Problem Chosen	2023	Team Control Number
B	MCM/ICM Summary Sheet	12

Long River Rafting Journey

Summary

In recent years, rafting travel has become more and more popular with tourists. However, when a large number of tourists arrive, the unreasonable travel makes the river congested, the river ecological environment damaged, and the tourist quality can not be guaranteed. Therefore, it is crucial for travel agencies to formulate a reasonable drifting route and determine the maximum bearing capacity of the river and the number of camps.

This paper sets up a model for arranging the long river rafting trip. Through **linear programming** model to develop the best schedule and determine the river's carrying capacity. In order to ensure that each group enjoys the wilderness experience, this paper simplifies the model based on the assumption that the drifting group behind will never catch up with the previous group. This paper calculates the maximum number of boat trips in six months and regards it as an objective function. Finally, this paper determines the timetable for launching the best travel combination. The duration and driving force of these trips are different, and the campsite will be used in the best way. This paper also establishes the maximum bearing capacity model and the temporary non-utilization rate model of camping sites based on the results obtained from the above models, analyzes the relationship between the maximum number of boat trips and the number of camping sites by using integer programming and control variable method, and gives some representative results.

Firstly for calculating the maximum number of boat trips in six months, we transformed the problem into finding **the maximum number of boat trips** per day, simplifying the way of thinking. According to the assumption, every group of tourists must use a camping site every night, and the tourists behind can't catch up with the tourists ahead. We found that the maximum number of ships dispatched every day is the number of camping sites that the ship passes through in a day. So we only need to find the maximum number of camping sites that the ship passes through in a day. We call this maximum value k_i. According to the conditions, the campsites are evenly distributed. We set the distance between the two campsites as Δl, and set the distance traveled by this batch of ships on the i day as $k_i \Delta l$, so that this batch of ships will not meet unless they reach the destination. At the same time, we need to ensure that the fastest ship of the next batch of ships does not exceed the slowest ship of this batch of ships. Finally, through integer programming with all constraints, we can use LINGO software to find the maximum value of the objective function, That is, the maximum value of k_1. At the same time, the relationship between k_1 and travel time t and camping site Y is obtained theoretically: represents the smallest integer

$$k_1 = \left[\frac{Y}{t-1} \right], \quad ([x] \text{ The smallest integer representing x})$$

Then we get that when the number of camping sites is $Y = 180$ and the travel time is $t = 6$, we can get $k_1 = 37$. When six months are regarded as 180 days, we can estimate the maximum number of boat trips $X = 180 \times 37 = 6660$ in six months.

For the calculation of the maximum carrying capacity model and the temporary non-utilization rate of the camping site, we use the control variable method to analyze the carrying capacity of the river flow and the temporary non-utilization rate of the camping site in the first six days when the number of camping sites remains unchanged, and the carrying capacity of the river flow and the temporary non-utilization rate of the camping site in the first six days when the number of travel days in the next day remains unchanged. Our final results can be summarized into two suggestions: when determining the number of camping sites, the number of tourist days on the second day should not be increased significantly, and should be controlled within 0-6 days, while the number of camping sites should be controlled between 200-250 when the number of tourist days on the second day remains unchanged.

Finally, we use the conclusions of the model to analyze the results and put forward corresponding suggestions to river managers.

Keywords: linear programming; Optimization model; Maximum number of trips

Contents

1 Introduction

1.1 Problem Background

Drive a boat without power, use the oars to grasp the direction, and go down the river in the sometimes turbulent and sometimes gentle current, and perform wonderful moments in the struggle with nature. This is rafting, a brave sport. A meandering river extends in the hard hinterland of the canyon. Take a rubber boat down the river, the sky is high, the water is long, the sun is shining, surrounded by green mountains on all sides, drifting in the middle, and coming face to face is a kind of anticipation. Looking forward to adventure! Looking forward to fighting with nature! We look forward to the relaxation after "danger free"! In the busy urban life, people have been looking for such a kind of excitement, a unique feeling different from ordinary life. It is this kind of feeling that makes urban people fall in love with it and make it a part of life. Through Camping along the Big Long River people can enjoy the beauty of nature. Visitors to the Big Long River can enjoy scenic views and exciting white water rapids.

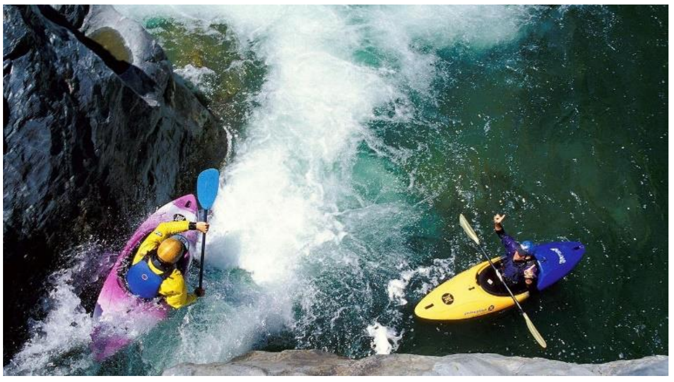

Figure1: people who were drifting

1.2 Restatement of the Problem

Considering the background information and restricted conditions identified in the problem statement, the park managers want to determine how they might schedule an optimal mix of trips, of varying duration (measured in nights on the river) and propulsion (motor or oar) that will utilize the campsites in the best way possible.

