Smart Toursim (2021) Volume 2 Issue 2, *9 pages*.
doi: 10.54517/st.v2i2.1698

ORIGINAL RESEARCH ARTICLE

Intelligent tourism route optimization based on teaching and learning optimization algorithm

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ABSTRACT

According to the principles of tourism route design and the needs of tourists, the teaching and learning optimization algorithm was improved, and a tourism route optimization method based on the improved teaching and learning optimization algorithm was established. The optimization test of travel routes in Hanzhong area shows that the tourism routes designed by using this algorithm are feasible and efficient, and it has certain practical value for tourism traffic planning, tourism routes design, especially for self-driving tourists to carry out efficient tourism activities.

Keywords: teaching and learning optimization algorithm; tourist routes; optimization

1. Introduction

Tourist route refers to a route with certain characteristics that reasonably runs through a number of tourist spots or cities in a certain region in order to make visitors get the maximum viewing effect in the shortest time[1]. Tourism routes are the spatial carriers for tourism activities to be realized. It is of great significance to regional tourism development, tourism destinations, tourism enterprises and tourists. Nowadays, tourism activities are becoming more and more popular and family-oriented, it is the common goal of the tourism industry to design scientific, efficient and reasonable tourist routes to meet the needs of tourists to the maximum extent. Foreign studies on tourist routes were conducted earlier, mainly exploring the best model of tourist route organization, such as Campbell model[2], Lundgren model[3] and Stewart-Vogt model[4]. Domestic research results on tourist routes mainly include design types of tourist routes[5], operational research methods of tourist route design[6], spatial organization mode of tourist routes[7], etc. With the maturity of computer technology and geographic information technology, theories such as GIS technology, data mining technology, intelligent optimization algorithm and mathematics are gradually applied to the design of tourist routes[8–12]. From the perspective of research, there are more studies from the perspective of "supplier"—Tourism planning and tourism enterprises, and less from the perspective of tourists. From the perspective of the research scope, there are more studies on trans-regional large-scale tourism route organization and less on small-scale tourism route design.

ARTICLE INFO
Received: June 12, 2021 | Accepted: July 28, 2021 | Available online: August 13, 2021

CITATION
He H, Sun G. Intelligent tourism route optimization based on teaching and learning optimization algorithm. Smart Tourism 2021; 2 (2): 9 pages.

In this paper, an improved teaching and learning optimization algorithm is introduced to study the optimization of tourist routes from the perspective of tourism demand—Tourists, and 18 scenic spots in Hanzhong City, Shaanxi Province are used for experiments. The purpose is to study the feasibility and efficiency of the improved teaching and learning optimization algorithm for the optimization design of tourist routes. It provides tools for tourists' choice of travel routes, travel agency's route design and regional tourism planning.

2. Description of tourism route optimization problem

Tourism route design is an important way for regional tourism development to launch tourism products. High-level tourism route design is an important measure to improve tourism attraction. Generally, the design of tourist routes is mainly from the perspective of travel agencies to design tourism projects with rich contents and different experiences for tourists, while the design of tourist routes is seldom studied from the perspective of tourists' "needs" for tourism products. As a special consumer goods, the consumption of money and leisure time constitutes the cost of tourists. At the same time, tourists always choose the most desirable scenic spots from numerous alternative scenic spots according to their own travel preferences, so as to obtain the best travel experience. In a word, tourists always try to get the maximum benefit at the least cost. In this study, the visiting time of tourist attractions is relatively consistent. For tourists, apart from the selected tourist attractions, space and time distance is the first factor they consider. Therefore, in the optimization design process of tourist routes, the travel time and the distance between scenic spots are the key factors to be considered, and will also become the constraints of the model construction.

3. Construction of tourism route optimization model

When tourists choose tourist destinations or scenic spots, they always hope to meet their own needs, and there are many tourist destinations or scenic spots that can meet such needs. Use $V = \{v_1, v_2..., v_N\}$ represents the collection of all alternative tourist attractions, where N represents the number of alternative tourist attractions; Due to the limitation of time, money or energy, tourists will always choose the most desirable and yearning scenic spots from numerous alternative scenic spots, using $selV = \{sv_1, sv_2..., sv_n\}$ represents the set of scenic spots selected by tourists, where sv_i represents the specific scenic spots selected by tourists, and n ($n \leqslant N$) represents the number of scenic spots selected. After selecting the destination, you can design the best tour route by using $lV = \{lv_1, lv_2..., lv_n\}$, where lv_i represents the optimized arrangement of the selected set $selV$.

