RESEARCH ON THE OPTIMAL INITIAL SHUNT STRATEGY
OF JIUZHAIGOU BASED ON THE OPTIMIZATION MODEL

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ABSTRACT. Tourism load imbalance is a serious problem in Jiuzhaigou, which may destroy the environment and reduce the feeling of tourists. A reasonable initial shunt strategy is the key factor in making the scenic become balance. So, this paper considers this problem by finding an optimal initial shunt strategy. An optimization model containing two flow models is built, which takes the total overload balance as objective. In order to solve this model and find the optimal initial shunt strategy, a hGA is proposed as solution method. Finally, a comparison analysis is conducted to show the efficiency of this model in remitting the local overload problem.

1. Introduction. According to statistic, tourism in China which benefits the transportation, accommodation, catering, entertainment and retailing sectors, has bloomed in the past few decades and generated nearly US $2 trillion in economic activity[1]. However, as rapid development of tourism making major contributions to nations economy, trade performance and prosperity, in them are hidden lots of environmental destruction. It shows clearly in Jiuzhaigou, which is a national park located in the Min Shan mountain range, Northern of Sichuan, South Western of China and was declared a UNESCO World Heritage Site in 1992. Tourists of Jiuzhaigou rose from 183000 in 1997 to 2530000 in 2007. Scenic ticket income increased from 14.53 million yuan in 1997 to 454 million yuan in 2007. As the development of tourism benefits the local economy in Jiuzhaigou, it also damages the natural and ecological environment. Both primeval forest and Five Flowers Sea have been seriously influenced. A serious problem led to this phenomenon is the local overload. However, a reasonable shunt program at the entrance can help to mitigate the local overload problem. So, how to choose a reasonable initial shunt program becomes one of the hottest topics in the tourism management.

Few papers have been involved in initial shunt strategy. As we know, the previous studies were almost concentrated on two aspects out of China. One is the traffic problems from departure to destination[11]. The other is based on the sustainable development[3]. The researches on transportation in national parks were focused on the mutual influence of environmental protection and tourist behavior. In his research, Steven R. Lawson studied the feasibility of the computer simulation to the management of social capacity in the National Park[9]. This is the prototype of the management of the internal traffic in scenic areas. Fay and Dave introduced

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the sightseeing bus system of Yosemite National Park[5][19]. Retzlaff introduced the public transport in Zion National Park[16]. Eaton et al. analyzed and assessed the feasibility of the public transport instead of the external traffic in British National Park[4], while Yoram Shifman et al. analyzed the demand of the scenic public transport system in detail[18].

The research on tourism in China is different because of the huge demands and the limitation of the tourism resources. Therefore the research consideration was given to the traffic problems both from departure to destination and the internal traffic problem in scenic area, as well. Wang et al. introduced the application of the Intelligent Tourism Transportation System (ITTS) in scenic area management[20]. Peng et al. discussed the intelligent transportation, operation scheme and vehicle scheduling algorithm in scenic area[12]. Sun studied the scenic area dispatching decision system based on RFID smart card. It divided the types of tourist by the path that tourist chooses, and gave the vehicle scheduling scheme using Genetic Algorithm (GA) [17]. In order to reduce the instantaneous load of scenic spots, and balance time and space distribution of tourists, Feng et al. studied the tourists peak time and space shunt navigation management of Jiuzhaigou which is based on Entropy Management and RFID. They intended to use RFID, eB3S and other information technologies, and designed diversion in the two dimensions of time and space for the scenic spots tourists. They established the time and space shunt navigation management model of peak travel period. The goal of their study is to increase the capacity of tourists of scenic spots, enhance the level of environmental protection and increase the satisfaction of the visitors[7]. Qiu et al. also studied the load balancing issues of Jiuzhaigou. They analyzed the spatial and temporal variation of tourists traffic in the scenic spots during the tourist season and indicated the imbalance of tourist distribution in time and space which leads to significant differences between the spots load. They provided ideas to analyze problems by building a mathematical programming model and making dynamic forecast scheduling and proposed to nest vehicle scheduling in forecast scheduling[15]. Qiu et al. studied the shunt problem based on cluster as well and found the shunt rate which goes along with the the capacity of the region[13]. Qiu et al. studied the diversion navigation management of time and space based on the control of complex system[14]. However, the details of the shunting strategy and the effectiveness of the schemes are not presented. Zheng et al. proposed the average shunt strategy[21], it is not the optimal strategy. In this paper, a simulink simulation model will be established and Genetic algorithm (GA) will be used to estimate the optimal shunt strategy.