- Problem 1：How to make use of the existing river and campsite resources and arrange relatively compact rafting boats so that more tourists can enjoy the natural scenery?
- Problem 2：Arrange an optimal mixed travel plan. we need to develop the best schedule and on ways in which to determine the carrying capacity of the river.
- Problem 3：Suggestions on the bearing capacity of rivers. How many more boat trips could be added to the Big Long River's rafting season?

1.3 Our Work

We need a model that works for developing the best schedule and on ways in which to determine the carrying capacity of the rive. Our work mainly includes the following parts:

Firstly we preprocess the data to get the distribution of the average daily drift time of tourists, the proportion of choosing motorboats and rubber rafts, and the probability distribution of the number of travel days.

Next establishing the planning model. The objective function is to maximize the number of ships dispatched every day. The number of ships dispatched every day is given when the number and time of the camps are known through the constraints of the number of ships dispatched every day, the constraints of the campsite and the non-encounter principle.

Finally by analyzing the carrying capacity of the river when the daily travel arrangement remains unchanged and the daily travel arrangement is different, the optimal arrangement for the manager is obtained.

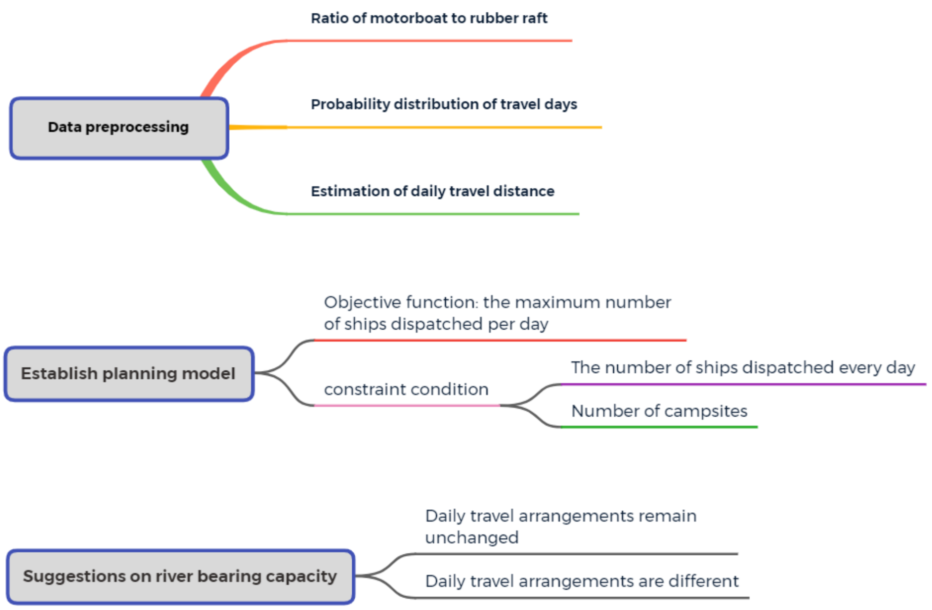

Figure2: flow chart

2 Assumptions and Justifications

Considering that practical problems always contain many complex factors, first of all, we need to make reasonable assumptions to simplify the model, and each hypothesis is closely followed by its corresponding explanation:

- **Assumption 1:** Six months are regarded as 180 days.
- **Assumption 2:** Each group can drift for 10 hours at most every day.
- **Assumption 3:** Each group must stay in the camp every night, and the time spent in the same camp cannot exceed one day.
- **Assumption 4:** Fast boat 8 mph, slow boat 4 mph.
- **Assumption 5:** Tourists can only go downstream, not upstream.
- **Assumption 6:** Tourists in the upper reaches of the river will never meet tourists in the lower reaches.
- **Assumption 7:** Do not consider rainy days, river rising tide and other special weather that will reduce the number of tourists.

3 Notations

The key mathematical notations used in this paper are listed in Table 1.

Table 1: Notations used in this paper

Symbol	Description	Unit
L	Length of long river	mile
X	Number of tourists in 6 months	group
Y	Number of camps	number
Δl	Distance between two adjacent camps	mile
k_i	The distance between two adjacent camps The number of ships dispatched per day (the multiple between the sailing distance of the first ship sent per day on the i day and Δl)	-
k_{Ai}	The multiple between the sailing distance of the ship departing on day A and the Δl on day i	-
t	Time required for a journey	hour
W	Bearing capacity of river	number
P	Temporary non-utilization rate of campsite	-
a	The number of sailing days of the ship on the second day is higher than that on the first day	day
Δk	The difference between the number of camps of the first ship departing on the second day and the last ship departing on the first day	number

4 Optimal mixed travel scheme module

4.1 Data preprocessing

According to the topic, tourists will stay in the river for 6-18 nights, and the total length of the Grand Long River is 225 miles, and tourists can choose only 4 miles per hour slow boat or 8 miles per hour fast boat. Let's assume that a group of tourists choose to play k nights, so the average daily drift time of the slow boat is:

$$t_1 = \frac{225}{4k} \tag{1}$$

The average daily drifting time of the express ship is:

$$t_2 = \frac{225}{8k} \tag{2}$$

Among them:

$$6 \le k \le 18, k \in Z \tag{3}$$

According to this, we can get the ship numbers of different drifting types as follows:

Table 2: Average travel time per day for different types of floats and different travel days

Select days/night	Average daily drift time of slow ship/hour	Average daily drifting time/hour of express ship
6	9.38	4.69
7	8.04	4.02
8	7.03	3.52
9	6.25	3.13
10	5.63	2.81
11	5.11	2.56
12	4.69	2.34
13	4.33	2.16
14	4.02	2.01
15	3.75	1.88
16	3.52	1.76
17	3.31	1.65
18	3.13	1.56

Draw the line chart corresponding to different ships. From the chart, we can see that the average drifting time per day will not exceed 10 hours, so we stipulate that all tourists can drift for 10 hours at most per day. Considering the actual situation, most tourists can accept the drift time less than 4 hours a day, which will not be very tired, but also experience the fun of wilderness drift.

