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T1 ________	201850	F1 ________
T2 ________	Problem Chosen	F2 ________
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T4 ________		F4 ________

2018

MCM/ICM

Summary Sheet

Research on Optimal Self-help Tour Based on Object Programming Model

With economic development and social progress, self-help travel has become more and more popular consumer items. Reasonable arrangements for self-tour not only save time and effort, but also can greatly reduce the cost of tourism. This article is based on the goal programming model for the best self-help travel research.

Question 1.1, design a travel plan to visit all attractions at a minimum cost. Firstly, the ticket fee is constant, so we only need to set up the single-objective programming model with the lowest transportation cost and accommodation cost. It is known from the characteristics of the problem that it is a special **traveling salesman problem** (TSP). Therefore, we adopt the **ant colony algorithm** specially modified for this problem to solve the shortest path measured by fare. In the end, we got a minimum travel cost of 2143 yuan for 5 days.(See details in Figure 4)

Question 1.2, for the case of not changing the hotel, the above models and algorithms are still available. We finally find the minimum travel cost of 2144 yuan for four nights at H027.

Question 1.3, we found that the number of days can no longer be shortened in the above program by calculating, so saving time will not help reduce the total cost. In addition, if the express way is used, transportation costs will rise significantly, so do not consider express way.

Question 2, according to the preferences of tourists to develop a three-day optimal travel program. We define the **satisfaction index** β to measure the tourists' interest in the program and make a comprehensive evaluation of the optimal travel program in combination with the cost. Therefore, we set up a multi-objective programming model with the lowest cost and the highest satisfaction index. Through the ant colony algorithm and the greedy algorithm, tourists are provided with 9 attractions, satisfaction index of 21, cost of 1293 yuan luxury tours and 8 attractions, satisfaction index of 19, cost of 1110 yuan economic tour. When the economic travel satisfaction index is only 7% lower than luxury travel, but the cost has dropped 14.2%. Therefore, for the budget tourists, economic travel is a better choice.

Question 3, on the basis of Question 2, consider the influence of the number of tourists on the time required for sightseeing and discuss the best three-day travel plan. First of all, based on the model of Problem 2, we set up a **floating factor** μ for visiting time $\mu \in (1,1.5)$. Through the MATLAB programming, we found that the program affected by the tourists varies widely. When the largest number of tourists (μ = 1.5), the satisfaction index of economic travel fell 31.5% lower than luxury, the cost decreased only 29.3%. So for tourists with better economic conditions, luxury travel is cost-effective.

Key words: programming model   Traveling salesman problem(TSP)   Ant Colony Algorithm

Contents

1. Introduction

1.1 Background

In recent years, with the rapid development of economy and the increasingly developed traffic, traveling is no longer the dream of people. Traditional team travel is gradually replaced by new self-help travel, which is being accepted and practiced by people of all ages. The charm of self-help travel lies in being able to fully choose and arrange tourism activities, there is plenty of tourist space for tourists to play for themselves.

Different from the traditional team travel, tour guides do not accompany the whole tour. Therefore, tourists need to consider their own travel programs. A practical travel program needs to consider factors such as transportation options, hotel selection, traveler's physical strength, attractions opening hours, travel route design and costs. A good travel plan will undoubtedly give travelers more enjoyment of the traveling process, avoiding unnecessary troubles and waste of time and money. Therefore, it is particularly important to plan a relatively practical and reasonable travel plan before traveling self-help.

1.2 Previous Research

So far, people have studied all aspects of travel planning. Travel Planning Past research topics are broadly divided into travel route design, self-help travel, self-help travel preparation, transport options, hotel arrangements and other issues, the vast majority of people have studied the issue of travel routes.

In literature [1], based on the known distance between the scenic spots in Dalian, a linear programming model can be established in Excel to find the shortest distance of the route, which can then be extended to the route planning of tourist attractions in different cities. Literature [2] proposed two improvements of ant colony algorithm: the algorithm of adventurous and the new proposal of path. The main purpose is to make the ant colony algorithm can meet the travel route planning problem well. Among them, the dynamic planning of the route can effectively realize the load balancing of tourist attractions and guide the tourists to the current small tourist attractions. On the basis of discussing the diversity of vehicles and fares in literature [3], authors established the simulated annealing algorithm to find out the straight-line distance between cities and find the shortest point to go back to the starting point after passing through provincial capitals, municipalities and other cities Route, and combined consideration of saving time and convenience as well as the beginning and end of the means of transport. In [4], Hopfield neural network is introduced to transform the coordinates of tourist attractions to calculate the best route for tourist attractions, so that tourists can visit more attractions as far as possible according to personal conditions within a limited time.

These studies have their own strengths, most of which focus on the shortest route planning issues existing tourist attractions. However, these studies did not solve the problem of comprehensive consideration of the route, route cost, tourists physical strength and hotel preferences. Therefore, we consider the above issues synthetically. With the support of technology and theory, we set up the goal planning model to determine the shortest time, the least cost, the tourist route and the choice of the hotel for tourists to visit all the scenic spots of a city. This model is more conducive to travelers on their journey control.

1.3 Our work

Question 1.1, we set up the single-objective programming model with the lowest transportation cost and accommodation cost. Then, we adopt the ant colony algorithm specially modified for this problem to solve the shortest path measured by fare.

Question 1.2, the above models and algorithms are still available. We solved the problem using above models and algorithms.

Question 1.3, we found that the number of days can no longer be shortened in the above program by calculating, saving time will not help reduce the total cost. so do not consider express way.

Question 2, we set up a multi-objective programming model with the lowest cost and the highest satisfaction index. Through the ant colony algorithm and the greedy algorithm, we solved the problem and found the result.

Question 3, based on the model of Problem 2, we set up a floating factor μ for visiting time $\mu \in$ (1, 1.5). Through the MATLAB programming, we found that the program affected by the tourists varies widely.

2. Assumptions and Justification

Assumption 1: Assuming that tourists take the bus in an ideal traffic condition, all buses are in normal operation, regardless of traffic congestion.

- **Reason:** This paper mainly lies in the normal line of the case, the optimal travel program modeling, considering the extreme case of the model is not meaningful, so this article will not be considered

Assumption 2: Assuming all the normal business attractions, no adjustment, decoration and other normal business impact.

