make great contribution to solve the contradiction between resource protection and tourism development.The regulation and control of tourists' queue congestion in the peak tourism season has become a key core issue[7], which can be solved by the technical plan of spatio-temporal diversion[8]. Tourist diversionmanagement can be divided into static diversionat the entrance of scenic spots, dynamic diversion in scenic spots and final diversion after tourists leave scenic spots[9], whose empirical study involves many types such as scenic spots[10], tourist resorts[11], theme parks [12,13] and world heritage sites[14-15]. Various algorithms and the expansion of mathematical models can provide method guarantee for tourist diversion.Lawson realized proactive adaptive management of social capacity of national parks by means of computer simulation modeling[16]. QiuYanqing made it clear that instantaneous passenger congestion could also occur in scenic spots when the maximum capacity was not reached, and simulated it with the Promodel simulation model[17].The angle and depth of the research on the temporal and spatial distribution of scenic spots are also continuously developing, focusing on the effective management of computer technology on the tourism environment capacity of scenic spots and the alleviation of congestion.

For heritage sites, the application and expansion of the model method are not rich enough. Due to the significant difference between tourists' preference and attraction of the scenic spots themselves, the number of tourists at heritage sites in the core area far exceeds the number of tourists in the edge area[18].The problem of congestion in scenic spots and proactive predictive management are still in the exploratory stage[4], and it is impossible to evaluate and optimize the diversion effect for different management decisions. Not only the spatial distribution of tourist flow in scenic spots has not been studied much, but also the concentration, density and intensity of each scenic spot at the same time have not been deeply involved [10], an attempt was made in this paper to explore the implementable management diversion plan and management decision-making control method for proactive predictive management through the shortest route and timed Petri net models.Considering many factors such as the road condition, congestion degree, time window of the scenic spot and the orientation of tourists entering the scenic spot, the characteristics, diversity and capacity of the scenic spot were integrated into the flow of tourists. In the management of tourists, the problem of diversion was not considered from a single angle, but gradually optimized in the process of route optimization.The internal and external diversion of the area were fully combined with the management measures to guide the travel route of tourists, so as to ensure the fair access of tourists to the heritage site, ensure the satisfaction of recreation, and realize the spatial-temporal balance control of tourist flow.The proactive diversion is time-efficient, with visible and adjustable effect, which provides a large flexible space for making management decision-making set accurately, and improves the operability and adaptability of solving practical problems of tourist diversionmanagement.

II. RESEARCH AT HOME AND ABROAD

In the past two years, the research of smart tourism has taken the realization of flow control and diversion control of tourist flow as one of the key issues in its research [19].A relatively perfect intelligent management platform has been established in Jiuzhaigou and Huangshan, the famous heritage sites, respectively to solve the problem of tourist diversion during the peak seasons[20].The research on the regulation of tourist diversion has reached a consensus on the research level and research logic from theory to empirical, which is further sorted out from the four main research directions as follows.

2.1 Tourism subject-oriented related research

Since tourists become an important research object as tourism subjects, information asymmetry problems such as unknown source and uncertain time will directly cause congestion in scenic spots[21]. In scenic spots, hot spots with similar visiting routes often have higher population flow in space and have certain spatial and temporal distribution rules of tourists' activities[22,23].Therefore, most scholars have selected hot spots in the holiday or golden week of the tourist season to extract the basic tourist flow data and conducted research on the time distribution of tourist flow at the micro level to provide theoretical and methodological support for the subsequent model building[23,24].The survey of tourists' related satisfaction in heritage sites shows that factors such as less parking spaces and poor toilet environment in scenic spots will affect tourists' interest in visiting[25], but tourists' crowding is the main reason for the decline of environmental quality in scenic spots. Preservation and display quality of heritage are the most important factor affecting the overall satisfaction of tourists[26]. Wagar pointed out that overcrowding will reduce the tourist experience and personal enjoyment, and that the tourist experience is also very important when making the decision of tourist diversion plan [27].As the tourist satisfaction will directly affect the recreation decision-making, monitoring it can contribute to the research on how to improve tourist satisfaction in scenic spots under congestion[28].Visitors can also reduce congestion by monitoring scenic spots, and provide good ideas for scenic spot planning and management decisions[29]. HouZhiqiang directly suggested that the process analysis software Poisson could be introduced to realize the management goal of scenic spots by monitoring the real-time trend of tourists[30].

2.2 Tourism object-oriented related research

Alan Wagar explored the recreational carrying capacity (RCC) as early as 1960s, which indicated that there is an upper limit on the number of tourists in relevant tourist destinations, which is the maximum damage degree that can be borne by the environment of tourist destinations[27].As the tourism object, the tourism destination itself has many differences in the recreation carrying capacity, so the calculation methods such as area method, route method, bayonet method and comprehensive capacity method are widely used in the capacity calculation of various types of recreation destinations[31].Bull put forward the control of scenic spot capacity by understanding the scenic spot capacity, so as to minimize the peak of passenger flow congestion and reduce environmental damage[32]. Different types of tourist destinations have different emphases on scenic spot capacity, scenic spot visiting time and management objectives. Heritage sites are similar to scenic spots and nature reserves, whose visiting time can not be accurately obtained because of the change of people's willingness and satisfaction with recreation.Besides, due to the long distance between adjacent scenic spots, it is necessary to divert traffic management to carry tourists for vehicle routing planning decision[15].In theme parks, the decision to divert tourists is the focus of management because of the relative concentration of recreational facilities[13].The continued enthusiasm of the public at heritage sites for the sites within the spot contributes to the increased frequency and intensity of this localized congestion.