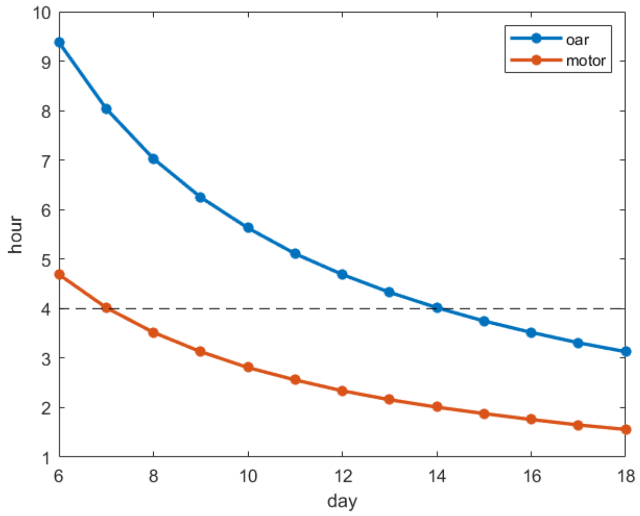

Figure 3: Average drift time chart

Therefore, we assume that the tourists who choose the slow boat have a Poisson distribution centered on 14 days of travel, and the tourists who choose the fast boat have a Poisson distribution centered on 7 days of travel.

We can give the distribution of the number of days for tourists who choose slow boats：

$$P(k)=\frac{14^k e^{-14}}{k!} \tag{4}$$

Distribution of the number of days for tourists who choose the express boat：

$$P(k)=\frac{7^k e^{-7}}{k!} \tag{5}$$

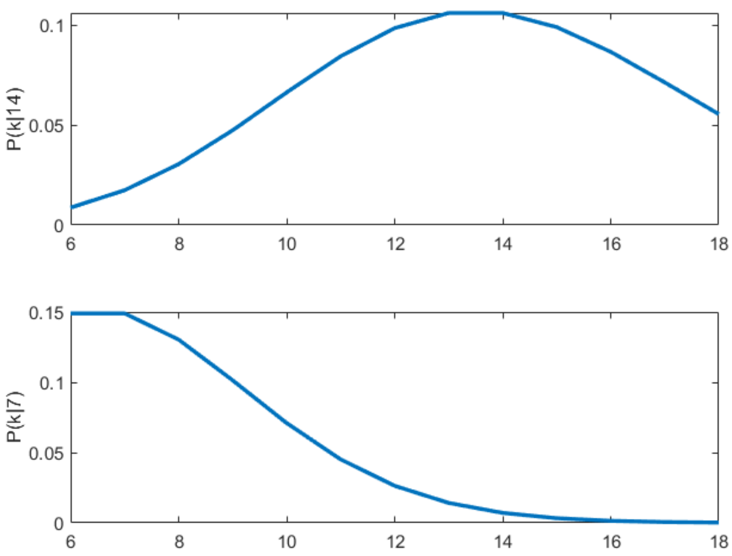

Figure 4: Probability distribution of tourism days

Since the speed of the fast boat is twice that of the slow boat, we assume that the reserve of the fast boat is also twice that of the slow boat, that is, the number of tourists who choose the fast boat is twice that of the slow boat, so we can estimate the selection strategy of tourists according to X, which is convenient for us to plan the camp.

Table 3: Probability of selecting motorized boats

motorized boats	**6**	7	8	9	10	11	12	13	14	15	16	17	18
50	7	7	6	5	3	2	1	1	0	0	0	0	0
100	14	14	12	10	7	4	3	1	1	0	0	0	0
250	36	36	31	24	17	11	6	3	2	1	0	0	0
400	57	57	50	39	27	17	10	5	3	1	1	0	0
650	92	92	81	63	44	28	16	9	4	2	1	0	0

Table 4: Probability of selecting oar- powered rubber rafts

oar- powered rubber rafts	**6**	7	8	9	10	11	12	13	14	15	16	17	18
50	0	0	1	1	1	2	2	2	2	2	2	1	1
100	0	1	1	2	2	3	4	4	4	4	3	3	2
250	1	2	3	4	6	8	9	10	10	9	8	7	5
400	1	3	5	7	10	13	15	16	16	15	13	11	8
650	2	4	8	12	16	21	24	26	26	24	21	18	14

4.2 The Establishment of Model

For camp operators, the premise of maximizing income is to maximize the use of the campsite. We can maximize the number of campsites that can be accommodated on the river by reasonably arranging the number of ships entering. If only two ships start on the first day, the first ship arrives at the second point after the first day, and the second ship arrives at the first point, then both ships will proceed in the way of two points per day. On the next day, the starting point again sent ships to advance according to the previous plan. It is easy to find from the picture that if ships are sent to set out and advance in this way every day, these ships will not meet, and the distance between two adjacent ships is only one camp away. When one ship reaches the destination, the campsite on the whole river will be used.