- **Reason:** Under normal circumstances, all attractions are operating normally, not only in exceptional circumstances, this article considers the usual state, the model is more universal adaptability.

Assumption 2: Assuming that the weather is normal during the tourist tour, visitors can travel normally without regard to the effects of extreme weather conditions.

- **Reason:** Most tourists choose to travel time to see the weather forecast in advance, under normal circumstances will not choose to travel when there are extreme weather conditions, so assume that tourists can normally visit all the scenic spots.

3. Symbols and Definitions

In the section, we use some symbols for constructing the model as follows:

Symbol	Symbol description
F	Total cost of travel

f_a	Ticket fee
f_t	Transportation fee
f_c	Accommodation fee
m_i	The number of attractions arranged on the i-th day
β	Satisfaction index
d	The minimum number of days

P.s. Other symbols instructions will be given in the text

4. Our solutions

4.1 Solution for task one

4.1.1 Problem analysis

Problem 1, according to the conditions of the project, we were supposed to calculate the minimum cost of visiting all the attractions and the corresponding journey planning. Due to the total cost of the ***journey = ticket costs + ride costs + accommodation costs***, and ticket fees are fixed, so only need to optimize ride and accommodation costs. From the optimal ride and lodging model, we know that it is a TSP traveling salesman problem. So, first, the shortest fare reachability matrix between attractions, attractions and hotels is calculated. Then the problem is turned into a problem solving a shortest path. This route passes through 14 scenic spots during which visitors need to return to the hotel if their physical stamina or time is exhausted. Therefore, an improved ant colony algorithm is used to solve the shortest path.

4.1.2 Model establishment

Visit all the attractions, calculate the minimum cost and the minimum number of days. This problem is a single goal planning problem because the less the total cost is, the fewer the number of days is.

(1). determine the objective function

The total cost of travel F by the total cost of attractions tickets f_a , total cost of accommodation f_c and the total cost of transportation f_t composition. Plan a reasonable travel plan to minimize the total cost. The target function is:

$$\min F = f_a + f_t + f_c \tag{1}$$

(2). determine the constraints

● The i-th attraction's ticket cost is v_i , because the travel process involves all the attractions, the total travel ticket costs:

$$f_a = \sum_{i=1}^{14} v_i \tag{2}$$

● Tour all the attractions, at the lowest total cost, tour days d , each day cost of accommodation recorded as c_i , the total cost of accommodation available is:

$$f_c = \sum_{i=1}^{d-1} c_i \tag{3}$$

● The i-th attraction to the next attractions required transport costs b_i, the i-th day travel costs from the corresponding hotel to attractions h_i, back to the hotel $h_i^{'}$, so the total transport costs:

$$f_t = \sum_{i=1}^{13} b_i + \sum_{i=1}^{d} (h_i + h_i^{'}) \tag{4}$$

● a_{ij} =1 means that the j-th attraction will be visited on the i-th day, and a_{ij} =0 means not to visit. C_i represents the set of attractions that will be visited on the i-th day, so the following expressions are available:

$$C_i = \{\mathrm{a}_{ij} : \mathrm{a}_{ij} = 1, 0 < j < 15\}\ i, j \in N^* and\ 0 < i < 7 \tag{5}$$

● Due to one and only one visit per attraction, the total number of days for the tour is d . we can get the following constraints:

$$C_1 \cap C_2 \cap ... \cap C_d = \varnothing \ \ and \ \sum_{i=1}^{d} \sum_{j=1}^{14} a_{ij} = 14 \tag{6}$$

● The number of spots arranged on the i-th day is m_i, where the tour time required for the j-th attraction is t_{ij} and the required physical value is e_{ij} . The conditions given by the problem shows the attractions open daily for about 8 hours. Assume that the daily browsing time is 8 hours, and assume that the physical value of the visitor is 1 at the beginning of each day. The following constraints can be obtained:

$$\sum_{i=1}^{d} (\sum_{j=1}^{m_j} a_{ij} t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{d} (\sum_{j=1}^{m_j} a_{ij} e_{ij} \le 1) \tag{7}$$

(3). Tour all the scenic minimum cost model

$$\min F = f_a + f_t + f_c$$

$$s.t\begin{cases} f_a = \sum_{i=1}^{14} v_i \\ f_c = \sum_{i=1}^{d-1} c_i \\ f_t = \sum_{i=1}^{13} b_i + \sum_{i=1}^{d}(h_i + h_i^{'}) \\ \sum_{i=1}^{d}(\sum_{j=1}^{m_j} a_{ij}t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{d}(\sum_{j=1}^{m_j} a_{ij}e_{ij} \le 1) \\ C_1 \cap C_2 \cap \ldots \cap C_d = \varnothing \ \ and \ \sum_{i=1}^{d}\sum_{j=1}^{14} a_{ij} = 14 \\ C_i = \{\mathrm{a}_{ij} : \mathrm{a}_{ij} = 1, 0 < j < 15\} \ i, j \in N^{*} and \ 0 < i < 7 \end{cases} \tag{8}$$

4.1.3 Model solution and result analysis (question a)

(1). Ant Colony Algorithm Based on TSP Problem

In the context of the user experience, we first calculate the minimum fare path of each attraction to the other 13 attractions within two transfers, and construct the full map with the fare between the vertices as follows.