2. Problem analysis. As we have discussed above, the overload of scenic is increasingly serious with the development of the tourism. The manager of Jiuzhaigou had proposed a previous scheme (eg. Three-Region Shunting) to deal with this problem. In this scheme, they assigned the tourists who arrived at Jiuzhaigou, to three spots (eg. Shuzhenggou, Rizegou and Zechawagou) as their start spots of their tour. But the performance was not very well. They find this scheme is useful only when the tourists number is less than 30 thousands. In order to further improve the performance, a new scheme named the Five-Region Shunting) is proposed. Compared with previous Three-Region Shunting scheme, this scheme increases two more spots for tourists selecting. Thus, the total five spots (Huohuahai, Xiniuhai, Jianzhuhai, Yuanshisenlin and Changhai) are be taken as the start spots. This scheme has improve the overload of scenic. But they also find that the density of
the tourists on a spot varies and the utilization of the spot is not ideally stable. The reason of this problem is that the initial shunting strategy of 16 major routes determined by Five-Region Shunting scheme is falseness [6]. So we can conclude that a better shunting strategy is key factor determining the performance of Five-Region Shunting scheme on reducing the overload of scenic. This paper researches the initial shunt strategy and finds the optimal shunt strategy which can remit local scenic overload without reducing the tourism scale for Jiuzhaigou.

The tourists flow among the spots in Jiuzhaigou is the foundation of the process to find optimal shunt strategy. The detailed description of the tourists flow is shown in Fig. 1

\[
x_3 = \sum_{i \neq 3} p_{i3} x_i \quad \text{(where } x_i \text{ refers to the tourists number of node } i, p_{i3} \text{ refers to the probability of the tourists number of node } i \text{ move to node 3).}
\]

3. The optimization model for initial shunt strategy. As we have analyzed, finding a best initial shunt strategy for Jiuzhaigou is the key factor to improve its tourists overload. This paper will build an optimization model to find the best initial shunt strategy. Some assumptions and symbols will be introduced before building the optimization model.

3.1. Assumptions. To construct an optimization model for finding the initial shunt strategy, the following assumptions are adopted.

(1) Tourist will visit all spots in Jiuzhaigou
(2) There is no waiting time such as waiting bus to next spot
(3) Tourist shall obey the arrangement of scenic

3.2. Notations. The following symbols are used in this paper:

(1) Index
\[i, j \text{ Index of spot in the scenic, } i, j = 1, 2, \cdots, N.\]
(2) Certain parameters
\[N \text{ Number of total spots in the scenic; }\]
\[TN \text{ The total tourists number in the scenic; }\]
Tourists average stay time on the spot $i$;
$c_i$ The capacity of spot $i$;
$BT = (bt_{ij})_{10 \times 10}$ The traveling time from spot $i$ to spot $j$ by bus;
$WT = (wt_{ij})_{10 \times 10}$ The traveling time from spot $i$ to spot $j$ by walking;
(3) Decision variables
$P = (p_{ij})_{10 \times 10}$ The shunt ratio matrix, where $p_{ij}$ indicates the shunt ratio from the spot $i$ to spot $j$.
(4) Auxiliary variables
$x_i(t)$ The tourists number which arrive at spot $i$ at time $t$,
$y_i(t)$ The total tourist number of scenic spot $i$ at time $t$.

### 3.3. The optimization model.

#### 3.3.1. Building hierarchical structure.
An obvious circuit may be appeared if we directly use the spots in scenic. For example, in the Fig.1, there are five spots. If they are used directly, a tour of 1-2-3-4-3-5 may appear. As we all know that the sub-tour of 3-4-3 is a circuit which may make the problem more complex as we do not know the arrival tourist number of spot 3. So in order to avoid this complex phenomenon, each spot shall be divided into several virtual points according to the routes tourist may select.

Take Jiuzhaigou as an example, its first spot (spot $i$) can be divided into four virtual points (eg. spot 1.1, spot 1.2, spot 1.3 and spot 1.4) according to the 16 routes. Based on the similar process, the other spots can be divided into several virtual points. The results of division are shown in Fig.2 and Table 1.