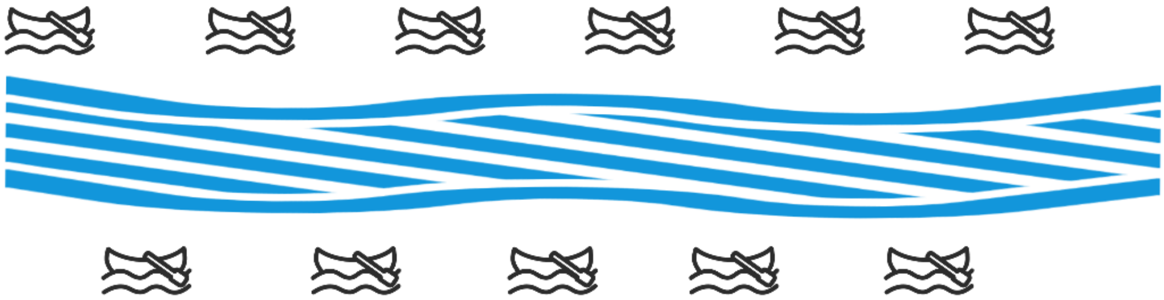

Figure 5: Daily vessel arrangement

Only two ships can be dispatched every day, and in the model, we require the maximum number of ships to be dispatched every day. According to the title, the campsites are evenly distributed in the river channel, set as Δl, then the distance from the starting point to the campsite that can be reached by the fastest ship in a day is, and so on. The distance from the starting point to the campsite that can be reached by the next ship is $k_1\Delta l$, and so on. The distance from the starting point to the campsite that can be reached by the next ship is $(k_1-1)\Delta l$ 、 $(k_1-2)\Delta l$, until the latest ship stops at the campsite that is Δl from the starting point, so it can be seen that, The maximum number of ships dispatched per day is equal to the multiple of the sailing distance of the first ship dispatched per day on the i day and the Δl. The ship sent on the first day will sail in the same way in the next journey, and the impact on the result will be negligible. Let's assume that the distance traveled by the ship on the third day is $k_i\Delta l$, so that the ship will not meet except for reaching the destination. At the same time, it is necessary to ensure that the fastest ship of the next ship does not exceed the slowest ship of the ship. At the same time, the relationship between k_1 and the journey time t and the camping site Y is obtained theoretically:

$$k_1 = \left\lceil \frac{Y}{t-1} \right\rceil, \quad \lceil x \rceil \text{ the smallest integer representing x} \tag{6}$$

From this result, we know that when the number of days t is smaller and the number of days Y is larger, the number of boat trips per day can be increased, which requires the tourism managers to adjust and improve profits.

For the best travel schedule, the travel mode and sailing mode of daily departure can be unchanged, or the number of days can be increased in the original journey, or the travel time can be reduced by 1 day in the original travel, which can ensure that the conditions are met. However, changing the time of the trip will affect the maximum number of trips to a certain extent. We can assume that the distance between adjacent camps is:

$$\Delta l = \frac{L}{Y+1} \tag{7}$$

According to the assumption, each group will be in the camp every night, that is to say, the distance traveled by the ship every day will be a multiple of Δl.

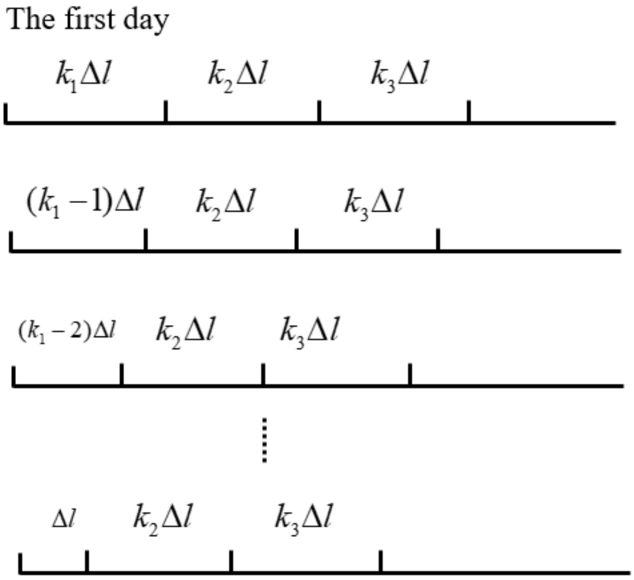

Figure 6: Distance between ships

Therefore, only when the second ship is in the camp at the distance of $(k_1-1)\Delta l$ after 6pm, and the third ship is in the camp of $(k_1-2)\Delta l$, and so on. When the last ship is in the camp closest to the departure point, it can meet the requirement of setting off k_1 ships in one day, so long as the required k_1 reaches the maximum, that is, the maximum number of boat trips per day.

