Assignment of Rafting Traffic from the Views of Passengers and Managers

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Abstract

The utilization of the campsites would reach maximization if we can establish a rational time schedule. Computer simulation had been introduced into the rafting traffic. Our work is to offer a time schedule with the help of mathematical deduce. This paper presents the descriptions of two models to establish the time schedule for the rafting traffic. Model 1 is built from the view of passenger, which the purpose is to best satisfy the diverse demands of the passengers (i.e., the options of the travelling times and forms of transportations). The Greedy Randomized Adaptive Search Procedure (GRASP) is introduced to simplify the solution and provide a quick local optimal solution that approaches the global optimal solution. In Model 2, we stay on the side of river manager, who want to utilize the campsites in the best way possible and yield minimal contact between the boats. By giving priority to the former objective, we introduce the latter objective to simplify the solution of Model 2.

Contents

1 Introduction

In order to develop the best schedule for Camping along the Big Long River, the following background is worth mentioning.

1.1 As the river is inaccessible to hikers, the only way to enjoy scenic views and exciting white water rapids is to take a river trip that requires several days of camping. The river has the length of 225 miles and is downstream. In the consideration of two forms of transportations, i.e., oar-powered rubber rafts and motorized boats, the whole trip needs 8–16 nights. Note that the average rates for oar-powered rubber rafts and motorized boats are 4 mph and 8 mph, respectively.

1.2 In order to enjoy a wilderness experience, it is necessary to minimize the contact with other groups of boats on the river. At the same time, we need to utilize the campsites in the best way possible to bring more visitors to river rafting.

1.3 In 1972, the Park Service inaugurated a research program on the ecological and sociological aspects of human use the river including motor rafting[1]. In 1981, the Cooperative National Park Resources Study Unit at the University of Arizona was asked to adapt the Wilderness Use Simulation Model[2] to whitewater boating through Grand Canyon National Park. In 1986, a modification of the Shechter-Lucas Wilderness Use Simulation Model, which is used for peak season boating on the Colorado River through Grand Canyon National Peak, USA, is evaluated as a tool for making management decisions[3]. In 1996, some work had developed a related intelligent-agent based program to study the interactions between jeep tours, bicyclists and hikers in a recreational setting in Sedona, Arizona[4].

1.4 However, very few researcher analysis and fix the problem in the consideration of resource allocation. In this study, we begin with an optimization problem and construct two different models so as to maximize the utilization of the campsites and minimize the contacts between the groups of boats.

2 The Description of Problem

2.1 What problems we are confronting

For the Big Long River with the length of 225 miles and downstream waterflow, passengers can take either oar-powered rubber rafts, which travel on average 4 mph or motorized boats, which travel on average 8 mph. The trips range from 6 to 18 nights of camping on the river, start to finish. Currently, the opening period of the Big Long River is six months (i.e., 180 days). There are X trips and Y campsites on the river. Therefore, the problem is how to schedule an optimal mix of trips, of varying duration (measured in nights on the river) and propulsion (motor or oar) that will minimal contact with other groups of boats on the river as well as utilize the campsites in the best way possible.

2.2 What we do to solve these problems

Since passengers usually travel in the day and rest in the night, it is realistic to assume a fixed interval to the sailing time for each day. From different views, we construct two different models in order to maximal utilize the campsites. The starting point of Model 1 is how to maximize the sailing frequency within six months and provide alternative transportations to the passengers, based on the hypothesis that the period of passengers demanding for travel follow a uniform distribution. For the convenient management and performance of managers in practice, we assume in Model 2 the travel stops for different travelling days and the sailing times for each day are both fixed. In this model, we regard the groups of passengers and the utilization of campsites are the 1st-level objectives, which determine the number of trips for each day. On the basis of the optimization of the 1st-level objective, we schedule the form of transportation for the passenger group in order to minimal contact with other groups of passengers. This is the optimization of the 2nd-level objective.

3 Terms and Definitions

- Travel stop: If the passenger group in a boat occupies a campsite, the campsite is considered as the travel stop of the boat.
- Common node: Different boats have the same travel stops at the same time.
- Travel mode: Various combinations of travel days and transportations.
- Ship path: the locations used to record the travel stops of the boat.

4 Basic Assumptions

- Sailing time: 8:00 – 18:00;
- Every passenger group doesn't change their boat on the trip;
- Every passenger group can occupy the same campsite for no more than one night;
- The last campsite is the destination, i.e., the whole trip can be uniformly divided into Y segments;
- The velocities of two forms of transportations are constant;
- Every passenger group can reach the destination within the validity period.

5 Models

5.1 Model 1

5.1.1 The model Description

We first number the campsites to create a unidirectional transmission state set. Then, we regard the six month period as a single entity, and describe the state change for each boat. Finally, the states of every boat within the six months are recorded in a matrix. According to the fact that no two groups of passengers can occupy the same campsite at the same time, the restriction of the accommodation period and the distance scale between the adjacent state points of each boat, we can construct a goal programming that maximum the number of all the trips in the six month period.

5.1.2 Additional Assumptions

1. The contact between the boats is not considered.
2. Passengers' requests for travel days obey the uniform distribution in the intervel of [6,18].

5.1.3 Symbols

- j: the label of the campsite;
- m: the total number of trips within the validity time;
- a_i: the sailing state for the i-th boat;
- a_{it}: the sailing state for the i-th ship in the t-th day;
- A: the state matrix of all the sailing ships within 180 days;
  $i = 1, 2, \ldots, m$; $t = 1, 2, \ldots, 180$; $j = 1, 2, \ldots, Y$;

$$a_{it} = \begin{cases} j, & \text{the } j\text{boat stop at the -th travel stop} \\ 0, & \text{no trip or reaching the destination} \end{cases}$$

5.1.4 Model Establishment

Object Function

For the purpose of utilizing the campsites in the best way possible, we need to sail as much boats as possible ,in order to schedule the maximum passengers.

$$\text{MAX } m$$

Constraint

(1) Two different groups of passengers can not occupy the same campsite at the same time.