2.3 Technology realization-based related research

In recent years, a variety of big data technology, Internet of Things and GIS have been deeply integrated, becoming an important tool to collect real-time tourist location data and dynamic passenger flow information in scenic spots[33].In order to realize the spatio-temporal diversion management of tourists, a certain amount of tourism models and decision-making methods must be stored[4]. Feng Gang introduced the management entropy theory and RFID technology, and established the "spatio-temporal diversion navigation" model of Jiuzhaigou scenic spot[34].Ren Peiyu's team applied cluster analysis, operational research, system theory, mathematical models, relevant simulation software and other methods to the tourist diversion navigation during the peak seasons of Jiuzhaigou Scenic Area[9,34,35]. Besides, they also used the hierarchical cluster method to initial flow separation[9,35,36], and tried to combine static and dynamic scheduling[37], gravitational model of physics[38], route optimization problem of ant colony algorithm[39], multi-traveler problem of operational research [10]and Logit model[40] to study the regulation and control of tourist flow in scenic area based on tourists' interest preference and individual demand[41, 42]. The tools and simulation models for spatial decision-making also include AEM and MASTEC models, cellular automata and multi-Agent system hybrid models[43,44].Some domestic and foreign scholars focused on the price as a lever to adjust the congestion problem in scenic spots[45,46].Lu Wenxing proposed a real-time diversion model of timed Petri net based on the dynamic tour of tourists in scenic spots[47].In terms of algorithm design, Li Jinhua introduced the successive decision plan of preferential selection mechanism[48] and Zheng Tianxiang[13] put forward the intelligent scheduling algorithm based on the idea of "successive decision". Taiwan scholar Tsai et al. brought tourist demand into algorithm design[12].

III. GENERAL SITUATION OF THE CASE AND DATA ANALYSIS

3.1 General situation of the case

Maiji Mountain, located in the western section of the Qinling Mountains, about 20 kilometers away from Tianshui City in Gansu Province, was published as the first batch of national scenic spots by the State Council in 1982.In 2014, the "Silk Road: Road Network of Chang'an- Tianshan Corridor" jointly declared by China, Kazakhstan and Kyrgyzstan was listed as a world cultural heritage site, and thus the Maiji Mountain Grottoes have officially become a world cultural heritage site.As a popular heritage site, Maiji Mountain Grottoes are under great pressure during the tourism peak seasons, especially during the Labor Day holiday, National Day holiday and small holidays. At this time, Maiji Mountain Grottoes Scenic Area has always maintained a high number of tourists. During the "National Day Holiday" in 2014, only one scenic spot in the Maiji Mountain Grottoes received a total of 58,200 people, with the maximum number of tourists reaching 12,100 on the 4th.The huge tourist flow of the scenic spot often exceeded the maximum capacity of the plank road. Tourists had to queue up for nearly 1 hour to go up the mountain, which caused a large number of tourists to be jammed and stranded at the foot of the mountain.Tourists in the scenic spot were extremely unevenly distributed in time and space.

3.2Basic data of research questions

Maiji Mountains include the Maiji Mountain, Xianren Cliff, Shimen and Quxi.In this paper, aiming at alleviating the tourist pressure of Maiji Mountain Grottoes Heritage Site during peak hours, the regulation of tourist diversionwas studied. Through the route planning of tour bus, the reasonable diversionof tourists can be effectively promoted and the overall tourist satisfaction can be improved.The time and space scope of the study was set as the scenic area scope that can be achieved by one-day trip during the peak period of tourist holidays. Therefore, Maiji Mountain scenic area, Xianren Cliff scenic area and the main scenic spots inside were taken as the research objects. According to the *Master Plan of Maiji Mountain Scenic Area (2016-2030)*, the daily tourist capacity of Maiji Mountain Scenic Spot is set at 12,900, with a maximum daily tourist capacity of 20,000, that of Xianren Cliff Scenic Spot is set as 11,800 with a maximum daily tourist capacity of 25,000.According to the plan, under the premise of reasonable diversionand organization, the instantaneous limit capacity of Maiji Mountain Scenic Area is 5,000 person-times and that of Xianren Cliff Scenic Spot is 7,500 person-times.

3.3 Data preprocessing and preliminary exploration of problems

According to the distribution of scenic spots, the cluster and grouping from scenic spots to tourist areas are completed, forming 5 key tourist areas in the Maiji Mountain Grottoes Scenic Spot and 8 key tourist areas in the Xianren Cliff Grottoes. A large number of self-driving tourists will enter the scenic spot from Jieting where the exit of the expressway is arranged in order to prevent too many tourists from gathering at the Maiji Mountain grottoes.Therefore, the combination of Jieting as a key transportation node and the museum is also included in the itinerary to achieve a total of 14 data collection points, with the corresponding stay time shown in Table I below.

TABLEI. Detailed list of visiting time in each scenic spot

S/N	Scenic spots	Visiting time in each scenic spot (min)	S/N	Scenic spots	Visiting time in each scenic spot (min)
1	Visitor Center and Museum of Maiji Mountain Grottoes	30	8	DanxiaFenglin	30
2	Maiji Mountain Grottoes and Ruiying Temple	60	9	Xianren Cliff grottoes	60
3	Luohan Cliff grottoes	30	10	Shilian Valley	30
4	Botanical Garden	45	11	Wangjiazhuang	30
5	Xiangji Mountain	30	12	Jingtu Temple	30
6	Visitor Center and Museum of Jieting	15	13	Geological museum	30
7	Visitor Center and Museum of Xianren Cliff	15	14	Houchuan Folk Street	45

Fig. 1 shows the geographical locations of the 14 scenic spots and the road connections between them.

The basic visiting time is expressed by a time unit of 15 minutes and marked in the figure in each scenic spot.

IV. INITIAL SCREENING OF PEAK-SHIFTING ROUTES

4.1Analysis of basic problems

The screening of peak-shifting routes was analyzed and abstracted as follows: Due to the large number of scenic spots and their different geographical locations, all scenic spots in a scenic spot needed to be grouped according to their adjacent relationship and whether they can be directly connected from the actual point of view of tourist route design. In this paper, the scenic spots were classified into several tourist areas to facilitate the next analysis. In addition, because the journey, time and personal will directly affected the quality of recreation and the content of experience, and the relationship between these factors was complicated, in order to protect the grotto sites and ensure the fairness of access, the journey was converted into time to find a reasonable time sequence relationship between tourists and scenic spots, which simplified the problem[49].A planning problem considering the stay time and journey time of scenic spots was established. The goal was to visit as many scenic spots as possible, while the constraint was to limit the visiting time to six hours in one day, and eight hours or so was appropriate for the journey time.Considering the tourist flow that scenic spots can bear, there should not be too many tourists visiting the same scenic spot at the same time. Instead, the tourist routes should be arranged separately to the greatest extent, so that every scenic spot can control the tourists within its bearing capacity as much as possible, and tour routes can be designed as richly as possible.