Since the maximum number of trips by boat is the most closely related to the number of k_1, and other factors have little influence on the number of trips by boat, it is stipulated here that ships departing on the same day will arrive at another campsite by the same way of sailing after the first day, and these ships are required to arrive at the destination on the same day. Here, assuming that the ship departing on the first day ends its journey on day t, and the distance the ship sails on day i is $k_i\Delta l$, while the whole journey is $(Y+1)\Delta l$, the following relationship can be obtained:

$$\sum_{i=1}^{t} k_i = Y+1 \tag{8}$$

If under the same navigation mode every day, due to the principle of no encounter required in the title, the number of ships departing on the second day cannot exceed the number of ships departing on the first day, the following constraints can be known from the figure:

$$1+\sum_{i=1}^{j}k_i > \sum_{i=1}^{j-1}k_i,\ j=1,2,\cdots,t-1 \tag{9}$$

The last ship to set sail on the first day is not k_t, but it has reached the destination on the last day. Therefore, the last ship to set sail on the first day must be ahead of the first ship to set sail on the second day.

To sum up, we can get:

$$\begin{cases} 1+k_i > k_1, i=2,3,\cdots,t-1, \\ \sum_{i=1}^{t}k_i = Y+1, \\ k \le \dfrac{80(Y+1)}{225}, \\ k_i \in Z^{+}, i=1,2,\cdots,t \end{cases} \tag{10}$$

4.3 The Solution of Model

Use lingo software to carry out integer programming, and calculate the maximum value of k_1 respectively. When the values of Y and t are given, the maximum number of boat trips can be obtained. As shown in the following table:

Table 5: Relation table of Y and t

t \ Y	40	60	90	130	180
6	9	13	19	27	37
9	6	8	12	17	23
12	4	6	9	12	17
15	3	5	7	10	13
18	3	4	6	8	11

Draw the relationship between k_1 and t when Y is fixed, and the relationship between k_1 and Y when t is fixed. It can be seen from the figure that when Y is taken as 180 and t is taken as 6, the number of ships dispatched per day k_1 is the maximum, and k_1 is 37. The number of tourists within 6 months X is 6660.

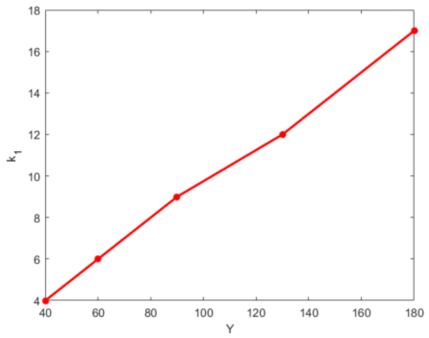

Figure 7: Diagram of Y and k_i

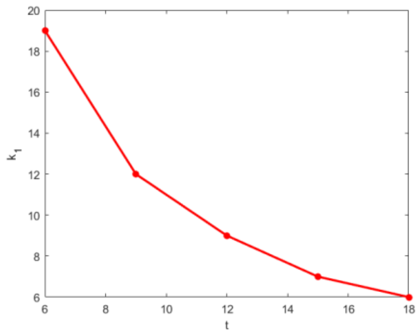

Figure 8: Diagram of t and k_i

4.4 Result analysis

From the above constraints, we can use the inequality to obtain the following relationship:

$$(t-1)k_1 + k_t \le Y + 1 \tag{11}$$

When k_t reaches the minimum value of 1, k_1 reaches the maximum value, that is $k_1 = \frac{Y}{t-1}$. If and only if $k_1 = k_2 = \cdots = k_{t-1}$, but $\frac{Y}{t-1}$ is not necessarily an integer, $k_1 = \left[\frac{Y}{t-1}\right]$ is obtained according to the formula analysis. Take the data in the table with this formula to get the same results, so the test results are completely consistent.

5 Suggestions on river bearing capacity

5.1 Best arrangement

- Daily travel arrangements remain unchanged

For this situation, it is obvious that this is a cyclical process. Therefore, for the maximum number of boat trips in six months, $(180-t)k_1$, and because the larger the t, the smaller the k_1, so to maximize the maximum number of boat trips in six months, the time required for travel must be reduced.

Next, we will analyze one of the representative cases. When $t=6$ and $Y=150$, we can get the $k_1=30, k_2=30, k_3=30, k_4=30, k_5=30, k_6=1$ by analyzing all the ships sent on a certain day A.

For the first ship launched on day A, the last stop on the first day was at the campsite at $k_1\Delta l = 30*\frac{225}{150+1} = 44.7$ miles. Since the maximum time spent on the river was 10 hours, the rubber raft powered by the oar could not reach the campsite. Therefore, the first ship in this situation needed motor sail travel except after the last day.

Suppose that a ship on the first day of departure passes through $x\Delta l$, and for $x\Delta l \le 40$,

$x \le 26.8$ is calculated. Since the interval between departure can be very short, which is negligible for 10 hours, the fifth ship on the first day of departure can use the rubber raft powered by the oar. Then, if the interval between departure is shorter, the ship can only use the rubber raft powered by the oar, If the interval is long or the last few ships depart, they can also travel with motor sails. In addition to the first day and the last day, all ships must travel by motor sail.