V001	V001												
V002	4	V002											
V003	8	5	V003										
V004	5	2	6	V004									
V005	4	2	6	2	V005								
V006	5	2	6	3	2	V006							
V007	4	1	5	2	2	2	V007						
V008	5	2	5	3	2	1	2	V008					
V009	5	1	5	2	2	3	2	3	V009				
V010	6	3	4	4	4	4	3	3	4	V010			
V011	4	2	6	2	1	3	2	3	2	4	V011		
V012	6	3	5	3	3	3	2	2	4	3	3	V012	
V013	4	1	5	2	2	2	2	2	2	3	2	3	V013
V014	4	1	6	2	2	2	2	2	3	4	2	3	1

Direct

Transfer once

Transfer twice

Figure 1 Shortest distance

And then use ant colony algorithm, take a certain number of ants, let them choose a scenic spot as a starting point, and then through pheromone update and other operations, calculate the cost of all the ants in the completion of their own choice of path, and finally, after many iterations, find The optimal solution to the TSP problem for all attractions. Ant colony algorithm improvements are as follows:

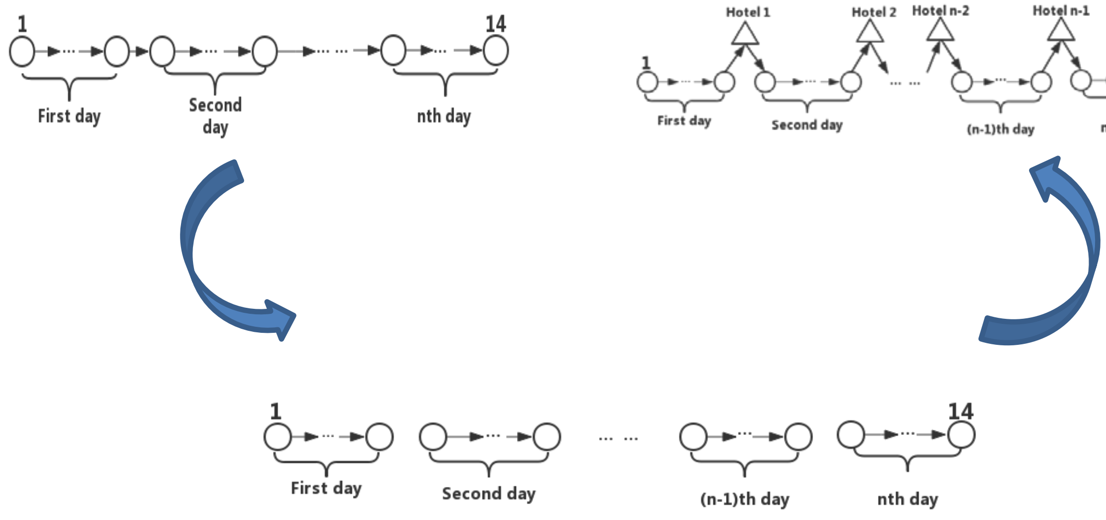

Figure 2 Improvement process of optimize goal

(2). Algorithm steps

STEP 1: Initialization, the first greedy algorithm to calculate, find all the attractions a_i and a number of hotels get a lower fare path L_0.

STEP 2 : Choose an initial a_i for each ant at random, and then use the roulette method to select the next attraction a_i + 1, and so on, until all the ants finish a path that includes all the attractions.

STEP 3 : The pheromone is updated to calculate the length of the path taken by each ant and update the pheromone on each edge.

STEP 4 : If the required conditions are satisfied, the global optimal solution is output and the procedure ends. Otherwise, ***STEP 2*** is continued.

(3). Algorithm results

Using MATLAB program, initialize 20 ants, iterate 200 times as follows:

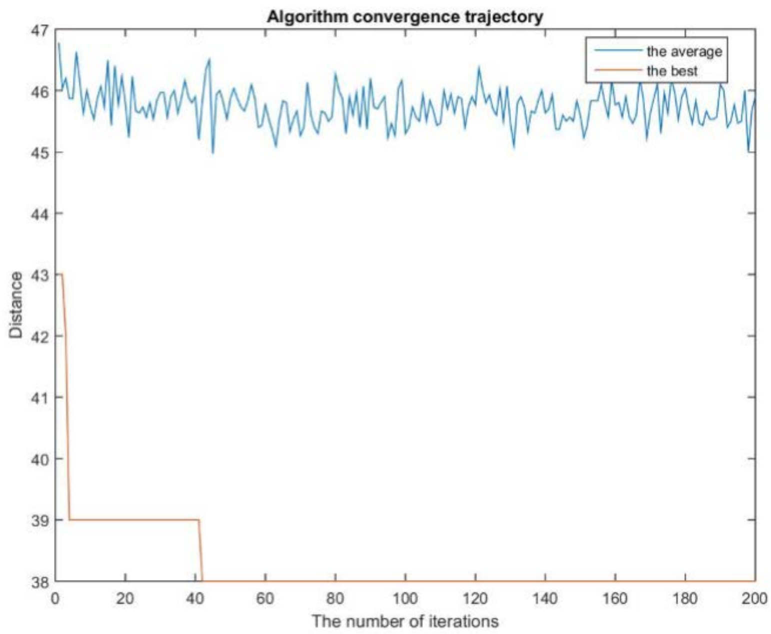

Figure 3 Algorithm convergence trajectory

It can be seen from the figure above that the optimal path length is 38. Combined with daily physical exertion and travel time limits, the optimal tour sequence is as follows:

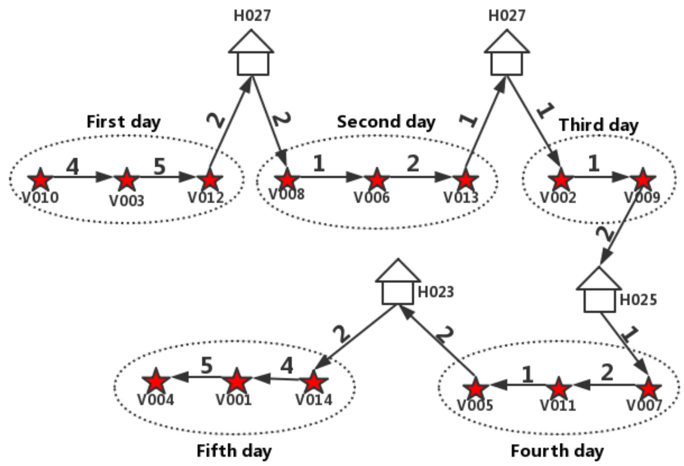

Figure 4 Optimal travel program

Each part of the cost and the final total cost as follows:

Table 1 Optimal travel costs1

	Ticket fee	Bus fee	Hotel fee	Total cost
Amount	1385	38	720	2143

(4). Result analysis

From the results, we can see that the optimal arrangement provides a tour plan that can visit all the scenic spots after spending 5 days and 4 nights only for 2143 yuan. In addition, the above program except the fourth day, we set aside 30 minutes for tourists traveling between different attractions consumption.