Figure 2. The Network Layer Diagram of Five Districts Diversion
### Table 1. The divided spots

| Scenic spot | The divided spots          |
|-------------|-----------------------------|
| 1           | 1.1, 1.2, 1.3, 1.4          |
| 2           | 2.1, 2.2, 2.3, 2.4, 2.5, 2.6|
| 3           | 3.1, 3.2, 3.3, 3.4          |
| 4           | 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8 |
| 5           | 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8 |
| 6           | 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8 |
| 7           | 7.1, 7.2, 7.3, 7.4          |
| 8           | 8.1, 8.2, 8.3, 8.4          |

#### 3.3.2. Tourists flow model.

According to the hierarchical structure of the scenic in Fig.2, the flow model is made of two parts. They are the initial flow model and the inter-scenic flow model. The initial flow model is the process that scenic manager uses scenic bus scheme to determine the initial shouting rate and send the tourists to five start points based on this rate from the entrance. The inter-scenic flow model is the process of tourists selecting their visiting order when they arrive at the start points.

Firstly, we will build the initial flow model. In this model, there are five spots named spot 2.1, spot 3.2, spot 8.3, spot 6.7 and spot 5.8. Tourists will be divided to five spots from the entrance spot 0. So the initial flow model can be represented as,

\[
x_{2,0}(t) = x_0(t - b_{t02}) \times p_{02} \\
x_{3,2}(t) = x_0(t - b_{t03}) \times p_{03} \\
x_{8,3}(t) = x_0(t - b_{t08}) \times p_{08} \\
x_{6,7}(t) = x_0(t - b_{t06}) \times p_{06} \\
x_{5,8}(t) = x_0(t - b_{t05}) \times p_{05}
\]

After the initial flow model being built, we will build the inter-scenic flow model based on the initial flow model. From Fig.2, we can find that there are four routes for tourists selecting when they take the spot 2.1 as the start point. According to investigation, the probability of selecting any routes is the same. That means the probability of selecting any a route from those four when taking spot 2.1 as the start point is 0.25. So the inter-scenic flow model of taking spot 2.1 as the start point can be represented as,

\[
\begin{align*}
x_{1,1}(t) &= x_{2,1}(t - w_{t21}) \times (0.25 + 0.25 + 0.25 + 0.25) \\
x_{3,1}(t) &= x_{1,1}(t - w_{t13}) \times (0.25 + 0.25 + 0.25 + 0.25) \\
x_{2,2}(t) &= x_{3,1}(t - w_{t32}) \times (0.25 + 0.25 + 0.25 + 0.25) \\
x_{5,1}(t) &= x_{2,2}(t - w_{t25}) \times 0.25 \\
x_{4,1}(t) &= x_{5,1}(t - w_{t54}) \\
x_{6,1}(t) &= x_{4,1}(t - w_{t46}) \\
x_{6,2}(t) &= x_{2,2}(t - w_{t26}) \times 0.25 \\
x_{5,2}(t) &= x_{6,2}(t - w_{t65}) \\
x_{4,2}(t) &= x_{5,2}(t - w_{t54}) \\
x_{8,2}(t) &= x_{2,2}(t - w_{t28}) \times (0.25 + 0.25) \\
x_{7,2}(t) &= x_{8,2}(t - w_{t87})
\end{align*}
\]
calculated by $-t_i$ spot, the tourist number of spot $i$ to Eq. (13).

At time $t$, simulated. There are two cases in calculating the tourist number of each spot. If time $t_{st_i} \leq t < t_{st_i} + \Delta t_i$ that tourist stays at the spot node, the tourist number of each spot can be represented as,

$$x_{out}(t) = x_{7.1}(t-bt_{710}) + x_{6.3}(t-bt_{610}) + x_{4.4}(t-bt_{410}) + x_{2.5}(t-bt_{510}) + x_{1.4}(t-bt_{110})$$

(13)

3.3.3. Aggregating the divided scenic spot. After the above processes, the tourist arrival numbers of all spots are determined respectively. However, the spots used in above processes are the virtual points according to the routes tourist may select. The results of them cannot be directly used. So we need to aggregate them to estimate the real spots arriving number of tourists at time $t$ according to the division results of all spots in Table 1. Take spot 1 as an example, the aggregating result can be represented as,

$$x_1(t) = x_{1.1}(t) + x_{1.2}(t) + x_{1.3}(t) + x_{1.4}(t)$$

(14)

3.3.4. Objective of the model. Tourists scheduling is to balance the tourist load of each spot and the whole scenic spot and then search the optimal shunt strategy for scenic, so we should build up a balance method. Firstly we need calculate the tourist number of each spot node at every time by the tourists flow model in Eq.(1) to Eq. (13).