Tourists can freely choose the starting point (lv_0) and ending point (lv_{n+1}) of the tour route (as shown in **Figure 1**).

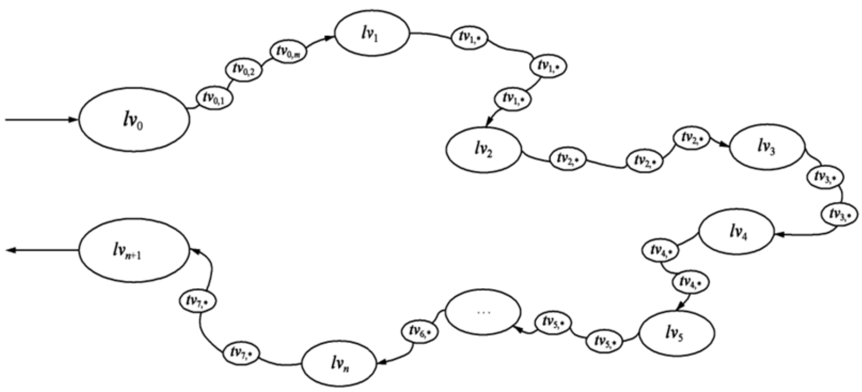

Figure 1. Tourist route map.

In accordance with the principle of the least time, the tourism route time minimization model is constructed:

$$\min f(t) = \sum_{i=1}^{n} t_1 + \sum_{j=0}^{n} \frac{Distance(lv_j, lv_{j+1})}{V(lv_j, lv_{j+1})}$$

Where: t_i $(i = 1,2..., n)$ is the time tourists stay in scenic spots, n is the number of scenic spots to visit; Distance(lv_j, lv_{j+1}) ($j = 0, 1, 2..., n$) is the distance from scenic spot lv_j to scenic spot lv_{j+1}; $V(lv_j, lv_{j+1})$ is the driving speed from scenic spot lv_j to scenic spot lv_{j+1}.

3. Research ideas and methods

3.1. Basic principles of teaching and learning optimization algorithm

Teaching-learning-based Optimization algorithm[13] is a new meta-heuristic algorithm, which improves knowledge level by imitating "Teaching" and "Learning" in people's Learning process. TLBO has the characteristics of few parameters and high performance. Since it was proposed in 2011, TLBO has been well applied in mechanical design optimization[13,14], heat exchanger optimization[15], thermoelectric cooler optimization[16] and other fields[17].

To facilitate understanding, the following are some basic definitions of TLBO algorithm:

Definition 1 Search space for an individual (solution vector) $X = (x_1, x_2..., x_D)$ are called Learner, x_i $(i = 1,2..., D)$ is the i course for students.

Definition 2 The set of all students is called a class.

Definition 3 Students with the highest level (fitness) $X^{best} = (x_1^{best}, x_2^{best}..., x_D^{best})$ is called $X^{teacher}$.

In TLBO algorithm, the class is equal to the population in genetic algorithm, the student is equal to the individual, and the teacher is the individual with the highest adaptive value. The task of a teacher is to teach hard and promote the average level of students in the class. Students improve their knowledge by learning from teachers and communicating with classmates. TLBO algorithm is divided into two stages: Teaching Phase and Learning Phase.

(1) The Teaching Phase algorithm is as follows:

For each learner $X^j = (x_1^j, x_2^j, \cdots, x_D^j)$ $(j = 1,2,\cdots,NP)$ Do

  $x_i^{j,new} = x_i^{j,old} + \text{rand}() \times (x_i^{best} - T_F \times Mean_i)$, $j = 1,2,\cdots,NP, i = 1,2,\cdots,D$

  If $X^{j,new}$ first $X^{j,old}$ then

    $X^j = X^{j,new}$

    End if

  End for

Where, $x_i^{j,old}$ and $x_i^{j,new}$ I represent the knowledge level of X^j's i course before and after teaching respectively. Rand () is a random number between (0,1).

$$T_F = \text{round}[1 + \text{rand}()], \quad Mean_i = \frac{1}{NP}\sum_{j=1}^{NP} x_i^j$$

NP is the total number of students and D is the number of courses (dimension).