4.1.4 Model solution and result analysis (question b)

For the travel process does not change the hotel's situation, do not need to change the above model. Only need to calculate the result of adding each hotel to the model in the ant colony algorithm solving process, and take the scheme with the lowest total cost as the following figure:

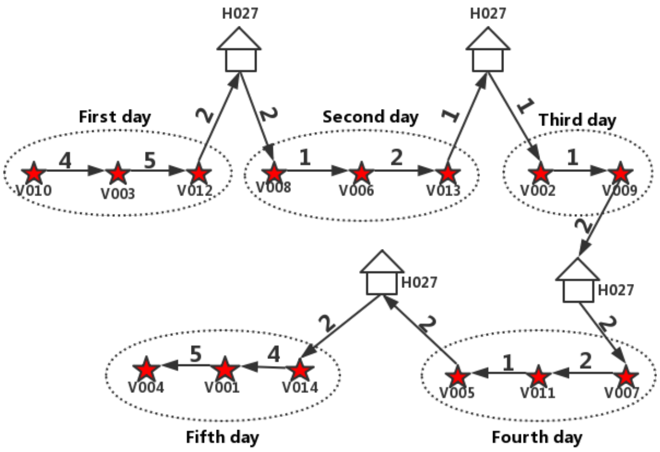

Figure 5 Optimal travel program2

The total cost is as follows:

Table 2 Optimal travel costs2

	Ticket fee	Bus fee	Hotel fee	Total cost
Amount	1385	39	720	2144

The above table shows that when the hotel can’t be changed, the above single-objective programming model still applies. When choosing H027, the minimum travel time is 5 days, and the lowest total cost is 2144 yuan.

4.1.5 Model solution and result analysis (question c)

Since the shortest time is 5 days, it can’t be shortened again. So save time to reduce the total cost does not help. And each station costs 3 yuan, a lot more than the original total transport costs, so do not consider this express car, so the original model does not need to change.

4.2 Solution for task two

4.2.1 Problem analysis

According to the preferences of tourists, develop a three-day best travel plan. This definition of satisfaction index *P* to measure tourists interested in the attractions, combined with the cost to a comprehensive evaluation of the best travel options. Due to the very different tourist purposes of tourists, therefore, according to the tourist's funding situation, we draw up two different travel plans for luxury tour and economic tour respectively for their reference. Among them, luxury tour aims to attract the most interesting tourist attractions as far as possible, without considering tickets and other factors. On the contrary, the economy tour provides tourists with the highest satisfaction index on the premise of considering the travel expenses of passengers.

The definition of important concepts:

➢ **The best travel:** The best travel consists of the best experience and the best planning. The best experience refers to the tourist attractions bring satisfaction to tourists, the best planning refers to after choose attractions to develop the most reasonable schedule.

Best travel = best experience + best plan

➢ **Satisfaction score:** According to the tourists' interest in the scenic spots, we evaluate the satisfaction scores of different scenic spots. The results are as follows:

Table 3 Satisfaction score

	Attraction name	Satisfaction score
Attractions I	V002、V004、V007、V009	3
Attractions II	V001、V005、V006、V014	2
Attractions III	V003、V008、V010、V011、V012、V013	1

➢ **Satisfaction index:** Satisfaction index measures visitors interested in the program's attractions, so get it:

Satisfaction index β ***= Satisfaction scores for all attractions on the trip***

➢ **Attraction Satisfaction Score Get Price:** Because of the attractions to get the satisfaction score need to spend tickets, physical and time costs. The night before spent on accommodation provided the second day of time and effort. We have the lowest room rate 180 per night, physical strength per day as 100%, play time 8h per day as the standard. Therefore, the cost of physical value of 1 yuan per 1%, the time cost of 10 yuan per hour. Through the physical and time into money way, depict V001-V007 scores of the first seven attractions get the price, as the following table (see Appendix 3 for all results):

Table 4 Attraction Satisfaction Score Get Price

	V001	V002	V003	V004	V005	V006	V007
Ticket	120	90	140	50	180	50	145
Energy	15	30	25	50	25	20	40
Time	20	20	30	30	30	10	20
Score	2	3	1	3	2	2	3
expense	77.5	46.7	195	43.3	117.5	40	68.3

4.2.2 Model establishment

Because the best travel options vary by type of travel, the two travel types are separately modeled:

1. Luxury travel

(1). Determine the objective function

Luxury travel tickets without considering the attractions, only the pursuit of the maximum satisfaction score, and then on this basis, planning the tour order between attractions so that the minimum transport costs f_t and f_c , so you can get the following goals:

$$\max \beta_l = \sum_{i=1}^{n} \sum_{j=1}^{m_i} S_{ij} \qquad n = 3$$
$$\min f_t + f_c \tag{9}$$

Where S_{ij} represents the satisfaction score of the j-th attraction visited on day i.

(2). Determine the constraints

- The number of attractions arranged on the i-th day is m_i, of which the j-th attraction requires a tour time of t_{ij} and the physical value consumed is e_{ij}. The conditions given by the problem let us know that the daily open time for the attraction is 8 hours, and we assume that the physical strength of the visitor is 1 at the beginning of each day. The following constraints can be obtained:

$$\sum_{i=1}^{d} (\sum_{j=1}^{m_j} a_{ij} t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{d} (\sum_{j=1}^{m_j} a_{ij} e_{ij} \le 1) \tag{10}$$

- Travel costs f_c and transport costs f_t in the same question a model (3),(4)

(3). Luxury travel the best travel program model

$$\max \beta_l = \sum_{i=1}^{n} \sum_{j=1}^{m_i} S_{ij} \qquad n = 3$$
$$\min \ f_t + f_c$$
$$s.t \begin{cases} f_c = \sum_{i=1}^{n} c_i \\ f_t = \sum_{i=1}^{p} b_i + \sum_{i=1}^{n-1} (h_i + h_i^{'}) \\ p = \sum_{i=1}^{n} m_i \\ \sum_{i=1}^{n} (\sum_{j=1}^{m_j} t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{n} (\sum_{j=1}^{m_j} e_{ij} \le 1) \end{cases} \tag{11}$$

2. Economic Tour

(1). Determine the target function

Economic tour not only the pursuit of satisfaction scores, but also consider the attractions tickets situation, and finally planning the attraction between the tourist order so that the transport costs f_t and accommodation f_c and minimum, so get the following goals:

$$\begin{aligned} &\max \beta_1 = \sum_{i=1}^{n} \sum_{j=1}^{m_i} S_{ij} \qquad n=3 \\ &\min f_a + f_t + f_c \end{aligned} \tag{12}$$

Where S_{ij} is the satisfaction score of the j-th tourist attraction on the i-th day, and n is the number of days of the tour.