The state change of the i-th boat is:

$$a_i = \{a_{i1}, a_{i2}, \ldots, a_{it}, \ldots, a_{i180}\}$$

Then the state matrix of all the boats is:

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1180} \\ a_{21} & a_{22} & \cdots & a_{2180} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{m180} \end{pmatrix}$$

As two different groups of passengers can not occupy the same campsite at the same time, the number of boats at campsite j would not exceed 1:

$$\text{number}(j) \leq 1$$

(2) Considering the limitation of the sailing time for every day, the distance between the two adjacent states has a range.

The maximum sailing time is 10 hours per day, therefore the maximum sailing distance of two transportations are 40 miles and 80 miles, respectively, i.e., the distance of the boats between the adjacent two days ranges from 0 to 80 miles. This can be written as follows:

If $a_{ip_i-1} = 0$, $a_{ip_i} \neq 0$; $a_{iq_i} \neq 0$, $a_{iq_i+1} = 0$ $(i = 1, 2, \ldots, m)$,

$$0 \leq (a_{it+1} - a_{it})\frac{225}{Y} \leq 80$$

then

$$a_{it+1} > a_{it},\ t = p_i - 1, p_i, \ldots, q_i - 1.$$

(3) The accommodation periods of the passengers are between 6 and 18 nights.

If $a_{ip_i-1} = 0$, $a_{ip_i} \neq 0$; $a_{iq_i} \neq 0$, $a_{iq_i+1} = 0$ $(i = 1, 2, \ldots, m)$, the accommodation period of the i-th passenger group is $q_i - p_i + 1$, then the constraint is

$$6 \leq q_i - p_i + 1 \leq 18.$$

The option of the departure time and the forms of transportations

(1) The option of the leaving time

For the i boat with the railing state of $a_i = \{a_{i1}, a_{i2}, \ldots, a_{i180}\}$ and $a_{ip_i-1} = 0$, $a_{ip_i} \neq 0$, a_{ip} is the state of the boat for the first night, and the boat only start sailing at the p_i day. Meanwhile, $a_{iq_i-1} \neq 0$, $a_{iq_i} = 0$ indicates the boat stop sailing at the q_i day. Therefore, the total accommodation nights are $q_i - p_i + 1$.

(2) The option of the forms of transportations

The form of transportations is determined according to the distance between the adjacent states during the trip. As the maximum sailing distance of the oar-powered rubber rafts and motorized boats are 40 and 80 miles, respectively,

- $40 \leq (a_{it+1} - a_{it})\frac{225}{Y} \leq 80$, the motorized boat is the only option;
- $0 < (a_{it+1} - a_{it})\frac{225}{Y} \leq 40$, either boats are the option.

$$t = p_i - 1, p_i, \ldots, q_i - 1.$$

5.1.5 Solution

Although the basic local search approach can improve the solution in part by multiple-starts, the efficiency of the approach is quite low because of the randomicity of the initial solution [5]. Recently, a new optimization algorithm, named Greedy Randomized Adaptive Search Procedure (GRASP), can produce various initial solution with good quality to improve the capability [6].

Greedy Randomized Adaptive Search Procedure

Step 1 Define the total time set as $V0 = (1, 2, \ldots, 180)$; Define the continuable departure time set at the same day as $V1$; $V2 = V0 - V1$ represents the un-continuable departure time set at the same day; Define the path set as A;

Step 2 Set the initialization $V1 = V0$ and $V2 = [\,]$;

Step 3 Choose vt from $V1$;

Step 4 Creat a path at in random according to vt.

Step 5 If no node can be found between at and any one element of A, then put at into A and go to the next step; otherwise, go to Step 4. If there is still a node after 5 loops, then vt is considered as the un-continuable departure time;

Step 6 Remove vt from $V1$ and meanwhile put vt into $V2$;

Step 7 Go to Step 3 until $V1 = [\,]$ and $V2 - V0$.

The method of producing path a_t

(1) At the time of vt, create a random integer p which follows the uniform distribution in the interval of $[\,6, 18\,]$;

(2) Equably divide $[\,1, Y\,]$ into p intervals, then randomly choose integers $b_1, b_2, \ldots, b_p$ from each interval, and $a_t = \{b_1, b_2, \ldots, b_p\}$ For any a_t, $(b_{i+1} - b_i) * (225/Y) < 225 * (2/p) < 225 * (2/6) < 80$, thus the abovementioned method is feasible.

5.1.6 Results and Analysis

The above-mentioned process is realized with Mathematic program (see Appendix A). We thus obtain the trip number for each day as well as travel modes (see Appendix C and D). A represents that the two transportations are both optional, while B represents that motorized boats are compulsory. Here we choose the first 18 days shown as table 1:

Table 1: Time schedule of the first 18 days

Transportations	1	2	3	4	5	6	7	8	9
A	2(13, 11)		1(12)	2(10, 15)	1(10)	1(13)	1(9)	1(9)	2(12,16)
B	4(6, 7, 8, 9)	1(7)	1(9)	2(6, 8)	1(6)	2(6, 7)	2(6,7)	1(7)	2(6,7)
Transportations	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
A	2(11, 18)	1(11)		2(7,15)	1(10)	1(13)			3(6, 11, 11)
B	1(7)	1(6)	1(6)	2(6,9)	1(8)	1(6)	1(6)	3(6, 6, 8)	1(8)

The elements in the table are the combination of the ship number and travel modes, e.g. 2 (11, 13) and 4 (6, 7, 8, 9) represent that the total ship number is 6 for the first day, and two types of transportations can be optional chosen on the 11th and 13th days, while only motorized boats can be utilized on the 6th,7th,8th,and 9th days.

The bar chart for the first 18 days is plot with EXCEL, see Figure 1:

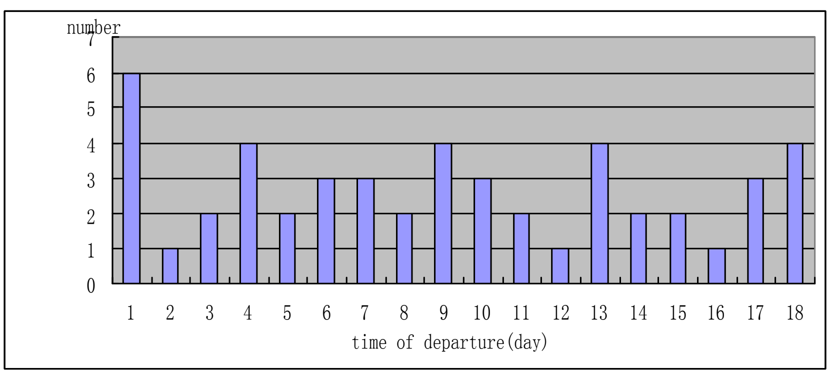

Figure 1: The bar chart of the first 18 days

X-coordinate represents the ship time, Y-coordinate represents the trip number, and the height of the bar chart represents the frequency. As shown in the Fig. , we can find that the trips of the first 18 days are 6, 1, 2, 4, 2, 3, 3, 2, 4, 3, 2, 1, 4, 2, 2, 1, 3, and 4.