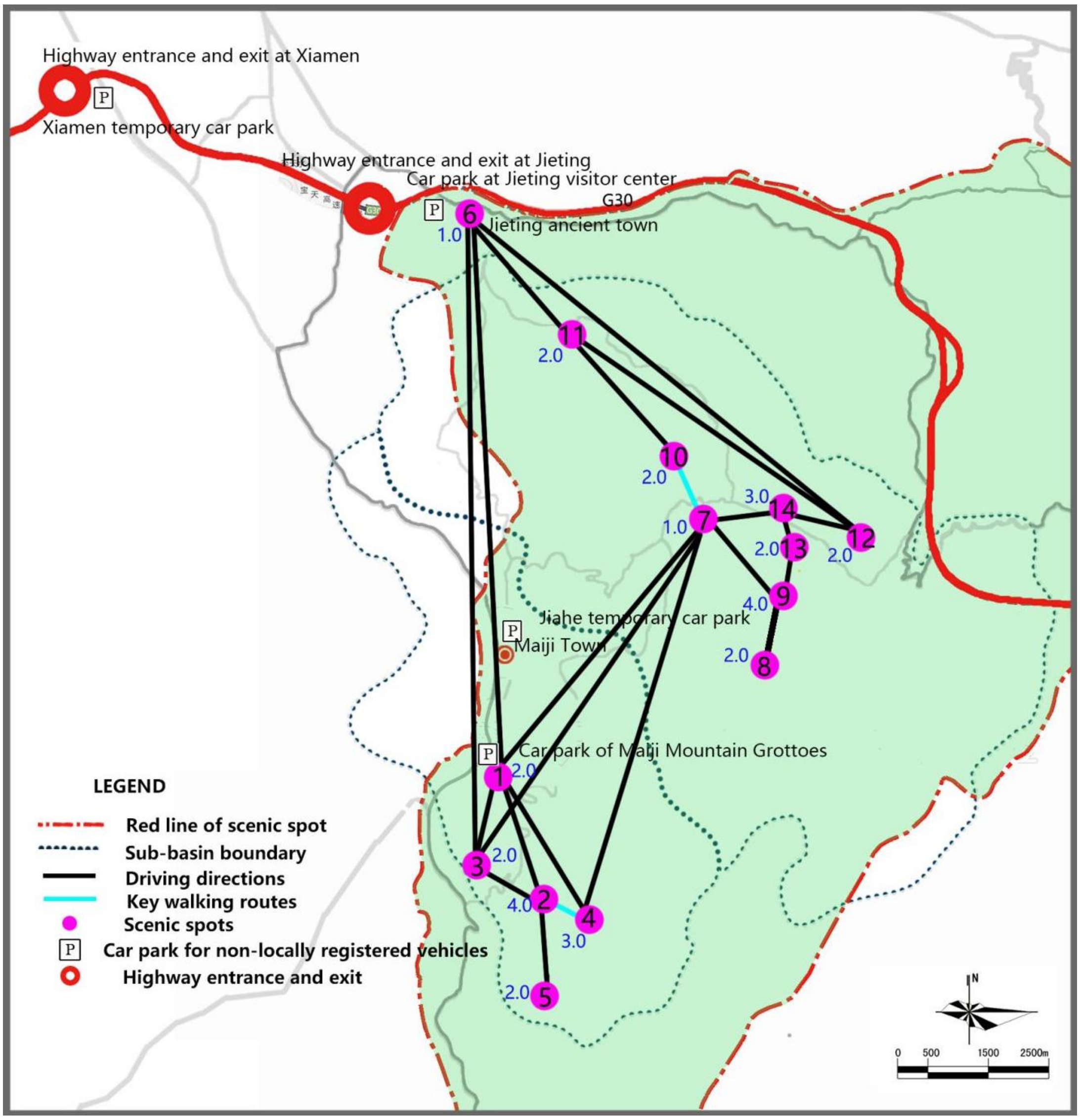


Fig. 1 Distribution of scenic spots and traffic lines

4.2Basic hypotheses

(1) The conversion from journey to time is estimated by dividing the highway mileage (km) between two scenic spots by the average speed of tourists visiting different tourist tools.The walking speed between the tourist areas is estimated at 2km/h and the vehicle speed is estimated at 25km/h;

(2) It is assumed that the time spent on the road from A to B for any two scenic spots of A and B is the same as that from B to A in the shifting of all scenic spots, that is, some differences in running time caused by different vehicle stops and uphill and downhill slopes are ignored;

(3) Assuming that the rest adjustment time in the sightseeing area or on the way to the scenic spot is merged into the sightseeing time of each scenic spot and no longer calculated separately.

4.3Modeling and solving steps

In tourism route planning, the related theories of graph theory and intelligent algorithm are usually integrated to achieve the optimal route[50].The number of tourist flows received by each scenic spot during the holiday peak seasons can be calculated based on the optimal duration of each of the 14 scenic spots.Since the reception capacity of each scenic spot varies greatly and the number of tourists received by each scenic spot at the same time is limited, it is hoped that as many tourists as possible can be arranged to visit different scenic spots at different times to stagger the peak flow of people at each scenic spot, so as to reduce the adverse effects caused by factors such as congestion and waiting, thereby improving tourists' recreational experience and increasing scenic spot management efficiency.

Therefore, the goal of modeling is to select a variety of possible tourism route options, that is, to minimize the number of scenic spots that are idle at any time, so that the two popular scenic spots of Maiji Mountain Grottos and Xianren Cliff can receive more tourists.The planning route calculated by the model not only pays attention to the factors of saving tourists' time on the road as much as possible, but also considers making the two adjacent scenic spots as close as possible.

Therefore, according to the best visiting time of each scenic spot area, 15 minutes is taken as a unit of time, and considering that part of the time spent on the way between scenic spots is not included in the tour time, the total tour time of one day is set to 6 hours first, and the time of one day is divided into 24 units. Then, each scenic spot area is divided into a plurality of sections, so that the number of units contained in each section is exactly equal to the visiting time of a group of tourists.The algorithm programmed and designed by Matlab is explained as follows:

T_j =the visiting time in the j -th scenic spot area;

t =the change of time shaft, $t \in [1,24]$;

Ar =a 14×24 matrix, indicating whether scenic spot i has been arranged to receive a certain group of tourists at any unit time j, if so $Ar_{ij} = 0$, otherwise $Ar_{ij} = 1$.