(2). Determine the constraints

- The number of attractions arranged on the i-th day is mi, of which the j-th attraction arranged is a_{ij}, the required tour time is t_{ij}, and the physical value consumed is e_{ij}. It is 8 hours for the tournaments to open on a day-to-day basis. We assume that the physical strength of a visitor is 1 at the beginning of each day. The following constraints can be obtained:

$$\sum_{i=1}^{n} (\sum_{j=1}^{m_i} t_{ij} \leq 8) \;\; and \;\; \sum_{i=1}^{n} (\sum_{j=1}^{m_i} e_{ij} \leq 1) \tag{13}$$

- Tickets for the j-th attraction on the i-th day are v_{ij}, so the total ticket fee f_a :

$$f_a = \sum_{i}^{n} \sum_{j=1}^{m_j} V_{ij} \tag{14}$$

- Travel costs f_c and transport costs f_t in the same question a model (3),(4)

(3). Economic Tour optimal travel program model

$$\max \beta_l = \sum_{i=1}^{n} \sum_{j=1}^{m_i} S_{ij} \qquad n = 3$$

$$\min\ f_a + f_t + f_c$$

$$s.t \begin{cases} f_c = \sum_{i=1}^{n} c_i \\ f_t = \sum_{i=1}^{p} b_i + \sum_{i=1}^{n-1} (h_i + h_i^{'}) \\ f_a = \sum_{i}^{n} \sum_{j=1}^{m_j} V_{ij} \\ p = \sum_{i=1}^{n} m_i \\ \sum_{i=1}^{n} (\sum_{j=1}^{m_j} t_{ij} \le 8) \ and \ \sum_{i=1}^{n} (\sum_{j=1}^{m_j} e_{ij} \le 1) \end{cases} \tag{15}$$

4.2.3 Model Calculation and Result Analysis

1. The result of luxury tour

According to the above model, the ant colony algorithm is used to calculate the optimal travel plan as follows:

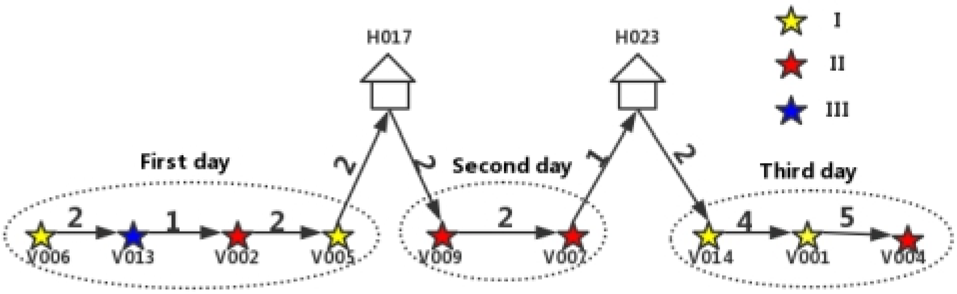

Figure 6 Optimal travel program3

The cost details are as follows:

Table 5 Optimal travel costs4

	Ticket fee	Bus fee	Hotel fee	Satisfaction index	Total cost

Amount	910	23	360	21	1293

2. The result of economic tour

(1). Greedy algorithm ideas:

The greedy algorithm is a choice that takes the best or the best (i.e the most advantageous) choice in the current state at each step choice, i.e the point of attraction of the attraction obtains the attraction with the lowest cost, to obtain the better or the optimal result. Satisfaction scores for the 14 spots get the lowest to highest price, as shown below:

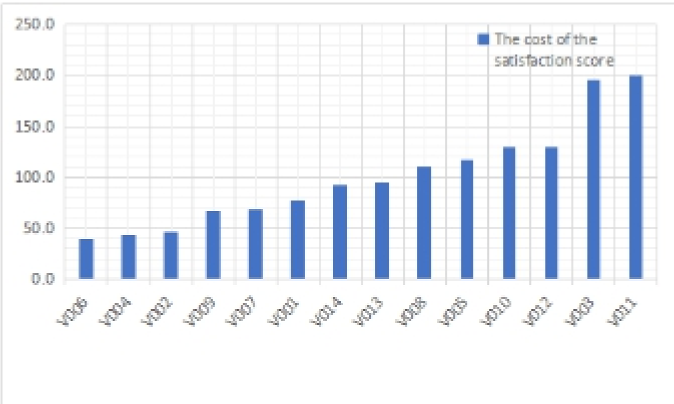

Figure 7 The cost of the satisfaction score

According to the above model using the greedy algorithm to calculate the optimal travel program is as follows:

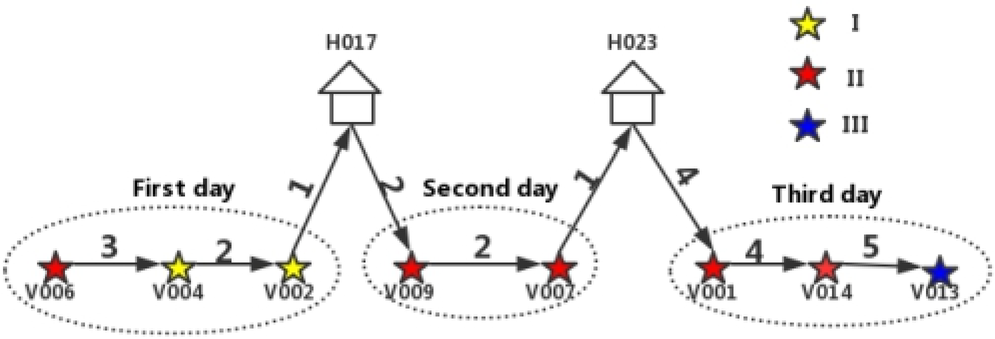

Figure 8 Optimal travel program4

The cost details are as follows:

Table 6 Optimal travel costs5

	Ticket fee	Bus fee	Hotel fee	Satisfaction index	Total cost
Amount	730	20	360	19	1110

Comparison of luxury travel and economic travel results found that economic travel satisfaction index compared to luxury travel only reduced by 7%, while the price has dropped 14.2%. So for tourists who are costly, economic tour is a better choice than luxury tour.