The diagram of 180 days plot with Mathematic,see Figure 2:

The path diagram of the first 18 days is plot with Mathematic, see Figure 3:

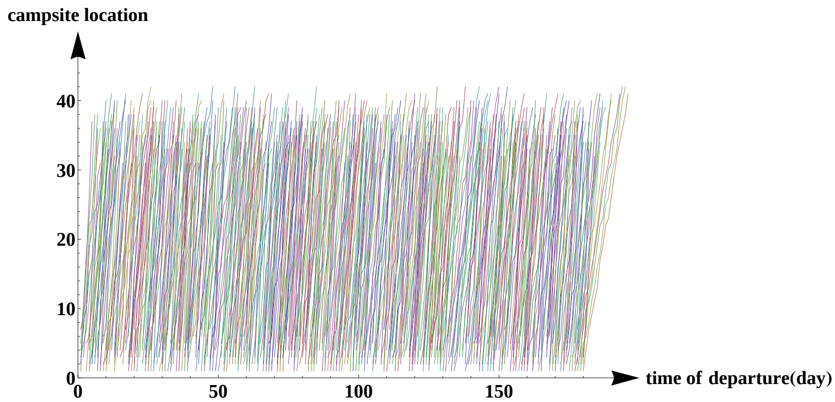

Figure 2: Path of 180 days

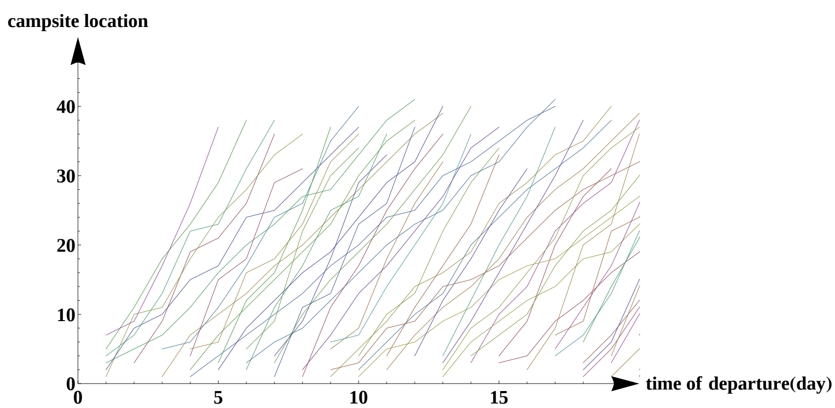

Figure 3: Path of the first 18 days

Each polyline represents the travel path of one boat, and the salient points are travelling stops and the corresponding times are the stopping moment.

5.1.7 Strengths and Weaknesses

Strengths: In reality, we hope more options of travel periods and forms of transportation. The construction of Model 1 has more humanity since it has respect to the various demands of passengers to the times and transportations.
Weaknesses: The model shows disregard for the contact between the boats. Besides, the model is inconvenient for the management of managers since its starting point is to satisfy the most requirements of passengers.

5.2 Model 2

5.2.1 The model Description

The groups of passengers and the utilization of campsites are regarded as the 1st-level objectives, which determine the trip number of the different kinds of passengers for each day. On the basis of the optimization of the 1st-level objective, we schedule the form of transportation for the passenger group in order to minimize contact with other groups of passengers. This is the optimization of the 2nd-level objective.

In Model 2, we first define a 0/1 variable to describe whether the campsites is utilized. Since the utility ratio of the campsites is proportional to the total accommodation nights of the campsites, the sum of the 0/1 variables can be used to describe the utilization of the campsites. As the locations of the campsites are assumed in fairly uniformly distribution throughout the river corridor, we adopt the time description method to record the time that the passenger group arrive and leave the different campsites for the purpose of fixing the counting problem of the contact of different groups of passengers. In such a way, we can describe the contact issue of different groups of the passengers and thus construct a time cyclic iteration optimal model.

5.2.2 Symbols

- m: the total number of trips during the valid time;
- I: the trip sets on the river route;
- K: the campsite sets on the river route;
- E: the interval sets formed by any two adjacent campsites;
- Ψ: the time set that the passengers are permitted to travel on the river route;
- $D_{i,k}$: the moment for the i-th passenger group arriving in the k-th campsite;

- $F_{i,k}$: the moment for the i-th group of passengers leaving from the k-th campsite;
- δ_{ik}: the labels of campsites for the i-th passenger group at the k-th campsite. If the i-th passenger group occupy the k-th campsite, $\delta_{ik} = 1$, otherwise, $\delta_{ik} = 0$;
- $[f_i^s, f_i^z]$: the leaving time domain for the i-th passenger group at the k-th campsite;
- $[d_i^s, d_i^z]$: the arriving time domain for the i-th passenger group at the k-th campsite;
- $[c^s, c^z]$: the time window of the passengers, i.e., the time period which passengers can not sailing.

5.2.3 Model Establishment

Object Function

(1) The groups of passengers and the utilization of the campsites

The total number of the trips during the valid time is m; The utilization of the campsites depend on the total accommodation nights of the passenger group, which is termed by ω, then

$$\omega = \sum_{i=1}^{X} \sum_{k=1}^{Y} \delta_{ik}$$

The more passenger groups, the more economic benefits for the Big Long River. Therefore we expect the maximum passenger groups in the bearing capacity of the river. While the biggest utilization ratio of the campsites reveals the full exploitation of the resources. Considering both of the above-mentioned indicant, we can define the utility function as follow:

$$F = m * \omega = m * \sum_{i=1}^{X} \sum_{k=1}^{Y} \delta_{ik}$$

(2) The contact frequencies P of the different groups of passengers

As shown in Figure 4, if the contact occurs, there is one interval $[k, k+1]$ which make at least two groups of passengers contact each other. In other words, at least two groups of passengers arrived at the same point A_k during the interval $[k, k+1]$, and $A_k \in [k, k+1]$, $[k, k+1] \in E$. As shown in Figure 5, the X ordinate represents time, and Y ordinate represents the location corresponding to the time. If two groups of passengers i and i' contact each other, the curves of the two groups of passengers l and l' would intersect between the interval $[k, k+1]$. The intersectant condition of the two curves is found as follow: the departure time of the passenger group i' from campsite k is not later than the time of the passenger group i from campsite k, meanwhile the arriving time of the passenger group i' at campsite $k+1$ is not earlier than the leaving time of the passenger group i from campsite $k+1$, and vice versa.