By the tourists flow model, the arriving number $x_i(t)$ in spot $i$ at time $t$ will be simulated. There are two cases in calculating the tourist number of each spot. If time $t$ less than the time $t_{st_i}$ that tourist stays at the spot node, the tourist number of spot $i$ is summation of the arriving number from time $0$ to time $t$, so it can be calculated by

$$\sum_{k=1}^{t} x_i(t)$$

(15)

The other case is that time $t$ more than the time $t_{st_i}$ that tourist stays at the spot, the tourist number of spot $i$ is summation of the arriving number from time $t - t_{st_i}$ to time $t$, so it can be calculated by

$$\sum_{k=t-t_{st_i}}^{t} x_i(t)$$

(16)

In summary, the number of tourist $y_i(t)$ in spot node $i$ at time $t$ can be calculated as follows,

$$y_i(t) = \begin{cases} 
\sum_{k=1}^{t} x_i(t), & 0 < t \leq t_{st_i} \\
\sum_{k=t-t_{st_i}}^{t} x_i(t), & t > t_{st_i}
\end{cases}$$

(17)
Thus, the whole spots tourist number can be got by Eq.(17). The load $l_{ri}(t)$ is rate of tourist number with the limited capacity $c_i$ on spot $i$, so it can be calculated by

$$l_{ri}(t) = \frac{n_i(t)}{c_i}, i = 1, 2, \cdots N$$  \hspace{1cm} (18)$$

Then, the load balance $lb(t)$ at time $t$ can be calculated by

$$lb(t) = \sum_{i=1}^{N} (lr_i(t) - \frac{1}{N} \sum_{k=1}^{N} lr_k(t))^2$$  \hspace{1cm} (19)$$

Thus, the load balance in a day can be calculated by

$$lb = \sum_{t=1}^{T} \sum_{i=1}^{N} (lr_i(t) - \frac{1}{N} \sum_{k=1}^{N} lr_k(t))^2$$  \hspace{1cm} (20)$$

So the Scheduling optimization model can be represented to a programming problem shown as follow,

$$\min J = lb$$

$$s.t. \begin{cases} X(t) = \sum_{i \in \Theta} P(t-1)X(t-i) \\ \sum_{i=1}^{n} p_{ij}(t) = 1, j = 1, 2, \cdots, n \\ p_{ij}(t) \geq 0, j = 1, 2, \cdots, n, i = 1, 2, \cdots, n \\ b = \sum_{t=1}^{T} \sum_{i=1}^{N} (lr_i(t) - \frac{1}{N} \sum_{k=1}^{N} lr_k(t))^2 \\ lb(t) = \sum_{i=1}^{N} (lr_i(t) - \frac{1}{N} \sum_{k=1}^{N} lr_k(t))^2 \\ lr_i(t) = \frac{n_i(t)}{c_i}, i = 1, 2, \cdots N \end{cases}$$  \hspace{1cm} (21)$$

4. Solution method for estimating optimal initial shunt rate. To evaluate the efficiency of a control system, there are several methods to manipulate. They are Analytic Hierarchy Process (AHP), Delphi Method and Gray Correlation Analysis Evaluation Method[2][10], etc. But these methods cannot used to evaluate the overload of scenic and its balance. In this paper a complex evaluation method is proposed in Eq.(16), Eq.(17) and Eq.(18). Then a scheduling optimization model is generated (seeing Eq.(21)). As the model is very complex which contains simulation model for simulate the tourists flow in scenic, solution method is very important.

In this paper, a hGA is proposed which combining the GA with DE. The GA is stochastic technique which may be used for estimation of unknown parameters in a system and is based on computer simulations of the biological evolution[8]. DE is a very popular evolutionary algorithm and exhibits remarkable performance in a wide variety of problems from diverse fields. So the hGA combining GA with DE will perform well in searching the optimal shunt strategy for the scenic.

The hGA contains five important operators. They are selection operator, crossover operator, mutation operator, rand/1 operator and best/1 operator.

The fitness function of hGA is the objective of model, seeing the Eq.(20). The chromosome of hGA for the problem considered in this paper can be represented as the optimal shunt rates from entrance to five start points.

The summary of hGA is shown in Fig 3.
There are several steps to generate the optimal initial shunt rate.

**Step 1.** Create initial 120 chromosomes of hGA for schemes randomly.

**Step 2.** Select the optimal 40 chromosomes (A) as Parents.

**Step 3.** Create 20 new chromosomes (B) by crossover the 20 chromosomes, and create 20 new chromosomes (C) by mutation the 20 chromosomes (A).

**Step 4.** Create 20 new chromosomes (D) by Rand/1 based on chromosomes (A), and create 20 new chromosomes (E) by Best/1 based on chromosomes (A).