Table 6: Table of propulsion modes of each ship at $t = 6$ and $Y = 150$

Boat/day Number	1	2	3	4	5	6
boat 1	motorized boats	motorized boats	motorized boats	motorized boats	motorized boats	Two ways
…	motorized boats	motorized boats	motorized boats	motorized boats	motorized boats	Two ways
boat 5	Two ways	motorized boats	motorized boats	motorized boats	motorized boats	Two ways
…	Two ways	motorized boats	motorized boats	motorized boats	motorized boats	Two ways
boat 26	Two ways	motorized boats	motorized boats	motorized boats	motorized boats	motorized boats
…	Two ways	motorized boats	motorized boats	motorized boats	motorized boats	motorized boats
boat 30	Two ways	motorized boats	motorized boats	motorized boats	motorized boats	motorized boats

- Daily travel arrangements are different

For this situation, it will be much more complicated than the above situation, but according to $k_1 = \left[\dfrac{Y}{t-1}\right]$, k_1 will decrease with the increase of $k_1, k_2, \cdots, k_{t-1}$, and the $k_{A1} \le k_{A2}$ will be basically the same when the maximum value is taken. So if there is already a trip arrangement on day A, set the $k_{A1} \le k_{A2}$ under the trip arrangement. If the number of days arranged on the next day increases by several days, then the $\sum_{i=1}^{j} k_{(A+1)i} \le \sum_{i=2}^{j+1} k_{Ai}, j = 2, 3, \cdots, t-1$ of that day can be obtained, which means that the arrangement is feasible on the next day, The ship arranged for the next day will not meet the ship of day A. Therefore, managers can achieve the desired effect by increasing the number of travel days on the basis of the original plan, while the original effect can be achieved without changing the ship navigation arrangement when increasing the number of travel days.

5.2 Calculate the maximum bearing capacity and temporarily unused rate of the river

- Daily travel arrangements remain unchanged

From the above calculation, it is easy to find that the carrying capacity of the river is related to time, travel days t and the number of camping sites Y, while the maximum carrying capacity of the river is only related to the number of camping sites. Because we calculate the number of ships that can be dispatched in a day according to the farthest camp that the first ship can reach every day, and the next day's journey remains unchanged. Therefore, ships departing at the same time every day arrive at the same camp. When the last ship on the first day arrives at the last camp, the last ship on the $t-1$ day arrives at the first camp, so the maximum carrying capacity of the river is:

$$W = k(t-1) = Y \tag{12}$$

We also select $t = 6,9,12,15,18$ and $Y = 40,60,90,130,180$ to list the maximum bearing capacity of the river, as shown in the following table:

Table 7: Relation table of Y and t

t / Y	40	60	90	130	180
6	40	60	90	130	180
9	40	60	90	130	180
12	40	60	90	130	180
15	40	60	90	130	180
18	40	60	90	130	180

■ The daily schedule is different

In real life, the daily travel arrangement is not exactly the same. The travel manager will change the daily travel arrangement according to the needs of tourists. Based on this consideration, we first assume that the number of days for tourists on the first day is 6 days. According to the model, if the administrator wants to change the travel arrangement, he can only increase the number of travel days on the original number of travel days to meet the requirements.

6 Sensitivity Analysis

6.1 Change the number of days to travel the next day

Considering the simplest case of different travel arrangements every day, assuming that the number of days to travel on the first day is 6, only the number of days to travel on the second day will be changed, and the number of days to travel on all subsequent days will be the same as that on the second day, so the carrying capacity of the river after 6 days is the same as that of the first case, and we will not discuss it again.

The following will discuss the carrying capacity of the river flow and the temporary non-utilization rate of the campsite in the first six days. According to the model, $k_1 = \left[\frac{Y}{t-1}\right]$, when t is larger, k_1 is smaller, and the number of travel days the next day will increase, which will inevitably lead to the decrease of k_1. Assuming that the number of travel days of the ship on the second day is a day more than that on the first day, the number of travel days on the second day is $t+a, 1<a<12$ and $k_2 = \left[\frac{Y}{t+a-1}\right]$. Therefore, the first ship departing on the second day and the last ship departing on the first day will not meet in the first six days.

Using Matlab software, when $a=1,2,\cdots,12$, the image of the maximum carrying capacity W of the river flow and the temporarily unutilized rate P of the campsite in the first six days is shown in the figure below. In particular, when $a=1,3,5,7$, the maximum carrying capacity W of the river flow and the temporary unutilization rate P of the campsite in the first six days are shown in the table below.

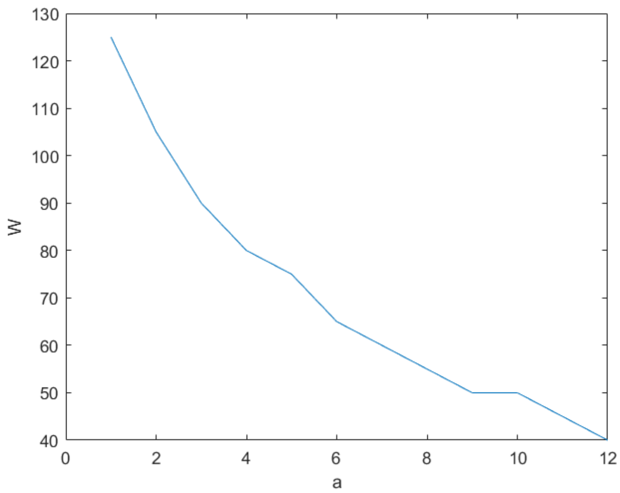

Figure 9: Diagram of a and w

Table 8: Relation table of a and w

a	1	3	5	7
W	125	90	75	60

From the figure below, we can find that when the number of campsites is determined, the maximum bearing capacity of the river flow in the first six days decreases with the increase of the number of days of boat travel the next day. From the figure above, we can find that the temporary non-utilization rate of the campsites in the first six days increases with the increase of the number of days of boat travel the next day. Therefore, the larger the number of tourist days the next day, the smaller the utilization of tourism resources, resulting in resource waste. Therefore, when determining the number of campsites, river managers are advised not to increase the number of tourist days in the next day as much as possible under the condition of satisfying tourists, so as to avoid resource waste.