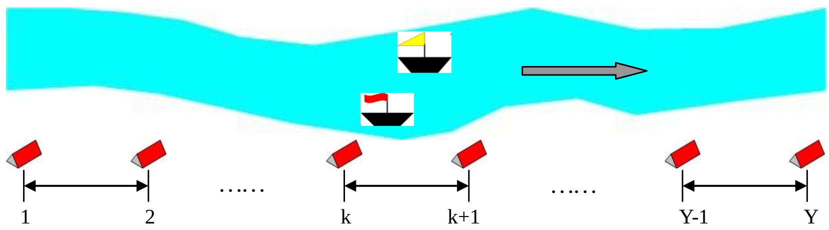

Figure 4: Virtual picture

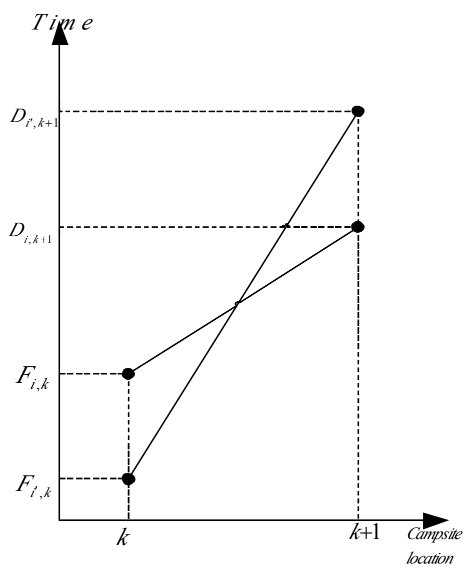

Figure 5: Coodinate chart of the connect situation

The mathematical expression that two groups of passengers contact each other between the interval $[k, k+1]$ can be written as follow:

$$F_{i',k} \leq F_{i,k}$$
$$D_{i',k+1} \geq D_{i,k+1}$$

Defining

$$P_{i,i',k} = \begin{cases} 1, & \text{if } F_{i',k} \leq F_{i,k} \text{and} D_{i',k+1} \geq D_{i,k+1} \\ 0, & \text{otherwise} \end{cases}$$

The total contact frequencies is then $P = \sum_{i,i' \in I} \sum_{k=1}^{Y-1} P_{i,i',k}$.

Therefore, the object functions are

(1) $F == m * \sum_{i=1}^{X} \sum_{k=1}^{Y} \delta_{ik}$ (1^{st}-level objective function)
(2) $\min P = \sum_{i,i' \in I} \sum_{k=1}^{Y-1} P_{i,i',k}$ (2^{nd}-level objective function)

Constraint

(1) The travelling time T_i of the passenger group i

δ_{ik} is the label of the i-th passenger group at the k-th campsite. If the i-th passenger group occupy the k-th campsite, $\delta_{ik} = 1$, otherwise, $\delta_{ik} = 0$. For all the δ_{ik} with the fixed i, the sum of $k = 1, 2, 3, \ldots, Y$ is the total camping frequencies of the passenger groups. As the camping time is one night, the travelling time of the passenger group i is $T_i = \sum_{k=1}^{Y} \delta_{i,k}$, which ranges from 6 to 18 nights. Therefore, the constraint of the travelling time of passenger group is shown as follows

$$6 \leq T_i = \sum_{k=1}^{Y} \delta_{i,k} \leq 18$$

(2) The arriving and departure time of the i-th passenger group at the k-th campsite

The passenger group only can sail during a certain time period of one day, we thus convert the times of a day into fraction, e.g., 18:00 in the 10^{th} day can be represented by $10\frac{3}{4}$. The obtained fractional time subtracting the integer equals the fractional moment of that day. This can be used to judge whether the passenger group can sail or not. The arriving time $D_{i,k}$ and leaving time $F_{i,k}$ of the i-th passenger group at the k-th campsite satisfy the following constraint

$$D_{i,k} - [D_{i,k}] \in [f_i^s, f_i^z]$$

$$F_{i,k} - [F_{i,k}] \in [d_i^s, d_i^z]$$

If the i-th passenger group does not occupy the k-th campsite, i.e., $\delta_{ik} = 0$, the arriving and departure time of the i-th passenger group are the same, i.e., $D_{i,k} = F_{i,k}$.

If the i-th passenger group occupies the k-th campsite, i.e., $\delta_{ik} = 1$, the i-th passenger group will occupy the k-th campsite for one night and set out tomorrow, obviously $D_{i,k} \neq F_{i,k}$. Meanwhile, if i-th passenger group occupy the k-th campsite for at least $c^z - c^s$ hours. Then $\delta_{ik} = 1$, the constraint is:

$$F_{i,k} - D_{i,k} \geq c^z - c^s$$

(3) One campsite can be occupied by only one passenger group at the same time

If the i-th passenger group occupies the k-th campsite, written as $[D_{i,k}] = m$, then $[F_{i,k}] = m + 1$. Assuming that $L = \{i|[F_{i,k}] = m + 1, [D_{i,k}] = m, m = 1, 2, 3, ldots, 180\}$, there would be constraint as follows:

$$\sum_{i \in L} \delta_{ik} \leq 1$$

(4) The sailing velocity of the passenger group

The i-th passenger group leaves from the k-th campsite at $F_{i,k}$ and reaches to the $k + 1$-th campsite at $D_{i,k+1}$. As the velocity is constant,

$$D_{i,k+1} - F_{i,k} = \frac{S_{k,k+1}}{v_i}$$

where $S_{k,k+1}$ and $|S_{k,k+1}|$ is the distance between the k-th and $k + 1$-th campsites, and v_i is the average sailing velocity of the i-th passenger group.