Step I

Set $t = 1$; we randomly choose an idle scenic spot A as the starting point at time 1, $Ar_{a1}, \ldots, Ar_{aT_a} = 0$, $t = t + T_a$.

Step II

List scenic spots for which reception tasks are not arranged in the next time period starting from time $t = T_a + 1$, and select the scenic spot closest to the previous scenic spot as the next visiting object, until $t > 24$ or there are no scenic spots for selection in the next time period.

Step III

Record the number of scenic spots traversed and the total time it takes. Set $t = 1$ to re-execute the first two steps until there is no initial scenic spot to choose from.

4.4Results and peak-shifting validation

Because of the randomness in the initial selection of this algorithm, the results of each run are not exactly the same.14 different routes can be obtained each time with the above algorithm, and tourists on different routes will not visit the same scenic spot at any time.Therefore, the calculation results need to be screened and optimized manually.Influenced by the popularity of Maiji Mountain Grottoes and Xianren Cliff Grottoes, tourists' preference for scenic spots will generally lead to the selection of scenic spots No.2 and No.9. Therefore, the following table lists the calculation results to screen out three of them which have a large number of satisfied scenic spots and contain scenic spots No.2 and No.9.The other 11 routes, which only include a few scenic spots, will not be considered in the planning.At the same time, because the tour route must start at the entrance of the heritage site, it is necessary to further optimize the three tour routes and finally obtain three plans for the tour route from the two service centers of Jieting and Maiji Mountain Grottoes respectively (see Table II).

TABLEII Summary of three management plans

Starting from the Maiji Mountain Grottoes service center:											
Plan A	S1	S3	S2	S1	S4	S14	S12	S13	S9	S7	S1	
Plan B	S1	S9	S13	S14	S12	S7	S2	S4	S5	S3	S1	
Starting from the Jieting service center											
Plan C	S6	S11	S10	S12	S14	S13	S9	S7	S1	S2	S5	S6

Note: The S+ number in the table is the number of scenic spots.

According to the above three tour plans, the visiting time of scenic spots and the time spent on the road are calculated respectively, and the results shown in Table III can be obtained:

TABLEIII Summary of visiting time of three route plans preliminarily selected

Unit (min)	Plan A	Plan B	Plan C
Visiting time	345	330	345
Time spent on the road	101	134	126
Total time	446	464	471

Because changing the starting point of the tour line and the tour order of scenic spots will have some influence on the planning goal of the peak-shifting tour of all scenic spots in the whole tour, it is necessary to validate the specific visiting time of each scenic spot area in each tour line to ensure the realization of the basic goal of peak-shifting tour. The validation results are shown in Tables IV-VI:

TABLEIV Validation of the peak-shifting visiting time of Plan A

Plan A	S1	S3	S2	S1	S4	S14	S12	S13	S9	S7	S1
Time to enter the scenic spot	0	15	60	123	158	228	278	318	353	416	446
Time to leave the scenic spot	0	45	120	153	203	273	308	348	413	431	446

TABLE V Validation of the peak-shifting visiting time of Plan B

Plan B	S1	S9	S13	S14	S12	S7	S2	S4	S5	S3	S1
Time to enter the scenic spot	0	18	83	118	168	208	241	309	368	419	464

Time to leave the scenic spot	0	78	113	163	198	223	301	354	398	449	464

TABLEVI Validation of the peak-shifting visiting time of Plan C

Plan C	S6	S11	S10	S12	S14	S13	S9	S7	S1	S2	S5	S6
Time to enter the scenic spot	0	8	48	90	125	175	210	273	303	336	402	471
Time to leave the scenic spot	0	38	78	120	170	205	270	288	333	396	432	471

The calculation and validation show that all the scenic spots on the three tour routes have basically achieved the peak-shifting visiting.

V. SIMULATION EXPERIMENT AND ROUTE OPTIMIZATION

The above three routes are the peak-shifting touring route arrangement for each scenic spot in the heritage site under ideal conditions. However, the tourists' satisfaction and the load of each scenic spot corresponding to each time node are unknown, and the matching amount of tourists transported from each route to the scenic spot is also unclear.In particular, it is still unclear whether popular heritage sites will cause local congestion, and the actual effect of tourist diversioncannot be verified.In order to verify the actual peak-shifting effect of the three routes of tourist diversionin the early stage and flow stabilization in the middle stage, it is necessary to further clarify the attraction of scenic spots, the satisfaction of tourists and the number of tourists allowed to be transported on each route. In this paper, a simulation experiment on the management strategy of tourist diversioncan be implemented through timed Petri net model.

5.1 Construction of Petri net model

Referring to timed Petri net method proposed by Lu Wenxing et al., it is applied to the initial diversionof scenic spots instead of steady diversion[47].Initial diversion refers to the separation of different tourist routes before entering the scenic spots. Its advantage is that the tourist routes are fixed, which is conducive to the management of the scenic spots, and important scenic spots will not be missed due to the long waiting time.The mathematical model involved in Petri net in this paper is defined as follows:

The load rate of the tourists at the i-th scenic spot at time j on each selected route is calculated as follows:

$$l_{ij} = \frac{m_{ij}}{M_i}$$

Where,

m_{ij} =the number of tourists at the i-th scenic spot at time j;

M_i = the maximum tourist capacity of the i-th scenic spot.

The empty-loading ratio is calculated as follows,

$$e_{ij} = 1 - l_{ij}$$

Thus, the average load rate L_j, variance of load rate E_{ij} and tourist satisfaction s_{ij} are defined as

$$L_j = \sum_i w_i l_{ij}$$

$$E_{ij} = (l_{ij} - L_j)^2$$

$$s_{ij} = \alpha e_{ij} m_{ij} w_i$$

Where,

w_i indicates the current weight of the i-th scenic spot, indicating the popularity of scenic spots and the preference of tourists, and $\sum_i w_i = 1$, α is the proportionality coefficient, which is usually a positive number greater than 0.