4.3 Solution for task Three

4.3.1 Problem analysis

Affected by the number of tourist attractions, the attractions required for the tour of time between $t-1.5t$ (t for the sights of the standard tour time). On the basis of Question 2, we will discuss the best three-day travel plan. Therefore, we add a randomly varying time-bound attraction constraint in the multi-objective model of Question 2. Then, we use the algorithm of Question 2 to calculate the optimal travel plan of luxury travel and economic travel separately under the influence of the number of people.

4.3.2 Model establishment

1. Luxury tour

(1). Determine the target function

Luxury travel tickets without considering the attractions, only the pursuit of the maximum satisfaction score, and then on this basis, planning the tour order between attractions so that the minimum transport costs f_t and f_c, so can get the following goals:

$$\begin{aligned} &\max \beta_1 = \sum_{i=1}^{n} \sum_{j=1}^{m_i} S_{ij} \qquad n = 3 \\ &\min f_t + f_c \end{aligned} \tag{16}$$

S_{ij} represents the Satisfaction Score of the j-th attraction visited on the i-th day.

(2). Determine the constraints

- The number of attractions arranged on the i-th day is m_i, of which the j-th attraction requires a tour time of t_{ij} and the physical value consumed is e_{ij}. It is known from the topic conditions that the daily open time of tour is 8 hours, and we assume that the physical value of tourist is 1 at the beginning of each day. The following constraints can be obtained:

$$\sum_{i=1}^{n}(\sum_{j=1}^{m_i} \mu \times t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} e_{ij} \le 1) \quad \mu \in (1,\ 1.\ 5) \tag{17}$$

μ is the time floating factor resulting from scenic spots impact by the number of people

- Travel costs f_c and transport costs f_t in the same question a model (3),(4).

(3). Luxury travel the best travel program model

$$\max \beta_l = \sum_{i=1}^{n}\sum_{j=1}^{m_i} S_{ij} \qquad n=3$$
$$\min\ f_t + f_c$$
$$s.t\begin{cases} f_c = \sum_{i=1}^{n} c_i \\ f_t = \sum_{i=1}^{p} b_i + \sum_{i=1}^{n-1}(h_i + h_i^{'}) \\ p = \sum_{i=1}^{n} m_i \\ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} \mu \times t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} e_{ij} \le 1) \quad \mu \in (1, 1.5) \end{cases} \tag{18}$$

2. Economic Tour

(1). Determine the target function

The economic tour not only seeks satisfaction scores, but also considerate the tickets for scenic spots. Finally, it plans the tour order between scenic spots, so that the transportation cost f_t and the accommodation fee will be f_c and the smallest:

$$\begin{aligned} &\max \beta_l = \sum_{i=1}^{n}\sum_{j=1}^{m_i} S_{ij} \qquad n=3 \\ &\min\ f_a + f_t + f_c \end{aligned} \tag{19}$$

(2). Determine the constraints

- The number of attractions arranged on the i-th day is m_i, of which the j-th attraction arranged is a_{ij}, the required tour time is t_{ij}, and the physical value consumed is e_{ij}. It is 8 hours for the tournaments to open on a day-to-day basis. We assume that the physical strength of a visitor is 1 at the beginning of each day. The following constraints can be obtained:

$$\sum_{i=1}^{n}(\sum_{j=1}^{m_i} \mu \times t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} e_{ij} \le 1) \quad \mu \in (1, 1.5) \tag{20}$$

- The entrance fee of the j scenic spot on day i is V_{ij}, so the total ticket cost is f_a:

$$f_a = \sum_{i}^{n}\sum_{j=1}^{m_j} V_{ij} \tag{21}$$

- Travel costs f_c and transport costs f_t in the same question a model (3),(4).

(3). Economic Tour optimal travel program model

$$\max \beta_l = \sum_{i=1}^{n}\sum_{j=1}^{m_i} S_{ij} \qquad n = 3$$

$$\min\ f_a + f_t + f_c$$

$$s.t\begin{cases} f_c = \sum_{i=1}^{n} c_i \\ f_t = \sum_{i=1}^{p} b_i + \sum_{i=1}^{n-1}(h_i + h_i^{'}) \\ f_a = \sum_{i}^{n}\sum_{j=1}^{m_j} V_{ij} \\ p = \sum_{i=1}^{n} m_i \\ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} \mu \times t_{ij} \le 8) \ \ and \ \ \sum_{i=1}^{n}(\sum_{j=1}^{m_i} e_{ij} \le 1) \quad \mu \in (1,1.5) \end{cases} \tag{22}$$

4.3.3 Model Calculation and Result Analysis

The model results of calculating the maximum number of people (that is, μ=1.5).

1. The result of luxury tour

According to the above model ant colony algorithm to calculate the optimal travel plan is as follows:

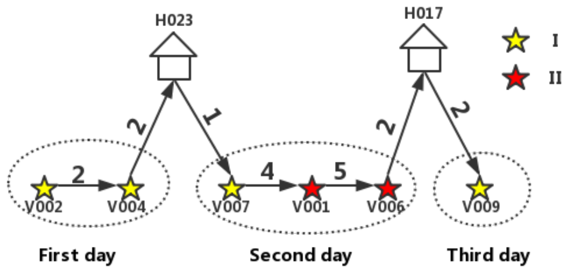

Figure 9 Optimal travel program5

The cost details are as follows:

Table 7 Optimal travel costs6

	Ticket fee	Bus fee	Hotel fee	Satisfaction index	Total cost
Amount	555	18	360	16	933

2. The result of economic tour

According to the above model using the greedy algorithm to calculate the optimal travel program is as follows