(5) The constraints of departure and arriving times for all the passenger group

In order to guarantee that all the passengers can finish the travel within the valid time, the departure and arriving times for all the passenger groups at any campsite are required in the time set that the passengers are permitted to travel on the river route, i.e.,

$$D_{i,k} \in \Psi, \; F_{i,k} \in \Psi.$$

5.2.4 Solution

Solution algorithm of the 1st-level objective function

Step 1 Two-dimensional array B with the size of $180 * 45$ is defined to record the usage of 45 campsites within 180 days. The corresponding elements are 1 when these campsites are occupied, otherwise, the corresponding elements are 0. Defining the integer variables as i and j, travel stop array as A, and the iterations as n.

Step 2 Travel stop array A, that meets the constraint, is randomly generated. The Integers from 6 to 18 are randomly arrayed as D;

Step 3 According to the travel stop array A and the occupancy of campsites B, the boats are considered whether to send in the order of D. Meanwhile, B is updated. Record the number of groups of sailing boats, usage of campsites and the program of dispatching;

Step 4 Go to step (3) for 1-180-day.

Step 5 Go to step (2), choose and update the superior values of the number of groups of sailing boats, usage of campsites and the program of dispatching;

Solution algorithm of the 2nd-level objective function

Step 1 First of all, according to the travel program produced from the 1ST-level objective function, the traveling distance can be calculated for each group of passengers in one day. If the maximum value of traveling distance is greater than the threshold that rubber rafts can travel in one day, the group of passengers are required to use motorized boats;

Step 2 For the remaining passengers, one day is used as a unit. We traverse the velocity of dispatching boats in that day and and record the corresponding number of contacts, from which we can choose the optimal program. The procedures are ordinally repeated until 180 days are all traversed.

If the number of sailing passengers is t, the complexity of the above algorithm is $n * 2^t$. Since the value of t is less than 16, this algorithm is polynomial.

5.2.5 Results and Analysis

The above-mentioned process is realized with C# program (see Appendix B).
(1) When we obtain the local optimal solution, the number of trips and the total number of the utilization of campsite are shown in the following table 2:

Table 2: The optical solution of model 2

Number of Trips	Total utilization number of campsites	The utilization ratio of campsites
638	7074	87.30%

The results reveal that the total number of the utilization of campsite and the utilization ratio of campsite are 7074 and 87.3%, respectively, when the number of the trips is 638. By now the utility function yield the optimal value.
(2) Meanwhile, we can obtain the trip number for everyday and the travel modes within six months. C and B represent the choices of rubber rafts and motorized boats, respectively. Here we choose the first 18 days, see table 3:

The elements in the table are the trip number and travel modes of the boat with corresponding propulsion for each day. For example, the first element in the table (i.e., 3 (6) and 1 (12)) represents that the number of the dispatched motorized boats, which leave on the first day and are with 6 travel days, is 3, while that with 12 travel days is 1; 1 (6), 1 (9), 1 (10) and 1 (12) represent that the numbers of the dispatched rubber rafts with 6, 9, 10, 12 travel days on the first day are all 1. By adding the number of the motorized boats and the rubber rafts, we can obtain the total number of the ships on the first day is 8.
(3) We plot the bar chart for the trip number in the first 18 days with EXCEL, see Figure 6:

X-coordinate represents the ship time, Y-coordinate represents the ship number, and the height of the bar chart represents the frequency. From the Fig. we can see that the trip number of the first 18 days are 8, 6, 5, 5, 4, 5, 5, 5, 4, 5,

Table 3: Time schedule of the first 18 days

Transportations	1	2	3	4	5	6
B	3(6) 1(12)	2(6) 1(7)	1(6) 2(7)	1(6) 1(7)	1(7) 1(13)	2(6) 1(8)
C	1(6) 1(9) 1(10) 1(12)	1(10) 2(12)	1(12) 1(15)	1(7) 2(12)	2(16)	1(12) 1(14)
Transportations	7	8	9	10	11	12
B	3(6)	2(6) 1(8)	2(6)	1(6) 1(7) 1(8)	2(6) 2(8)	1(6) 1(7)
C	1(14) 1(16)	1(12) 1(14)	1(14) 1(16)	1(16) 1(17)	1(6) 1(18)	1(11) 1(17)
Transportations	13	14	15	16	17	18
B	2(6)	2(6) 2(7)	1(6) 1(8)	1(6) 1(7) 1(8)	1(6) 1(7)	2(6) 1(16)
C	1(13) 1(16)	1(17)	1(17) 1(18)	1(18)	1(16)	2(16)

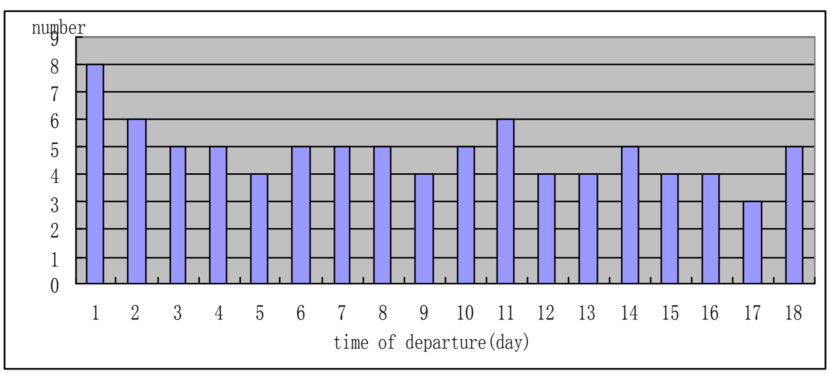

Figure 6: The bar chart of the first 18 days

6, 4, 4, 5, 4, 4, 3, and 5. The trip schedule in the Table shows that the contact frequency in the first 18 days is 42, which is the local optimal solution.

5.2.6 Strengths and Weaknesses

Strengths: In the multi-level objective model, we use the passenger group and the utilization of campsites as the 1st-level objective. On the basis of the optimization of the 1st-level objective, travel modes are arranged to achieve the minimum contact (i.e., the optimization of the 2nd-level objective). The complexity of calculation is then simplified.
Weaknesses: Since the diversification of the traveling modes (e.g., the options of leaving times for each day) is not considered in the solution, the model would not satisfy the personal demands of the passengers. Moreover, the solution for the model is local optimal. Therefore the global optimal solution is not guaranteed.