(2) The Learning Phase algorithm is as follows:

For each learner X^j $j = 1,2... NP$,

Select a student X^k at random from the class ($j \neq k$)

If X^j is superior to X^k then

$X^{j,\text{new}} = X^{j,\text{old}} + \text{rand}(1,D) \times (X^j - X^k)$

Else

$X^{j,\text{new}} = X^{j,\text{old}} + \text{rand}(1,D) \times (X^k - X^j)$

End

If $X^{j,\text{new}}$ is superior to $X^{j,\text{old}}$ then

$X^j = X^{j,\text{new}}$

End if

End for

Where rand(1,D) means that a D-dimensional vector is randomly generated within the interval (0,1).

3.2. Tourism route optimization based on TLBO

The basic TLBO algorithm is mainly used for real number optimization problems. For discrete combinatorial optimization problems, it needs to be redesigned. This paper presents an improved teaching and learning optimization (ITLBO) algorithm for tourism route planning. Its "teaching" and "learning" methods are as follows:

(1) Teaching Phase

In the teaching stage, each student adopts PMX, a partial matching crossover operator, to learn from $X^{teacher}$. The algorithm is as follows:

For each learner X^j *(j = 1,2... , NP) Do*

$X^{new} = X^j$

Select a random element R_s in the set {1, 2, ... *D-Step*}.

$R_e = R_s + Step$ (as a closing crossover point)

Partially matched crossover (PMX) algorithm for X^{new} and $X^{teacher}$[18]

If X^{new} is better than X^i

$X^i = X^{new}$

End if

End for

Among them,

$$Step = \begin{cases} \text{Int}(D/2)+1, & t < T_{\max}/5, \\ \text{Int}(D/3)+1, & t < 2T_{\max}/5, \\ \text{Int}(D/4)+1, & t < 3T_{\max}/5, \\ \text{Int}(D/5)+1, & t < 4T_{\max}/5, \\ 1, & \text{otherwise}, \end{cases}$$

The cross-Step size is dynamically adjusted as the optimization progresses, which helps the algorithm to achieve a balance between global exploration and local refinement.

(2) "Learning Phase"

In the mutual learning stage, students randomly select other students for cross-learning, using the following methods:

For each learner X^i (i = 1,2..., NP)

$X^{new} = X^i$

X^j students were randomly selected (j = 1,2... NP, $j \neq i$) as the learning object

Randomly selected crossover starting point $R_s \in \{1,2..., D\text{-}Step\}$, end point $R_e = R_s + Step$

Perform partial matching crossover operator (PMX) on X^{new} and X^j[19,20]

If X^{new} is better than X^i

$X^i = X^{new}$

End if

End for

In the basic TLBO algorithm, students' knowledge level is improved by learning from teachers and communicating with classmates. However, we know that in addition to learning from teachers and students, the most important thing should be "self-study", and the self-study process is not reflected in the basic TLBO algorithm. In this paper, self-learning is introduced based on TLBO algorithm.

(3) Self-learning

The "self-learning" stage algorithm is as follows:

For each learner X^i (i = 1,2..., *NP*) *Do*

$X^{new} = X^i$

Execute two-point crossover on X^{new} at *J* and *J_round* (J *is* {1,2..., a random integer in *D}*, *J_round* is a random integer near *J*)

If X^{new} is better than X^i

$X^i = X^{new}$

End if

End for

The algorithm flow is shown in **Figure 2**.

3.3. Tourism route optimization system architecture design

For tourists, by PC computer, internet-enabled tools such as mobile phones and tablets into the optimization of system interface, input interested in scenic spots and enter the tourist area of the starting point and end point, click on the submit, information sent to the back-end business logic server, the business logic from the database server related scenic route data to be obtained, Then the proposed ITLBO algorithm is used to optimize the line. After completion, the business logic server sends the optimization result to the client. The system architecture is shown in **Figure 3**.

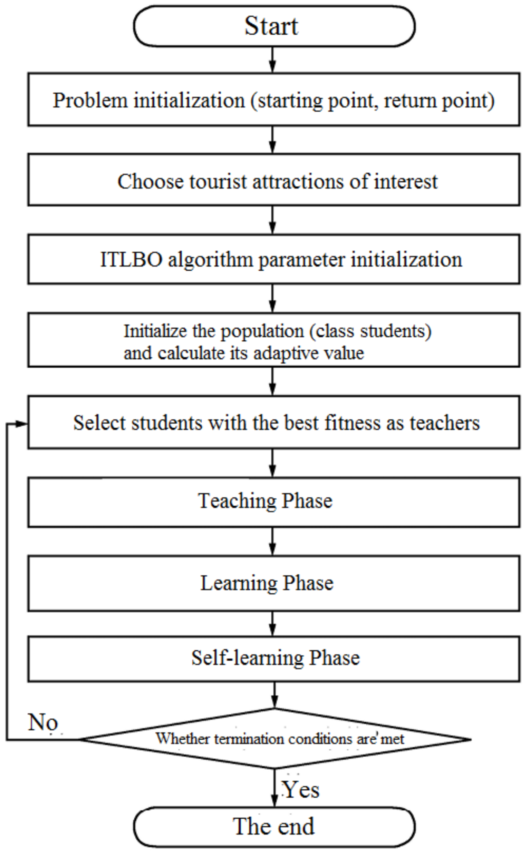

Figure 2. Travel route optimization flow chart by ITLBO algorithm.