The objective of the scenic spot management operators is to reduce the load rate variance of the selected lines while improving the tourists' satisfaction. Therefore, the objective function of the model can be expressed as follows:

$$z_1 = \sum_i s_{ij}$$

$$z_2 = \sum_i E_{ij}$$

Where,

z_1 =the sum of tourist satisfaction of all scenic spots on the route at a certain moment, and a larger number indicates a higher satisfaction by tourists on the route;

z_2 =the sum of variance of load rate of all scenic spots on the route at a certain moment, and a smaller number indicates a more balanced tourist distribution on the route.

5.2 Simulation results of different routes

In the natural state, tourists choose scenic spots randomly, which will lead to the constant change of load rate and satisfaction of scenic spots.Especially during peak periods, congestion and waiting at famous heritage sites can result in low tourist satisfaction.In order to better verify the effectiveness and applicability of the initial state diversionof the time-constrained Petri net model, in this paper, the simulation is used to analyze and the virtual clock is used to simulate the process of tourists' flow and visiting in the scenic spots through the change of time.

As shown by the total length of the three routes, the maximum visiting time is 471 minutes and the minimum is 446 minutes. Therefore, the virtual clock length in the simulation is determined to be 500 minutes and the step length is 1 minute. In addition, the parameters that need to be input in advance for simulation include: (1) average visiting time and maximum tourist capacity of tourists of each scenic spot on each route; (2) the weight of each scenic spot and the time distance between upstream and downstream scenic spots; (3) the speed (person/minute) of tourists entering the scenic spot during the simulation period; (4) the initial state of the scenic spot; (5) mathematical parameters. See Table VII to Table IX for details.

TABLEVII Parameters of each scenic spot of Route A

Name of scenic spot	S3	S2	S1	S4	S14	S12	S13	S9	S7
Capacity/person	1250	3000	2000	1100	2200	1300	1500	1800	1500
Visiting time/min	30	60	30	45	45	30	30	60	15
Weight	0.1	0.25	0.05	0.1	0.1	0.1	0.1	0.15	0.05

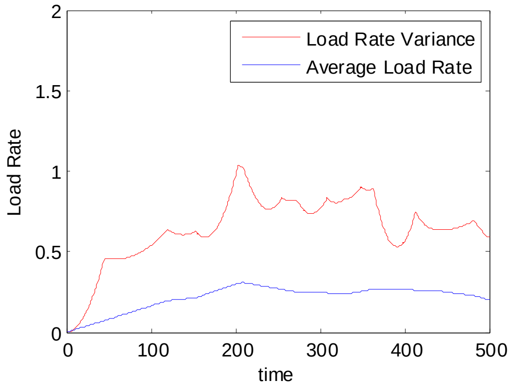
TABLE VIII Parameters of each scenic spot of Route B

Name of scenic spot	S9	S13	S14	S12	S7	S2	S4	S5	S3
Capacity/person	1800	1500	2200	1300	1500	3000	1100	1200	1250
Visiting time/min	60	30	45	30	15	60	45	30	30
Weight	0.15	0.1	0.1	0.1	0.05	0.25	0.1	0.05	0.1

TABLEIX Parameters of each scenic spot of Route C

Name of scenic spot	S11	S10	S12	S14	S13	S9	S7	S1	S2	S5
Capacity/person	2000	1300	1300	2200	1500	1800	1500	2000	3000	1200
Visiting time/min	30	30	30	45	30	60	15	30	60	30
Weight	0.05	0.1	0.1	0.1	0.1	0.15	0.05	0.05	0.25	0.05

The time distance between the upstream and downstream scenic spots on route A is f=[15, 3, 5, 25, 5, 10, 5, 3], that on route B is f=[5, 5, 5, 10, 18, 8, 14, 21], and that on route C is f = [10, 12, 5, 5, 5, 3, 25, 3, 6]. It is assumed that the tourists on each route only enter the scenic spot in the first 3.5 hours at the speed of $g_0 = 20$ person /min. For the convenience of calculation, $\alpha = 1$, the initial number of tourists in each scenic spot is zero.As the spatial-temporal distribution of the number of tourists in each scenic spot, the load rate of each scenic spot and the management entropy value of the spatial-temporal distribution system of scenic spots will change with time[51], in order to verify whether the route planning can effectively alleviate the local congestion of tourists in scenic spots, balance the spatial-temporal distribution of tourists and synchronously realize the environmental protection of scenic spots and the improvement of tourists' satisfaction, the parameters selected in the simulation output include: the average load rate of all scenic spots on the simulated route at each moment, the variance of load rate and the sum of tourists' satisfaction in each scenic spot (note: for ease of comparison, the satisfaction shown in Figs. 2- 7 is one-tenth of the actual satisfaction).



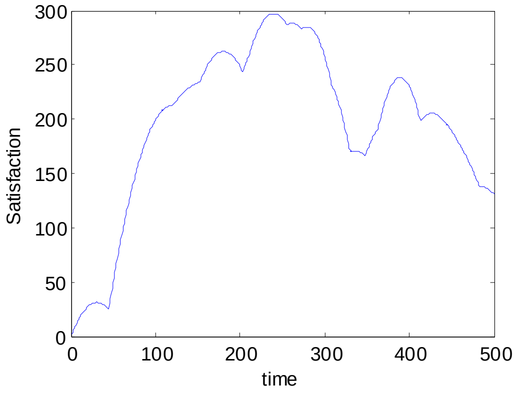
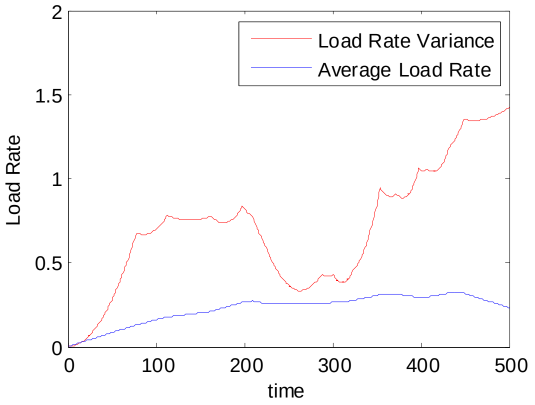


Fig. 2a Change in load rate of Route A **Fig. 2b Change in tourist satisfaction of Route A**