6 Conclusions

- In order to best satisfy the diverse demands of the passengers, by defining the number of campsites by 45, i.e., 45 campsites are evenly distributed throughout the 225 miles river corridor, 490 trips have reached the maximum value. The trip number for each day (see Appendix) and path diagram of the 490 trips are also yielded at the same time.
- From the view of river manager, by also defining the number of campsites by 45, the maximal number of trips is 638 within six months. The maximal utilization ratio of campsites is 87.3%.

7 Future Work

- The solutions for the Models only consider single ship time for each day. However, the ship time can be various in reality. We can design more complicated schedule according to the train schedule.
- We assume in the models that the passenger group occupies the same campsite for no more than one night. However, the passengers may spend more time in some tourist attractions. This means that the passengers might occupy the same campsite for more than one night, from which we can construct improved model.

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Appendix A

```
Y = 45;
A = {{0, 0}};
V0 = Table[i, {i, 180}];
V1 = V0;
V2 = {};
m = 0;
index = {1};
Do[
  If[V1 == {}, Break[], num = RandomInteger[{1, Length[V1]}];
   b = V1[[num]]];
  n = 0;
  Label[Place1];
  xi = RandomInteger[{6, 18}];
  y = Table[
    RandomInteger[{IntegerPart[(i - 1) Y/xi + 1],
      IntegerPart[i Y/xi]}], {i, 1, xi}];
  Ai = Table[{b + j - 1, y[[j]]}, {j, xi}];
```

```
  judge = 1;
  Do[
   Do[
    If[Ai[[jj]] == A[[ii]], judge = 0]
     , {jj, Length[Ai]}]
    , {ii, Length[A]}];
  If[
   judge == 1,
   A = Join[A, Ai]; index = Join[index, {xi}],
   n++; If[n <= 100, Goto[Place1], V1 = Drop[V1, {num}];
    V2 = Join[V2, {b}]]
   ];
  m = m + judge;
  , {i, 100000}];
result = Table[0, {i, m}];
p = 1;
Do[
  result[[i]] = Take[A, {p + 1, p + index[[1 + i]]}, All];
  p = p + index[[1 + i]], {i, m}];
Export["11.xls", A];
mark = {};
Do[
  temp = {0, 0, 0};
  temp[[1]] = result[[i]][[1, 1]];
  temp[[2]] = Length[result[[i]]];
  temp[[3]] = "A";
  temp1 = Join[{0}, Flatten[Take[result[[i]], All, {2}]]];
  temp2 = Table[temp1[[i + 1]] - temp1[[i]], {i, Length[temp1] - 1}];
  Do[If[temp2[[j]] > 8, temp[[3]] = "B"], {j, Length[temp2]}];
  mark = Join[mark, {temp}]
  , {i, Length[result]}];
Export["s11.xls", mark];
su = Table[0, {i, 180}, {j, 3}];
Do[
  su[[mark[[i, 1]], 1]]++;
  If[mark[[i, 3]] == "A", su[[mark[[i, 1]], 2]]++,
   su[[mark[[i, 1]], 3]]++]
  , {i, Length[mark]}];
Export["su11.xls", su]
ListLinePlot[result, PlotStyle -> Directive[Thick],
 AxesStyle -> Directive[Large, Bold, Arrowheads[0.05]],
 AxesLabel -> {"Time of departure/day", "Comping Position"},
 PlotRange -> {{0, 200}, {0, 50}}]
```

Appendix B

```
namespace smjs
{
    public partial class MainForm : Form
    {
        public MainForm()
        {
            InitializeComponent();
            MaxDay = Convert.ToInt32(this.textBox1.Text);
            MaxSY = Convert.ToInt32(this.textBox2.Text);
            excelkk = new Microsoft.Office.Interop.Excel.Application();
            excelkk.Workbooks.Add(true);
        }

        void UpdatePointStatus(int SDay, int AIndex)
        {
            int Loop_Index, dayindex,tmp;
            dayindex = SendPerDayList[AIndex - 6];
            for (Loop_Index = 0; Loop_Index < dayindex + 6; Loop_Index++)
            {
                if ((Loop_Index + SDay) >= 180) break;
                CustomPath[CustomIndex, Loop_Index] = SPoint[dayindex, Loop_Index];
                PointStatus[SPoint[dayindex, Loop_Index] - 1, Loop_Index + SDay] =
                PointStatus[SPoint[dayindex, Loop_Index] - 1, Loop_Index + SDay] + 1;
            }
            SResult[SDay, dayindex] = SResult[SDay, dayindex] + 1;
        }
        bool IsCanSend(int SDay, int AIndex)
        {
            int Loop_Index, Loop_IndexND, dayindex;
            dayindex = SendPerDayList[AIndex - 6];
            bool bflag = true;
            for (Loop_Index = 0; Loop_Index < dayindex + 6;Loop_Index++ )
            {
                if ((Loop_Index + SDay) >= 180) break;
                if (PointStatus[SPoint[dayindex,Loop_Index]-1,Loop_Index+SDay]>=1)
                {
                   // this.richTextBox1.Text = this.richTextBox1.Text + "  " +
                   AIndex.ToString() + " " +
                   SPoint[dayindex, Loop_Index].ToString() + "," +
                   Loop_Index.ToString() + ";";
                    bflag = false;
                    return false;
                    break;
                }
```

```
            else
            {
                bflag = true;
            }
        }
        return bflag;
    }

    void showmsg(int k)
    {
        int i, j, count, sum, tmp;
        count = 0;
        sum = 0;
        for (i = 0; i < 180; i++)
        {
            tmp = 0;
            for (j = 0; j < 13; j++)
            {
                count = count + SResultMax[i, j];
                tmp = tmp + SResultMax[i, j];
            }
        }

        for (i = 0; i < 45; i++)
        {
            tmp = 0;
            for (j = 0; j < 180; j++)
            {
                sum = sum + PointStatusMax[i, j];
                tmp = tmp + PointStatusMax[i, j];
            }
        }
        ss[k * 3 + 2] = "";
        for (i = 0; i < 13; i++) ss[k * 3 + 2] =
        ss[k * 3 + 2] + " " + SendPerDayList[i].ToString();
        ss[k * 3 + 0] = "number trips" + count.ToString();
        ss[k * 3 + 1] = "number campsite" + sum.ToString();
        this.richTextBox1.Lines = ss;
    }
    void RecordMaxResult()
    {
        int i, j;
        for (i = 0; i < 180; i++)
        {
            for (j = 0; j < 13; j++)
            {
```

```
                SResultMax[i, j] = SResult[i, j];
            }
        }

        for (i = 0; i < 45; i++)
        {
            for (j = 0; j < 180; j++)
            {
                PointStatusMax[i, j] = PointStatus[i, j];
            }
        }

        for (i = 0; i < 1000; i++)
        {
            for (j = 0; j < 18; j++)
            {
                CustomPathMax[i, j] = CustomPath[i, j];
            }
        }

    }
  }
}
```

Appendix C

Table 4: Description Here.