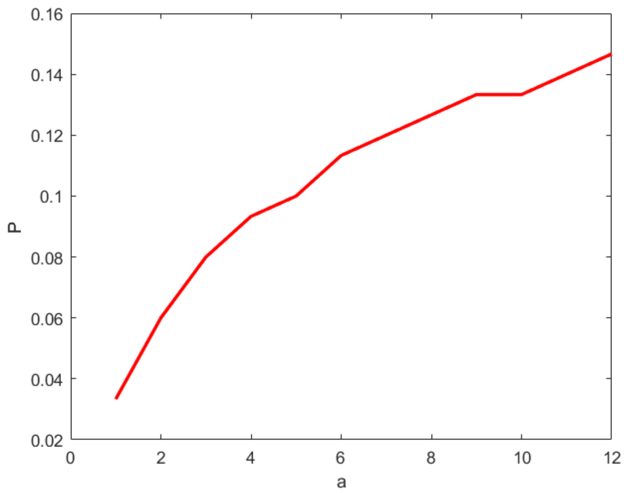

Figure 10: Diagram of a and p

Table 9: Relation table of a and p

a	1	3	5	7
P	0.03	0.08	0.10	0.12

Assuming that the number of days to travel on the second day is 7, discuss the carrying capacity of the river flow and the temporary non-utilization rate of the campsite in the first 6 days, and draw a similar conclusion on other days. In the first 6 days, the difference between the number of campsites between the first ship departing the next day and the last ship departing the first day is $\Delta k = \left[\frac{Y}{5}\right] - \left[\frac{Y}{6}\right]$, the maximum carrying capacity of the river reaches the maximum value for the first time, which is $Y - (\left[\frac{Y}{5}\right] - \left[\frac{Y}{6}\right])$ and the temporary non-utilization rate of the campsite is:

$$P = \frac{\left[\frac{Y}{5}\right] - \left[\frac{Y}{6}\right]}{Y} \tag{13}$$

Using Matlab software, when $Y = 30, 35, 40, \cdots, 300$, the images of the maximum carrying capacity W of the river flow and the temporarily unutilized rate P of the campsite in the first six days are shown in the figure below. Especially when $Y = 40, 60, 90, 130, 180$, the maximum carrying capacity W of the river flow and the temporarily unused rate P of the camping site in the first six days are shown in the following table.

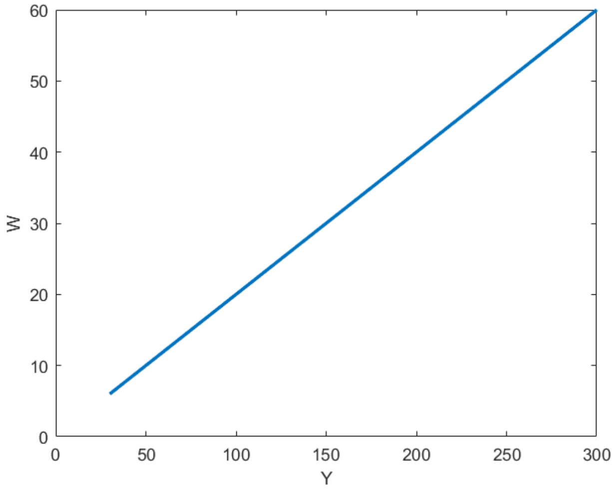

Figure 11: Diagram of Y and w

Table 10: Relation table of Y and w

Y	40	60	90	130	180
W	13	17	23	31	41

It can be seen from the figure that the maximum bearing capacity W of the river flow in the first six days increases with the increase of the number of open camps Y, and the temporarily unused rate P of the open camps in the first six days fluctuates and decreases with the increase of the number of open camps Y. Therefore, we can analyze that the more the number of exposed camps is within a certain range, the better. In order not to cause resource waste, if the construction cost of the camp is relatively low, we recommend to build at least one camp per mile, that is, $Y \geq 225$; If the construction cost of the camp is relatively high, we suggest to take the number of campsites when the temporary non-utilization rate P of the camp in the previous six days drops steadily. This will not cause waste of resources, ensure the utilization rate of the campsite, and try to increase the maximum bearing capacity of the river.

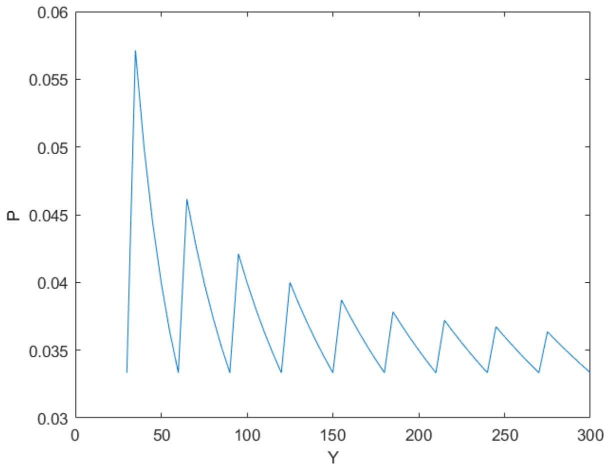

Figure 12: Diagram of Y and P

Table 11: Relation table of Y and P

Y	40	60	90	130	180
P	0.029	0.034	0.034	0.031	0.033

7 Model Evaluation and Further Discussion

7.1 Strengths

•**Accuracy of results**. We relied on data and literature for model simplification. To ensure the accuracy of results through verification of different methods.