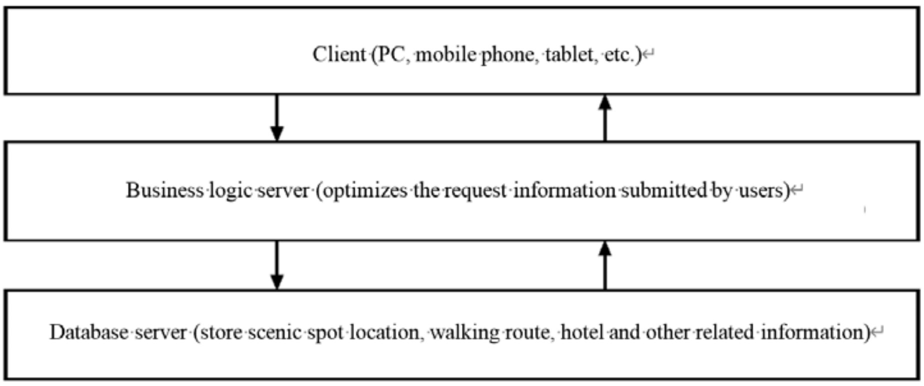

Figure 3. Tourism route optimization system architecture diagram.

4. Case analysis

4.1. Overview of the case area

Located in the southwest of Shaanxi Province, Hanzhong has jurisdiction over 1 district and 10 counties. It is adjacent to Ankang city in the east, Gansu Province in the west, Bashan Mountain and Sichuan Province in the south, and Baoji City in the north, with an area of about 2.72 × 10^4 km^2. Hanzhong and Han dynasties, with their rich cultural deposits and unique natural scenery, are known as "Tianfu of Qinba". In recent years, with the implementation of the "South-to-North Water Diversion" project and the proposal of the tourism propaganda slogan of "Cultural Shaanxi, Landscape Qinling" in Shaanxi Province, the tourism development of Hanzhong has received unprecedented "attention", and the number of tourists has increased year by year. According to statistics, in 2013, the city received 22.498 million tourists, achieving a total tourism revenue of 10.601 billion yuan, up 84.7% and 76.9% year-on-year respectively[21]. However, restricted by traffic conditions, infrastructure construction lags behind, tourism service system is not perfect, and the relatively scattered distribution of scenic spots, the satisfaction of tourists' tourism experience is greatly reduced. Through optimizing the design of tourist routes, organizing and arranging efficient and reasonable tourist itineraries has become the common demand of both sides of tourism "supply and demand".

4.2. Choice of tourist attractions

In this paper, 18 scenic spots, such as conventional line scenic spots, tourist hot spots recommended by travel agencies, emerging scenic spots and various theme scenic spots, are selected for testing. The actual walking distance (non-linear distance) between 18 scenic spots was calculated by using Baidu electronic map and actual traffic road network. Among them, 1{Wuhou Temple (tomb)}, 2{Dingjunshan Scenic area}, 3{Qingmuchuan ancient town}, 44{Nanhu Scenic area}, 5{Hongsi Lake}, 6{Liping Forest Park}, 7{ancient Hantai}, 8{Shimen plank Road}, 9{Zhangliang Temple (Zibai Mountain)}, 10{Orange Garden Scenic area}, 11{Zhang Qian Memorial Hall}, 12{Nansha Lake Scenic Area}, 13{Changqing (Huayang)}, 14{Crested ibis Pear Garden}, 15{CAI Lun's tomb}, 16{Yingtaogou}, 17{Wuzi Mountain}, 18{Dapingyu ecological scenic spot} (as shown in **Table 1**).