Time	Number	A	B	Time	Number	A	B
1	6	2	4	91	2	1	1
2	1	0	1	92	4	4	0
3	2	1	1	93	4	1	3
4	4	2	2	94	2	1	1
5	2	1	1	95	3	2	1
6	3	1	2	96	3	3	0
7	3	1	2	97	1	0	1
8	2	1	1	98	3	1	2
9	4	2	2	99	4	2	2
10	3	2	1	100	3	3	0
11	2	1	1	101	3	3	0
12	1	0	1	102	3	2	1
13	4	2	2	103	1	1	0
14	2	1	1	104	2	1	1
15	2	1	1	105	4	3	1

To be continued. . .

Time	Number	A	B	Time	Number	A	B
16	1	0	1	106	2	2	0
17	3	0	3	107	1	1	0
18	4	3	1	108	2	1	1
19	3	2	1	109	3	1	2
20	3	1	2	110	2	1	1
21	3	2	1	111	4	1	3
22	1	1	0	112	4	3	1
23	3	1	2	113	2	1	1
24	4	3	1	114	2	1	1
25	3	2	1	115	3	1	2
26	2	0	2	116	3	1	2
27	2	1	1	117	1	1	0
28	2	1	1	118	3	2	1
29	4	2	2	119	4	1	3
30	3	0	3	120	3	1	2
31	3	1	2	121	3	2	1
32	1	1	0	122	2	2	0
33	4	2	2	123	3	1	2
34	2	1	1	124	2	0	2
35	2	0	2	125	5	2	3
36	4	1	3	126	3	2	1
37	1	0	1	127	2	1	1
38	4	1	3	128	4	2	2
39	5	2	3	129	4	2	2
40	2	1	1	130	3	1	2
41	1	1	0	131	1	1	0
42	4	1	3	132	4	2	2
43	2	0	2	133	2	2	0
44	3	0	3	134	3	3	0
45	4	2	2	135	0	0	0
46	1	0	1	136	1	0	1
47	4	2	2	137	2	2	0
48	3	1	2	138	3	2	1
49	2	2	0	139	3	2	1
50	1	1	0	140	1	0	1
51	2	1	1	141	3	0	3
52	3	2	1	142	3	3	0
53	2	1	1	143	4	2	2
54	4	2	2	144	2	1	1
55	2	1	1	145	1	1	0
56	3	1	2	146	4	3	1
57	3	2	1	147	3	2	1
58	2	1	1	148	5	2	3
59	4	1	3	149	1	1	0
60	3	1	2	150	3	1	2
61	3	1	2	151	3	1	2
62	1	1	0	152	3	1	2

To be continued...

Time	Number	A	B	Time	Number	A	B
63	2	0	2	153	1	1	0
64	3	1	2	154	3	3	0
65	2	1	1	155	4	2	2
66	3	2	1	156	2	0	2
67	2	1	1	157	4	1	3
68	5	3	2	158	2	2	0
69	2	2	0	159	4	0	4
70	1	0	1	160	4	3	1
71	4	2	2	161	0	0	0
72	4	3	1	162	3	2	1
73	3	2	1	163	1	0	1
74	2	0	2	164	3	1	2
75	3	1	2	165	2	1	1
76	3	1	2	166	1	0	1
77	4	2	2	167	4	1	3
78	3	2	1	168	3	2	1
79	3	1	2	169	3	1	2
80	2	1	1	170	3	3	0
81	4	1	3	171	3	1	2
82	2	2	0	172	2	2	0
83	4	1	3	173	3	1	2
84	3	2	1	174	4	2	2
85	2	0	2	175	2	2	0
86	1	0	1	176	2	1	1
87	3	1	2	177	4	3	1
88	4	1	3	178	4	2	2
89	3	2	1	179	3	2	1
90	2	2	0	180	3	1	2

Appendix D

Table 5: Description Here.

Time	Kind of Trips	A/B	Time	Kind of Trips	A/B	Time	Kind of Trips	A/B
1	13	A	61	7	B	121	8	B
1	7	B	61	10	A	121	10	A
1	8	B	61	6	B	121	7	A
1	9	B	62	11	A	122	13	A
1	11	A	63	6	B	122	8	A
1	6	B	63	6	B	123	9	A
2	7	B	64	11	A	123	8	B
3	9	B	64	7	B	123	6	B
3	12	A	64	6	B	124	8	B
4	15	A	65	7	A	124	6	B
4	10	A	65	8	B	125	11	A
4	8	B	66	7	B	125	7	B
4	6	B	66	9	A	125	15	A

To be continued...