Fig. 2Change in load rate and of tourist satisfaction Route A



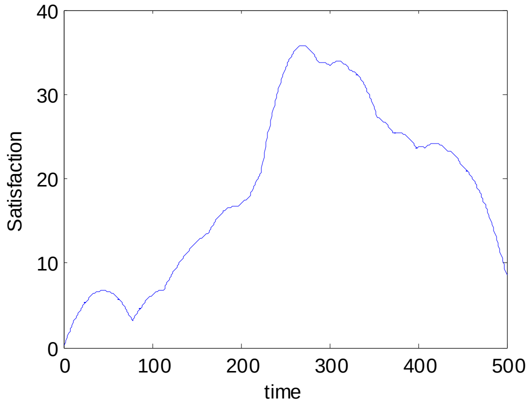
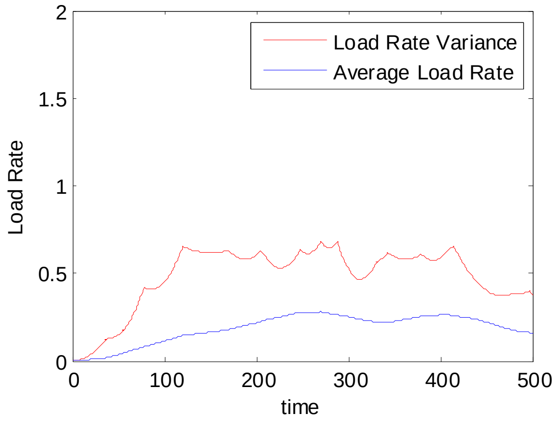


Fig. 3a Change in load rate of Route B **Fig. 3b Change in tourist satisfaction of Route B**

Fig. 3 Change in load rate and of tourist satisfaction Route B



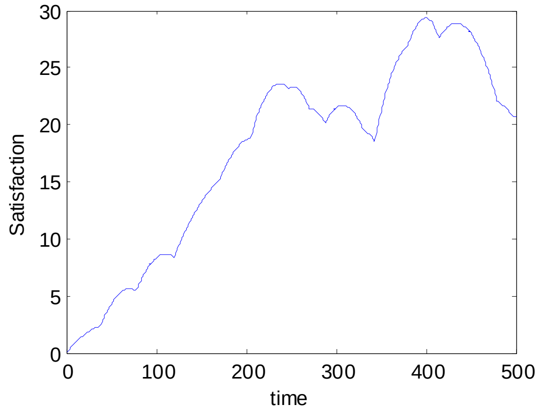


Fig. 4a Change in load rate of Route C **Fig. 4b Change in tourist satisfaction of Route C**

Fig. 4 Change in load rate and of tourist satisfaction Route C

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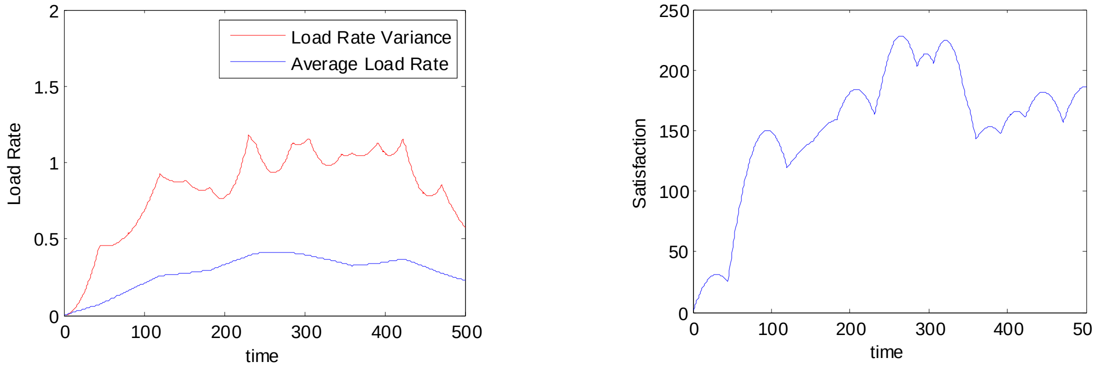

Fig. 5a Change in load rate of Route A after optimization

Fig. 5b Change in tourist satisfaction of Route A after optimization

Fig. 5 Change in load rate and of tourist satisfaction Route Aafter optimization

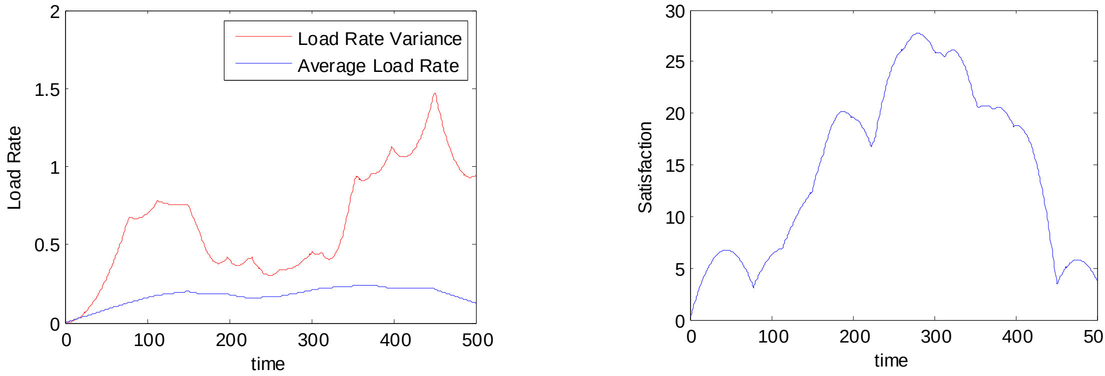

Fig. 6a Change in load rate of Route B after optimization

Fig. 6b Change in tourist satisfaction of Route B after optimization

Fig. 6 Change in load rate and of tourist satisfaction Route B after optimization