**Step 5.** Take (A, B, C, D, E) into model and calculate the load balance (lb) of each arriving tourist distributions.

**Step 6.** If the fitness function satisfies the condition, then output the optimal shunt rate and stop. Else, go to Step 2.

5. **Empirical analysis.**

5.1. **Presentation of case problem.** The case used in this paper is the famous scenic in China, named Jiuzhaigou which contains 8 famous spots (Pengjintan, Huohuahai, Xiniuhai, Jinghai, Jianzhuhai, Yuanshishenlin, Wucaichi and Changhai).

5.2. **Results and discussion.** In order to show the function of the proposed model, we take the tourists arrival data on August 12, 2012 to the model. Then run the solution algorithm hGA on the MATLAB for 50 times and take their mean value as the final results shown in Table 3.

After obtaining the optimal shunt strategy, the overload can be calculated. Take the optimal shunt strategy into Eq.(20), then get that the total load balance of this shunt strategy is 15164.
Table 2. Scenic spots capacity and stay time of passenger

| Spots               | Capacity | Stay time |
|---------------------|----------|-----------|
| Spot 1 (Pengjintan)| 144      | 10        |
| Spot 2 (Huohuahai) | 239      | 20        |
| Spot 3 (Xiniuhai)  | 950      | 30        |
| Spot 4 (Jinghai)   | 350      | 15        |
| Spot 5 (Jianzhuhai)| 414      | 20        |
| Spot 6 (Yuanshishenlin)| 480  | 30        |
| Spot 7 (Wucaichi)  | 60       | 15        |
| Spot 8 (Changhai)  | 268      | 30        |

Table 3. The optimal shunt strategy

| The range of time | Huohuahai | Xiniuhai | Changhai | Yuanshishenlin | Jianzhuhai |
|-------------------|-----------|----------|----------|----------------|------------|
| 7:00-7:50         | 0.1729    | 0.3507   | 0.2790   | 0.1213         | 0.0761     |
| 7:50-11:40        | 0.2387    | 0.2252   | 0.2382   | 0.1080         | 0.1899     |
| 11:40-19:00       | 0.2778    | 0.2549   | 0.1361   | 0.0073         | 0.3239     |

Table 4. The total load balance

| Strategies         | Total load balance | Improve degree (%) |
|--------------------|--------------------|--------------------|
| Optimal shunt strategy | 15164              | —                  |
| Average shunt strategy | 16140             | 6.04%              |
| Current shunt strategy | 16824             | 9.87%              |

5.3. Model comparison. In order to convince the reader that the optimal shunt strategy generated by this paper can remit local overload better than the existing two shunt strategies (average shunt strategy and the current used shunt strategy in Jiuzhaigou), a comparison analysis is conducted among our method, average shunt strategy and the current used shunt strategy in Jiuzhaigou. The comparison results are shown in Table 4 and Fig. 4.

Table 4 shows that the total load balances of our method, Average shunt strategy and Current shunt strategy are 15164, 16140 and 16824 respectively. It is obvious that the result of our method performs better than other two methods. By calculating the improve degree compared with average shunt strategy and current shunt strategy, we can find that the optimal shunt strategy obtained by our method has improved 6.04% and 9.87% in performance compared with average shunt strategy and current shunt strategy respectively.

Furthermore, Fig. 4 shows the detailed results of our method, Average shunt strategy and Current shunt strategy. In the Fig.4, the red line shows the load balance of current shunt strategy at any time in a day. From this line, we can find that the maximum load balance has exceeded 140, almost reached. That means the performance of this strategy is very bad. The yellow line in Fig.4 shows the load balance of Average shunt strategy at any time in a day. From this line, we can find that the maximum load balance decreases to 120. That means this strategy is still not very good. The blue line in Fig.4 shows the results of our method. Compare
these three lines, we can conclude that the optimal shunt strategy performs better than other methods.

6. Conclusion. Tourism load imbalance among the spots in Jiuzhaigou is a very common phenomenon. This phenomenon will cause the environment pollution, decreasing tourists visiting and wasting of scenic resources. So, how to make Tourism load balance is the key problem in scenic management. This paper considers this problem by finding an optimal shunt strategy for scenic to make the tourism load balance. Based on the analysis of the Jiuzhaigous tourism route, route structure and stay time, an optimization model is built, which takes the total overload balance as the objective and uses two flow models to simulate the tourists activity in scenic. In order to search the optimal shunt strategy, a hGA is proposed as solution method. Finally, an empirical Analysis is conducted to show the effectiveness of our method.

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RESEARCH ON THE OPTIMAL INITIAL SHUNT STRATEGY

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