Table 1. Actual distance matrix diagram of 18 test scenic spots in Hanzhong (Unit: km)

	sc1	sc2	sc3	sc4	sc5	sc6	sc7	sc8	sc9	sc10	sc11	sc12	sc13	sc14	sc15	sc16	sc17	sc18
sc1	0	5.1	135	62.2	49.7	70.6	51.3	38.7	122	73	90.8	75.1	176	154	111	124	130	211
sc2	5.1	0	141	57.7	46.4	65.2	51.5	47.7	121	71.9	90.7	74.9	176	106	111	124	133	210
sc3	135	141	0	198	226	165	208	184	257	208	248	232	333	262	268	281	268	367
sc4	62.2	57.7	198	0	12.1	57.6	20.1	41.1	115	74.8	50	45.6	147	75.6	82	95.1	104	181
sc5	49.7	46.4	226	12.1	0	49.5	32.2	53.2	127	86.9	73.5	57.8	159	87.7	92.6	107	116	193
sc6	70.6	65.2	165	57.6	49.5	0	73	94	168	115	103	103	204	133	140	153	161	239
sc7	51.3	51.5	208	20.1	32.2	73	0	22.2	95.8	42.2	30.2	29.2	141	70	76.5	89.5	98	176
sc8	38.7	47.7	184	41.1	53.2	94	22.2	0	86.1	36.9	39	44.1	145	74	76.6	93.2	102	180
sc9	122	121	257	115	127	168	95.8	86.1	0	119	122	123	223	153	159	172	180	258
sc10	73	71.9	208	74.8	86.9	115	42.2	36.9	119	0	19.7	37.1	120	45.7	55	102	110	154
sc11	90.8	90.7	248	50	73.5	103	30.2	39	122	19.7	0	24.3	103	32.1	41.4	88.1	77.8	140
sc12	75.1	74.9	232	45.6	57.8	103	29.2	44.1	123	37.1	24.3	0	116	44.8	50.2	62.2	70.7	151
sc13	176	176	333	147	159	204	141	145	223	120	103	116	0	75.9	66.8	132	141	168
sc14	154	106	262	75.6	87.7	133	70	74	153	45.7	32.1	44.8	75.9	0	13.6	103	118.4	115
sc15	111	111	268	82	92.6	140	76.5	76.6	159	55	41.4	50.2	66.8	13.6	0	150	108	101
sc16	124	124	281	95.1	107	153	89.5	93.2	172	102	88.1	62.2	132	103	150	0	13.4	179
sc17	130	133	268	104	116	161	98	102	180	110	77.8	70.7	141	118.4	108	13.4	0	164
sc18	211	210	367	181	193	239	176	180	258	154	140	151	168	115	101	179	164	0

4.3. Hanzhong travel route optimization test

According to the mathematical model and optimization algorithm (ITLBO) established in this paper, 18 tourist attractions in Hanzhong are simulated and tested. Parameters of ITLBO algorithm are set as follows: maximum iteration times T_{max} = 500 (set to 2,000 when the number of nodes exceeds 100), population size NP = 200.

In view of the characteristics of tourists' universal demand for the shortest space distance, the most efficient time distance and the diversified travel schedule when choosing tourist attractions, we design three tourist routes:

Experiment 1: Tourists choose sc4 -- sc8, sc10, sc12, sc13, sc16 and sc18 as tourist attractions, sc6 as entry point and sc18 as return point. The optimized route is sc6 → sc5 → sc4 → sc7 → sc8 → sc10 → sc12 → sc16 → sc13 → sc18 by using the ITLBO algorithm proposed in this paper, as shown in **Figure 4**.

Experiment 2: Tourists are going to enter the scenic spot from scenic spot sc10, plan to visit 8 scenic spots sc1, sc2, sc4-sc8, and sc10, and finally return from scenic spot sc7. The route optimized by ITLBO algorithm is sc10 → sc8 → sc1 → sc2 → sc6 → sc5 → sc4 → sc7, as shown in **Figure 5**.

Experiment 3: Tourists enter the scenic spot from scenic spot sc7, choose sc1 -- sc8, sc10 -- sc12, and sc14 -- sc17 as the play target, and finally return to scenic spot sc7. The optimized route by using the ITLBO algorithm proposed in this paper is sc7 → sc4 → sc5 → sc6 → sc3 → sc2 → sc1 → sc8 → sc10 → sc11 → sc15 → sc17 → sc16 → sc12 → sc7, as shown in **Figure 6**.