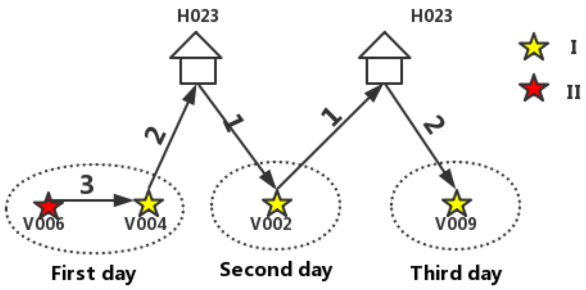

Figure 10 Optimal travel program

The cost details are as follows:

Table 8 Optimal travel costs7

	Ticket fee	Bus fee	Hotel fee	Satisfaction index	Total cost
Amount	290	9	360	11	659

By assuming that the number of people in the scenic spots is the most, μ=1.5, respectively, found that two types of tourism programs were affected by the number of people in the scenic spots. The contrast between luxury and economic travel showed that when the satisfaction index of the economic tour decreased by 31.5% compared to the luxury tour, the price was also reduced by 29.3%. Therefore, for the tourists with better economic conditions, the cost performance of the luxury tour is higher.

5. Strengths and weaknesses

5.1 The strengths of the model

(1). The ant colony algorithm is adopted to solve the TSP path planning problem. The ant colony algorithm has a wide range of application fields and ant colony algorithm can be adopted in many path optimization problems.

(2). In the solution to problem two, we designed two kinds of models, that is, luxury and economy. They fully considered the tourists' various situations and made the result more comprehensive.

5.2 The weaknesses of the model

(1). When we solve the problem of bus routes, because our algorithm design is very complex, resulting in a higher level of computer hardware requirements, the computer run for about 15 minutes before the results obtained. Our team is thinking about algorithmic optimization issues.

(2). The ant colony algorithm has many iterations, and the result of the solution has the local optimal value instead of the global best quality characteristic, which makes the result of the solution have a certain randomness and infinitely approach the optimal value instead of the optimal value.

6. Future Improvements

Our team based on the ant colony algorithm to establish the model used to find the shortest path, and ant colony algorithm used in a very wide area, but also can be used in seeking the traveler's problem.

In the TSP path planning NP problem, this article uses ant colony algorithm to solve. Since this problem is solved by only 14 nodes and fewer nodes, our team is considering using dynamic programming to solve this path planning problem.

The establishment and solution of this model is mainly for the main tourist attractions in C city. Make hotel selection and transportation route planning. The model can also be applied to different urban tourist attractions route planning. The model established in this paper not only can find the shortest route, but also can find the shortest time, the lowest cost and so on.

7. A letter to the director of the local travel agency

Dear Sir:

It is my pleasure to be able to write to your travel agency. Thank you for taking a few minutes to read some of our team's suggestions.

With the rapid development of self-help travel in recent years and the impact of the global tourism industry, the rapid development of self-help travel and the huge heat wave that the urban residents are pursuing the liberty and freedom have caused a great impact on travel agencies. Today, all-inclusive tourism and semi-self-help travel coexist. If the travel agency still uses traditional group business, no doubt it can’t adapt to the current society. Tourists hope that according to their own special interests and hobbies, choose a targeted, theme and focus on the way of travel, it is suggested that travel agents to change the traditional mode of service to help visitors customize personalized travel.

Our team conducted an analysis of the 14 tourist attractions in city C, 28 hotels, as well as all the bus lines combined with the opening hours of tourist attractions, physical strength of tourists. Based on our analysis, the recommendations are as follows.

First of all, based on the traveler's travel purposes classification, if the traveler wants to spend the shortest possible time and the most economical, all the attractions in C city all visit again, then we can use the ant colony algorithm to solve the TSP path planning calculated as a result, tourists travel routes, transit routes and daily accommodation arrangements, so that both to meet the individual needs of tourists, but also in the booking for tourists to save some costs and time. Similarly, using our calculation model to meet other tourist purposes, such as taking the shortest route, changing the minimum number of vehicles, etc., for tourists to arrange their travel routes, and travel by themselves planning to enjoy.

Second, according to the tourists' travel priorities, as well as preferences. If travelers have special attractions, then you can develop personalized travel solutions for the tourists. If the passengers in addition to consider their own areas of interest but also take into account each of the attractions of the time and effort, as well as the cost of tickets. Then we will be based on the specific number of tourists want to travel the number of days, as well as the cost of each attraction, given the tourist options for tourists to choose, at the same time for tourists to arrange affordable hotel accommodation. If the passengers just want to go to their own attractions of interest without considering other cost factors. Then you can according to the tourists want to go to the attractions, arrange fewer reversing times, more convenient and quick to reach the attractions, and at the end of each day after the tour near the accommodation arrangements to maximize the tourist experience.

Finally, our model based on the actual situation of travel, such as the light travel, peak season and so on. The number of tourists is greatly influenced by the season. according to which we have analyzed according to the tourist light, peak season points to plan tourists every day the number of tourist attractions and the hotel’s arrangement.

The above conclusion is only a discussion based on the conclusions drawn by our model. The actual situation can be specifically determined by the model. Of course, our model is based on ideal traffic conditions, so there are some limitations. Use should be combined with the actual situation.

I hope our model can help you!