•**Universality**. Considering the needs of managers and travelers, a reasonable proportion of the two types of ships is given.

•**Stability and high fault tolerance.** Take full account of the actual needs of the travel team, and give the travel team the choice of travel days and the freedom of travel every day thus making the travel team enjoy more fun.

7.2 Weaknesses

•**Too idealistic**. In question 1, it is assumed that tourists' choice of travel days follows Poisson distribution, which is too idealistic.

8 Conclusion

In this question, we put forward the best travel schedule by carrying out a series of constraints on the camping mode to maximize the number of boat trips. We stipulate that we must stay in the camp after 6 p.m. and leave after 8 a.m. the next day to avoid staying in the same camp for more than one day. We believe that the campsite is evenly distributed on the river. Let the distance between the campsite and the starting point that can be reached by the fastest boat in a day be $k_1\Delta l$, and our goal will be simplified to find the maximum value of k_1 . We agreed that there would be no encounter between ships, and the next batch of fastest ships could not exceed the slowest ships of the current batch, so we got the constraint conditions. Finally, we got the k_1 value of different travel time t and the number of camping sites Y through integer programming and the maximum value of k_1 obtained by using LINGO software from all the constraint conditions, and obtained the relationship between k_1 and travel time t and the number of camping sites Y through theoretical analysis. At the same time, we introduced two parameters, the maximum bearing capacity and the temporary non-utilization rate of the camping site. Through calculation and using MATLAB software to draw a graph, we obtained that the maximum bearing capacity W was negatively correlated with the number of days a traveled the next day and positively correlated with the camping site Y; There is a positive correlation between the temporary non-utilization rate P of the camping site and the number of days of travel a the next day and the camping site Y. Therefore, we believe that the more campsites within a certain range, the better, in order not to waste resources. If the funds allow, we suggest to build at least one campsite per mile; If the cost of the campsite is high, we suggest to take the number of campsites when the temporarily unused rate P of the campsite in the previous 6 days drops steadily. This will not cause waste of resources, ensure the utilization rate of the campsite, and try to increase the maximum bearing capacity of the river.

References

[1] Fang Peng, Ruiyan Yang, Haijun Xiao, Mingshui: Methods in Mathematical Modeling, p.90
[2] B. Cipra. “Mathematicians Offer Answers to Everyday Conundrums: Shooting the Virtual Rapids.” Science 283:925,1999
[3] George O. Mohler and Martin B. (2009). Short Geographic profiling from kinetic models of criminal behavior
[4] Zarouk Yaser,Mahdavi Iraj,Rezaeian Javad,Santos Arteaga Francisco J.. A novel multi-objective green vehicle routing and scheduling model with stochastic demand, supply, and variable travel times[J]. Computers & Operations Research,2022(prepublish).
[5]. Engineering - Mechanical Engineering; Study Findings from Wuhan University Provide New Insights into Mechanical Engineering (A New Knowledgeable Encapsulation Method of Steel Production Scheduling Model)[J]. Journal of Engineering,2020.

Appendix

Memo to managers

From team #12

TO River transportation management department

Date 2012 2 13

In view of the increasing number of tourists in the "Big Long River", we propose a scheduling method that can make full use of campsites in the river to maximize profits. At the same time, we need to consider that each trip of the travel team can enjoy the experience of the wild freely, and contact other ships on the river at least. Considering the above considerations, we have established the Optimal mixed travel scheme module.

For calculating the maximum number of boat trips in six months, we transformed the problem into finding the maximum number of boat trips per day, simplifying the way of thinking. According to the assumption, every group of tourists must use a camping site every night, and the tourists behind can't catch up with the tourists ahead. We found that the maximum number of ships dispatched every day is the number of camping sites that the ship passes through in a day. So we only need to find the maximum number of camping sites that the ship passes through in a day. We call this maximum value k_i. According to the conditions, the campsites are evenly distributed. We set the distance between the two campsites as Δl, and set the distance traveled by this batch of ships on the i day as $k_i \Delta l$, so that this batch of ships will not meet unless they reach the destination. At the same time, we need to ensure that the fastest ship of the next batch of ships does not exceed the slowest ship of this batch of ships.

Then we get that when the number of camping sites is $Y = 180$ and the travel time is $t = 6$, we can get $k_1 = 37$. When six months are regarded as 180 days, we can estimate the maximum number of boat trips $X = 180 \times 37 = 6660$ in six months.

Our final results can be summarized into two suggestions: when determining the number of camping sites, the number of tourist days on the second day should not be increased significantly, and should be controlled within 0-6 days, while the number of camping sites should be controlled between 200-250 when the number of tourist days on the second day remains unchanged.

The above are our suggestions and plans. I hope they can help you. We hope the river tourism industry will continue to develop under your careful management.