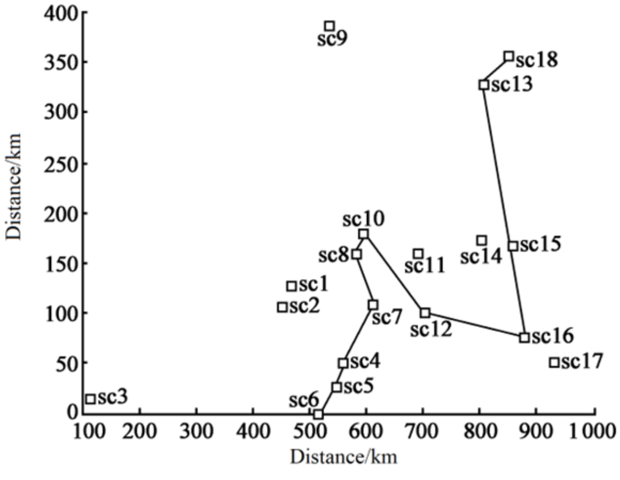

Figure 4. Tourism route optimization diagram of Experiment 1.

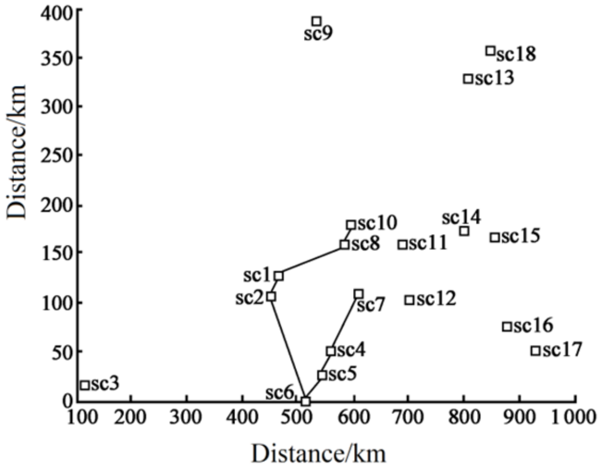

Figure 5. Tourism route optimization diagram of Experiment 2.

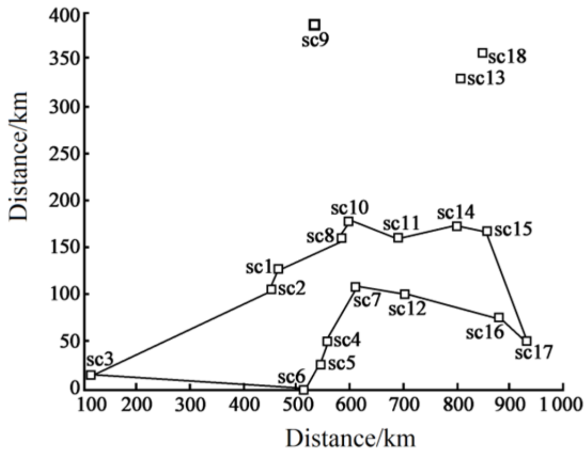

Figure 6. Tourism route optimization diagram of Experiment 3.

4.4. Comparison with traditional travel routes

The organization and design of general tourist routes depends on the actual traffic routes, and the organization and selection of "points" in tourist routes are the key factors to determine whether the routes are optimized or not. For most travel agencies, the design of travel routes is always centered on a certain point, and the routes are designed radiatively, which wastes tourists' time and leads to the phenomenon of "backtracking" everywhere. Using the algorithm provided in this study, the whole circuit of experiment 1 is about 419. 1 km, the total length of experiment 2 line is about 227.6 km, the total length of experiment 3 is about 541.6 km.

5. Conclusions

Optimization algorithm based on the improvement of teaching and learning, the Hanzhong area tourist traffic optimization and line organization has carried on the empirical study, through the simulation of tourist attractions, tourist's choice to calculate more ideal and efficient travel routes, and compared with traditional travel agencies circuit design, found that the algorithm design of the circuit has certain feasibility, It can provide reference for practical tourism traffic planning and route design, especially for self-driving tourists and individual tourists.

There are still the following areas to be further studied in this study. This study relies on the existing expressway traffic as the route design, without considering the railway, water transport and aviation traffic. This study considers that the visiting time and accommodation time of tourists are relatively fixed, and different situations are not considered. Only the principle of shortest travel time is considered in the route design, and the distance is positively correlated with the travel time, and the problem of travel cost is not considered. This study is mainly designed for self-driving tourists, but there is no in-depth study on the specific demand preferences and special needs of self-driving tourists. Therefore, the next step is to consider the travel costs in the travel schedule, further understand the demand characteristics of self-driving tourists, and design targeted, scientific and reasonable travel routes.

Conflict of interest

The authors declare no conflict of interest.

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