Time	Kind of Trips	A/B	Time	Kind of Trips	A/B	Time	Kind of Trips	A/B
5	10	A	66	10	A	125	6	B
5	6	B	67	9	A	125	6	B
6	7	B	67	9	B	126	8	B
6	6	B	68	10	A	126	7	A
6	13	A	68	9	A	126	11	A
7	6	B	68	9	A	127	18	A
7	7	B	68	6	B	127	6	B
7	9	A	68	6	B	128	13	A
8	9	A	69	11	A	128	6	B
8	7	B	69	8	A	128	10	A
9	6	B	70	8	B	128	6	B
9	12	A	71	11	A	129	13	A
9	16	A	71	8	A	129	7	B
9	7	B	71	6	B	129	6	B
10	18	A	71	6	B	129	9	A
10	11	A	72	9	A	130	18	A
10	7	B	72	15	A	130	6	B
11	11	A	72	6	B	130	8	B
11	6	B	72	7	A	131	11	A
12	6	B	73	7	B	132	6	B
13	15	A	73	11	A	132	16	A
13	6	B	73	9	A	132	6	B
13	9	B	74	6	B	132	11	A
13	7	A	74	6	B	133	11	A
14	8	B	75	7	A	133	12	A
14	10	A	75	8	B	134	15	A
15	6	B	75	6	B	134	18	A
15	13	A	76	8	B	134	12	A
16	6	B	76	11	A	136	6	B
17	8	B	76	7	B	137	8	A
17	6	B	77	10	A	137	8	A
17	6	B	77	12	A	138	17	A
18	11	A	77	7	B	138	8	A
18	11	A	77	6	B	138	8	B
18	6	A	78	12	A	139	13	A
18	8	B	78	6	B	139	7	B
19	11	A	78	8	A	139	9	A
19	8	A	79	6	B	140	9	B
19	6	B	79	12	A	141	8	B
20	12	A	79	6	B	141	6	B
20	6	B	80	12	A	141	6	B
20	8	B	80	6	B	142	9	A
21	13	A	81	6	B	142	9	A
21	8	A	81	9	A	142	7	A
21	7	B	81	6	B	143	10	A
22	8	A	81	7	B	143	15	A
23	12	A	82	10	A	143	6	B
23	7	B	82	13	A	143	7	B
23	6	B	83	13	A	144	8	B
24	7	B	83	7	B	144	9	A
24	9	A	83	7	B	145	9	A
24	12	A	83	6	B	146	15	A
24	9	A	84	15	A	146	10	A
25	12	A	84	8	B	146	9	B

To be continued...

Time	Kind of Trips	A/B	Time	Kind of Trips	A/B	Time	Kind of Trips	A/B
25	14	A	84	9	A	146	7	A
25	6	B	85	9	B	147	10	A
26	6	B	85	6	B	147	6	B
26	7	B	86	9	B	147	10	A
27	6	B	87	6	B	148	7	B
27	13	A	87	8	B	148	6	B
28	17	A	87	10	A	148	13	A
28	6	B	88	6	B	148	11	A
29	8	A	88	9	B	148	6	B
29	7	B	88	7	B	149	11	A
29	17	A	88	11	A	150	12	A
29	7	B	89	10	A	150	8	B
30	8	B	89	12	A	150	6	B
30	9	B	89	6	B	151	6	B
30	7	B	90	14	A	151	7	B
31	7	B	90	11	A	151	13	A
31	7	B	91	8	A	152	9	A
31	9	A	91	6	B	152	7	B
32	18	A	92	13	A	152	6	B
33	6	B	92	9	A	153	8	A
33	8	A	92	6	A	154	11	A
33	12	A	92	11	A	154	8	A
33	6	B	93	6	B	154	8	A
34	9	A	93	13	A	155	18	A
34	6	B	93	7	B	155	12	A
35	6	B	93	8	B	155	6	B
35	6	B	94	8	A	155	7	B
36	10	A	94	8	B	156	6	B
36	6	B	95	11	A	156	9	B
36	6	B	95	6	B	157	12	A
36	6	B	95	8	A	157	7	B
37	6	B	96	11	A	157	9	B
38	10	A	96	13	A	157	6	B
38	6	B	96	8	A	158	17	A
38	7	B	97	7	B	158	10	A
38	6	B	98	6	B	159	6	B
39	15	A	98	7	B	159	7	B
39	8	B	98	9	A	159	6	B
39	6	B	99	10	A	159	8	B
39	6	B	99	6	B	160	16	A
39	11	A	99	8	B	160	11	A
40	6	B	99	9	A	160	8	A
40	9	A	100	12	A	160	8	B
41	7	A	100	9	A	162	15	A
42	16	A	100	11	A	162	10	A
42	7	B	101	7	A	162	7	B
42	6	B	101	12	A	163	6	B
42	7	B	101	9	A	164	6	B
43	8	B	102	10	A	164	17	A
43	6	B	102	14	A	164	7	B
44	7	B	102	6	B	165	7	B
44	6	B	103	14	A	165	10	A
44	8	B	104	10	A	166	6	B
45	14	A	104	6	B	167	9	A

To be continued. . .

Time	Kind of Trips	A/B	Time	Kind of Trips	A/B	Time	Kind of Trips	A/B
45	9	B	105	16	A	167	6	B
45	12	A	105	14	A	167	6	B
45	6	B	105	8	A	167	7	B
46	6	B	105	6	B	168	10	A
47	12	A	106	8	A	168	6	B
47	6	B	106	9	A	168	8	A
47	8	B	107	10	A	169	10	A
47	13	A	108	14	A	169	6	B
48	13	A	108	6	B	169	8	B
48	7	B	109	9	A	170	8	A
48	6	B	109	6	B	170	11	A
49	9	A	109	6	B	170	10	A
49	13	A	110	12	A	171	8	B
50	15	A	110	6	B	171	11	A
51	9	A	111	12	A	171	6	B
51	7	B	111	8	B	172	10	A
52	7	B	111	6	B	172	15	A
52	18	A	111	6	B	173	10	A
52	7	A	112	12	A	173	6	B
53	10	A	112	13	A	173	6	B
53	9	B	112	6	B	174	14	A
54	6	B	112	8	A	174	11	A
54	10	A	113	13	A	174	6	B
54	6	B	113	7	B	174	8	B
54	11	A	114	7	B	175	7	A
55	6	B	114	13	A	175	14	A
55	9	A	115	15	A	176	14	A
56	9	B	115	8	B	176	8	B
56	11	A	115	6	B	177	11	A
56	6	B	116	10	A	177	6	B
57	14	A	116	7	B	177	15	A
57	12	A	116	6	B	177	18	A
57	7	B	117	10	A	178	18	A
58	8	A	118	7	A	178	6	B
58	6	B	118	6	B	178	11	A
59	18	A	118	10	A	178	6	B
59	6	B	119	11	A	179	18	A
59	8	B	119	6	B	179	6	B
59	6	B	119	7	B	179	13	A
60	7	B	119	7	B	180	8	B
60	7	B	120	7	B	180	6	B
60	12	A	120	7	B	180	18	A
			120	9	A			