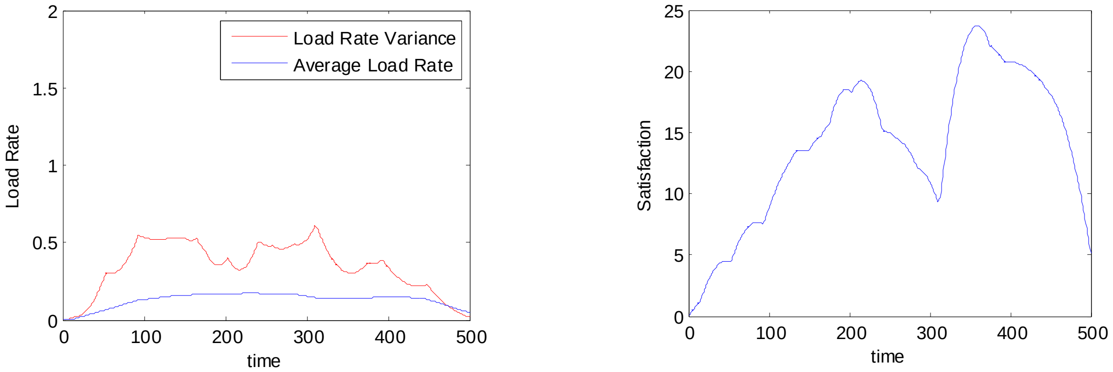

Fig. 7a Change in load rate of Route C after optimization

Fig. 7b Change in tourist satisfaction of Route C after optimization

Fig. 7 Change in load rate and of tourist satisfaction Route C after optimization

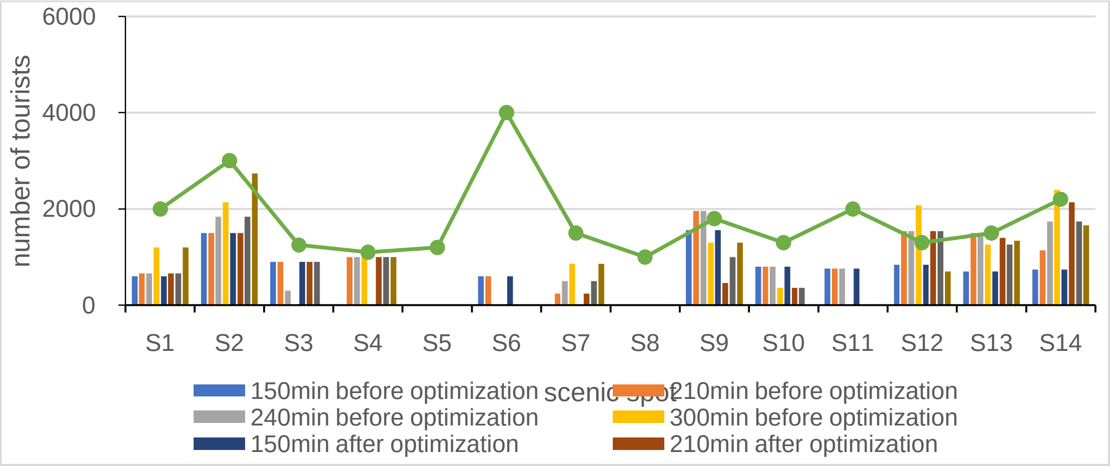

Fig. 8 A comparison of the number of tourists at different times in each scenic spot before and after optimization

5.3 Analysis of simulation result

In the simulation of this paper, it is assumed that there are no tourists in the scenic spot at 0 o'clock, and then people enter at the speed of 20 people per minute for 3.5 hours.Since the load rate and satisfaction are related to the number of tourists in each scenic spot, the starting point is at 0 o'clock.

As shown in Figs. 2a-4a, the load rate variance of Route A and Route C rose from 0 and then fluctuated slightly around 0.5, then rose slightly at about 200 minutes, reached the highest point, then dropped at about 0.5, while that of Route B rose from 0 to between 0.5 and 1, and then rose slightly to close to 1.5;the average load rate was basically stable.As shown in Figs. 2b–4b, the satisfaction of the three routes rose rapidly from 0, and then declined gradually after reaching the peak with a fluctuation. Compared with the other lines, the satisfaction of Route B declined faster.

On the whole, Figs. 2-4 show that each scenic spot in each route failed to reach the maximum capacity, and the satisfaction increased with the passage of time, and then gradually decreased with the end of tourists' visit.Except for Route B, the variance of the load rates of the other two routes changed steadily, and both were around 0.5, which indicates that the expectation of a balanced distribution of tourists in time and space was basically achieved.

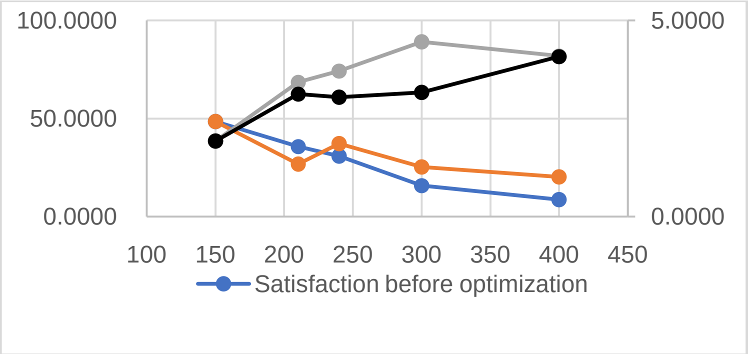

Fig. 9 Comparison of total satisfaction and total load variance before and after optimization

5.4 Route optimization

At the beginning, tourists were supposed to enter from three routes at the same time, and the bus departure frequency was 20 people /min. The results showed that the vacancy rate of Route A, especially heritage site S2, was high and the variance performance was poor in the earlier period, which was inconsistent with the actual peak period. In order to achieve a better balance of time and space, the route was optimized and adjusted in the simulation stage.