Sincerely,
MCM Team Members

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Appendix

Appendix 1:Ant Colony Algorithm for TSP Path Planning

```
clc
clear
 NC_max=200
 m=30
 Alpha =0.2
 Beta=10
 Rho=0.8
 Q=0.2
 R_best=[]
 L_best=[]
global D;
global data;
global map;
D=xlsread(' Ride arrangements.xlsx');
map=xlsread('Path.xlsx','matrix');
n=9;
Eta=1./D;
Tau=ones(n,n);
Tabu=zeros(m,n);
NC=1;
R_best=zeros(NC_max,n);
L_best=inf.*ones(NC_max,1);
L_ave=zeros(NC_max,1);
while NC<=NC_max       %%
Randpos=[];   %

for i=1:(ceil(m/n))
   Randpos=[Randpos,randperm(n)];
end

Tabu(:,1)=(Randpos(1,1:m))';    %
%%
for j=2:n
    for i=1:m
        visited=Tabu(i,1:(j-1));
        J=zeros(1,(n-j+1));
        P=J;
        Jc=1;
        for k=1:n
            if length(find(visited==k))==0
                J(Jc)=k;
                Jc=Jc+1;
            end
        end
        for k=1:length(J)
            P(k)=(Tau(visited(end),J(k))^Alpha)*(Eta(visited(end),J(k))^Beta);
        end
        P=P/(sum(P));
        Pcum=cumsum(P);
        Select=find(Pcum>=rand);
        to_visit=J(Select(1));
        Tabu(i,j)=to_visit;
```

```
    end
end
if NC>=2
    Tabu(1,:)=R_best(NC-1,:);
end
global L;
global R;
global min_dist;
min_dist=cell(30,1);
min_d=cell(200,1);
L=zeros(m,1);
for i=1:m
    R=Tabu(i,:);
    for j=1:(n-1)
        L(i)=L(i)+D(R(j),R(j+1));
    end
    %     L(i)=L(i)+D(R(1),R(n));      %
    addHotel(i);
end
L_best(NC)=min(L);           %
index=find(L==L_best(NC));
min_L{NC}=min_dist{index};
pos=find(L==L_best(NC));
R_best(NC,:)=Tabu(pos(1),:); %
L_ave(NC)=mean(L);           %
NC=NC+1
Delta_Tau=zeros(n,n);
for i=1:m
    for j=1:(n-1)
Delta_Tau(Tabu(i,j),Tabu(i,j+1))=Delta_Tau(Tabu(i,j),Tabu(i,j+1))+Q/L(i);
    end       Delta_Tau(Tabu(i,n),Tabu(i,1))=Delta_Tau(Tabu(i,n),Tabu(i,1))+Q/L(i);
end
Tau=(1-Rho).*Tau+Delta_Tau;
Tabu=zeros(m,n);
end
Pos=find(L_best==min(L_best));
Shortest_Route=R_best(Pos(1),:)
Shortest_Length=L_best(Pos(1))
plot(L_ave)
hold on
plot(L_best)
title('Algorithm convergence trajectory')
xlabel('The number of iterations')
ylabel('Distance')
legend('the average','the best')
 % m1=0;
% for k=1:length(Shortest_Route)-1
%     i=Shortest_Route(k);
%      j=Shortest_Route(k+1);
%      m1=m1+D(i,j);
% end
% disp(sprintf('The length is %d:',m1))
```

```
global D;
global map;
global data;
```

```
time=0;
energe=0;
dist=ones(1,2)*100;
global min_dist;
m=ones(6,2);
cnt=0;
i=1;
while i<10
    time=time+data(R(i),2);
    energe=energe+data(R(i),1);
    dist(1,2)=1000;
    if time>8 || energe>100
        L(t)=L(t)-D(R(i-1),R(i));
        for j=15:18
            d=map(j,R(i-1))+map(j,R(i));
            if dist(1,2)>d
                dist(1,1)=j;
                dist(1,2)=d;
            end
        end
        if i==14
            L(t)=L(t)+180;
            i=i+1;
        end
        cnt=cnt+1;
        m(cnt,1)=dist(1,1);
        m(cnt,2)=dist(1,2);
        L(t)=L(t)+dist(1,2);
        i=i-1;
        time=0;
        energe=0;
    end
    i=i+1;
end
min_dist{t}=m;
end
```

Appendix 2:Calculate the shortest path between attractions

```
clc
 clear
global price;
global attr;
global map;
global dist;
[t1,txt]=xlsread('Annex.xlsx','A1:A41');
[t2,attr]=xlsread('Attractions.xlsx');
price=xlsread('Price.xlsx');
map=cell(41,1);
for i=1:41
    line=regexp(txt{i},'-','split');
    map{i}=line;
end

dist=ones(18)*100;
direct();
changeOne();
changeTwo();
```

```
disp('end')
```

```
function changeTwo()
global map;
global dist;
global attr;
global price;
for i=1:18
    for a=1:3
        start=attr(i,a);
        for j=i+1:18
            for b=1:3
                final=attr(j,b);
                for k=1:41
                    s=find(strcmp(map{k},start));
                     f=find(strcmp(map{k},final));
                    if ~isempty(s)&& isempty(f)
                        for l=1:length(map{k})
                            start2=map{k}{l};
                            for m=1:41
                                s2=find(strcmp(map{m},start2));
                                f=find(strcmp(map{m},final));
                                if ~isempty(s2)&& isempty(f)
                                   for n=1:length(map{m})
                                       start3=map{m}{n};
                                       for p=1:41
                                           s3=find(strcmp(map{p},start3));
                                           f=find(strcmp(map{p},final));
                                           fee=price(p)+price(m)+price(k);
                                           if ~isempty(s3)&& ~isempty(f)&&dist(i,j)>fee
                                               dist(i,j)=fee;
                                               dist(j,i)=fee;
                                           end
                                       end
                                   end
                                end
                            end
                        end
                    end
                end
            end
        end
    end
end
end
```

```
function direct()
global map;
global dist;
global attr;
global price;
for i=1:18
    for a=1:3
        start=attr(i,a);
        for j=i+1:18
            for b=1:3
                final=attr(j,b);
```

```
                for k=1:41
                    s=find(strcmp(map{k},start));
                     f=find(strcmp(map{k},final));
                    if ~isempty(s)&& ~isempty(f)&&dist(i,j)>price(k);
                        dist(i,j)=price(k);
                        dist(j,i)=price(k);
                    end
                end
            end
        end
    end
end
end
```

```
function changeOne()
global map;
global dist;
global attr;
global price;
for i=1:18
    for a=1:3
        start=attr(i,a);
        for j=i+1:18
            for b=1:3
                final=attr(j,b);
                for k=1:41
                    s=find(strcmp(map{k},start));
                     f=find(strcmp(map{k},final));
                    if ~isempty(s)&& isempty(f)
                        for l=1:length(map{k})
                            start2=map{k}{l};
                            for m=1:41
                                s2=find(strcmp(map{m},start2));
                                f=find(strcmp(map{m},final));
                                fee=price(m)+price(k);
                                if ~isempty(s2)&& ~isempty(f)&& dist(i,j)>fee
                                    dist(i,j)=fee;
                                    dist(j,i)=fee;
                                end
                            end
                        end
                    end
                end
            end
        end
    end
end
end
```