Route A as the main line was the preferred route for tourists. The adjustment plan for Route A is to remove scenic spot 4 that is prone to congestion, add scenic spot 8, and then switch the order of scenic spots 7, 8 and 9 with scenic spots 14, 12 and 13, and increase the entry time, which is more consistent with the actual peak days of scenic spots.Therefore, in the optimization, the entry time was increased from 3.5 hours to 4 hours to increase the tourist transportation volume of Route A, which can better solve the problem of high vacancy rate in the early stage of the grotto heritage sites. However, in order to balance the total number of tourists, the entry time of the auxiliary Route B and Route C was reduced to 2.5 hours, and in order to reduce the congestion of the tourists in the scenic spot 14, the scenic spots 14 in the Route C were removed and the scenic spot 6 was added, which can not only improve the congestion of the scenic spot 14, but also reduce the total time of the route. The results are shown in Figs. 5 to 7.With reference to Figs. 2-4, there was little change in satisfaction before and after the optimization of the three routes, although the variance of load rate after the optimization of Route A was slightly larger, and that of Route B and Route C was significantly smaller than that before the optimization, indicating that the spatial and temporal distribution of tourists entering each scenic spot was more balanced. The previous analysis is based on a single route, but it is more important to look at the peak-shifting effect caused by the simultaneous opening of the three routes on the peak travel day for scenic spots.Therefore, the number of tourists of each scenic spot of the three routes at the same time was superimposed, and four time points before and after optimization were selected for comparison. The comparison results are shown in Fig. 8.The four key time points of 150 minutes, 210 minutes, 240 minutes and 300 minutes were selected respectively according to the following bases: the entering time of each route before and after optimization, i.e., the time when the total number of tourists in the scenic spot reached its maximum, and the time when the peak time basically passed from 8:00 a.m. when the scenic spot was opened to 1:00 p.m.. After addition and comparison, Fig. 8 show that before optimization, the total number of tourists exceeded the maximum capacity at scenic spot 9, scenic spot 12 and scenic spot 14 at a certain time, among which scenic spot 9, namely Xianren Cliff Grottoes, is an important scenic spot and a must-see place, which is a key scenic spot for peak-shifting tourism and management regulation.Therefore, although there was still a small number of overcrowding in the scenic spot 12 after optimization, scenic spots 9 and 14 were obviously optimized without excess capacity.On the other hand, the total satisfaction and total load factor variance of each scenic spot at the above time points were calculated, and the results are shown in Fig. 9. It is shown in the figure that the satisfaction after optimization was higher than that before optimization except for that at 210 minutes, and the load rate variance after optimization was significantly smaller than that before optimization.To sum up, the optimization goal of planning route has been basically achieved. The final optimized route is shown in Table X:

TABLE X Summary of optimized three routes and management plans

Starting from the Maiji Mountain Grottoes service center												Entry duration
Plan A	S1	S3	S2	S1	S7	S8	S9	S13	S14	S12	S1	4 hours
Plan B	S1	S9	S13	S14	S12	S7	S2	S4	S5	S3	S1	2.5 hours
Starting from Jieting service center												
Plan C	S6	S11	S10	S12	S13	S9	S7	S1	S2	S5	S6	2.5 hours

Note: The S+ number in the table is the number of scenic spots.

VI. CONCLUSIONS AND DECISION SETS

6.1Conclusions

(1) The influence of attraction of scenic spots should be fully considered in the diversionnavitation of tourists around heritage sites.It is also important for popular scenic spots with large differences in attraction between internal scenic spots. It is necessary to try to open the space sightseeing framework and give consideration to tourists' satisfaction so as to meet the fairness of tourists visiting the heritage sites.In the algorithm of tourist diversion technology, many factors, such as the actual situation, the degree of congestion, the time window and the orientation of tourists entering scenic spots, are taken into account to solve the problem of tourists' convergence in route selection.

(2) In the tourist diversion management, the separation outside the area should be fully combined with the steady flow and separation in the area.The process of route optimization is carried out step by step, and the management decision is to guide the tourists' traveling route in depth, so as to ensure that tourists can enter the heritage site fairly, ensure the satisfaction of recreation, and realize the relative balance of the space allocation of tourists in each scenic spot during the peak seasons, which is reflected in the load rate variance curve of scenic spots and the overall satisfaction degree of tourists at any time on each line.

(3) The diversion effect should be more effective, visible and adjustable, providing great flexibility for making management decisions.Through the simulation experiments in different situations of management decision-making, the problems exposed by different scenic spots can be responded to the maximum extent, which fully proves that this method can be an effective tool to realize the diversionand proactive management of tourists.

(4) There are several existing problems and areas to be optimized, such as the control of visiting time. As the way to enter the scenic spot is in sequence according to time, for those who start sightseeing two hours later, if they complete the tour according to the tour route plan, the time to leave the scenic spot will be delayed for two hours.However, in reality, tourists will choose attractive scenic spots to complete the tour before the scenic spots are closed.As a result, this part of people's willingness of recreation behavior is not fully reflected.In addition, the setting of the time period for entering the scenic spot in the model is mainly aimed at the problem of crowd separation during the peak holiday hours. In fact, a small number of

tourists will enter the scenic spot at the later time points, which are not taken into account.

6.2 Decision sets of tourist diversion management

The management and regulation of tourists' peak shifting can not only be solved through the setting of three tour route plans, but also be combined with the actual situation of scenic spots to support a series of management measures to achieve the proactive management goal of scenic spots. The specific management measures are as follows:

(1) Effective diversionof scenic spots periphery can be realized through different entrance management decisions.The three-level car parks can be fully used to organize tourists. For example, self-driving tourists who choose to take Route B can make online reservations with priority to the first-level and second-level car parks which include the 50 car parking spaces in the Grotto Service Center and the 200 car parking spaces in Jiahe.According to the order of arrival, the self-driving tourists will be shown and informed directly on the electronic screen at the periphery of Xiamen. Before the capacity of the parking lot at Jieting is exceeded, they will be prompted to stop at the Xiamen high-speed exit and enter the three-level temporary parking lot. A total of 4,000 parking spaces will be planned.Different tour routes are suitable for tourists from different places. It is the key to fully consider the information of tourists, and it is best to make an appointment to determine the time of entering the scenic spot when choosing a suitable tour route.

(2) For the planning of three tourist routes on the peak day, in order to ensure the efficiency of tourist transportation, special tourist bus lines with specific scenic spots should be added to guide tourists reasonably due to the long duration of the whole day.It is proposed to add five special lines between scenic spots, such as Luohan Cliff Tourist Area-Xianren Cliff Scenic Area Service Center.

(3)The peak operation time of tourists at heritage sites is from 9: 40 a.m. to 11: 40 a.m., during which time the dispatching of tour buses on Route A should be strengthened.In addition, due to the limitation of parking space near the heritage site, it is necessary to consider direct transportation of tourists from Jieting entrance 6 to the Grottoes 1 entrance, so as to ensure the smooth development of the tour of Route A, especially to ensure that the more appropriate instantaneous capacity of the grotto heritage site is about 2,000 people, which is the key to realize the peak-shifting tour of the heritage site for all tourists on each route without crowding or waiting.

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