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Modeling the Schedules Designed Interactions the Big River Trip Simulation

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Abstract

In this paper, we propose the schedules designed for different tour trips along the Big Long River. We build three models on the basis of the characteristics of drifts, that is: the model based on maximum effective coefficient, the model based on optimization the utilization of the camping sites, the model based on the distribution of camping sites for motorizes boats. According to our analysis, there are certain relationships with the number of tourists on the river at present, the number of newly-launching tourists, the number of tourists finishing their journey and the number of previous tourists on the river. Making use of the method of iteration, we construct the model based on maximum effective coefficient to maximum the effective coefficient and to reach the minimum contact. Introducing 0-1 variables ant colony algorithm, total launching tours every day, the transport choice and each tour group sailing days are available.

Key words: Evaluation coefficient; Effective coefficient; Optimization; The big river trip simulation; Designed interactions

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INTRODUCTION

With the development of society and the increasingly diversified demand of people's lives, there is a strongly growing favorite field trip, such as the wilderness portion of Isle Royale National Park. Since 1990, the tourist arrivals growth rate retains 4%-5% per year.

In terms of tourists, the Big Long River is a good place for enjoying scenic views and exciting white water rapids. Due to its application to tour constantly increasing, the opportunity to travel is limited under current river management system, which becomes a troublesome problem for the river managers. Taking into account how to avoid excessive use of the river tourism resources, the river managers must consider priority to reach the maximum access capacity of the river.

In fact, this is not a new problem and many researchers had done a lot of work (Underhill, Xaba, & Borkan, 1986; Bieri & Roberts, 2000; Roberts, Stallman, & Bieri, 2002). All the research took use of computer simulation model to reasonably arrange the tour groups and has achieved gratifying results. The model has a good ability to adapt to its wide range of applications; however, considering the complexity of the management, this simulation is difficult to take full advantage of the river tourism resources. Therefore, the issue has not received a satisfactory solution. Obviously, there are several factors that affect the manager's decision-making, such as, the reception capacity, full utilization of the travel resource permitted by the ecological environment, the choice of transport tools, the expenditure on whole travel, the choice of camping tents, daily travel time, scenic service and the expectations differences of various tourists, etc. (Owen, Gates, & Flug, 2014; Lu, 2012; Fatta-Kassinos, Kalavrouziotis, Koukoulakis, & Vasquez, 2011; Erdogan, Bauer, & Taylor, 2015). These factors are taken into account the management and decision-making is clearly unrealistic. Therefore, the park managers only consider the following factors: The reception capacity, full utilization of the travel resource permitted by the ecological environment, the choice of camping tents and daily travel time.

In this paper, we only consider these main factors while ignore some minor and achiever the target that it is reasonable arrangements for the daily tour groups to maximum the reception capacity and minimum the opportunities as little as possible for contact.

1. ASSUMPTION AND HYPOTHESIS

1.1 Assumptions

a) The annual tourist season includes 6 months which contains 30 days.
b) With considering the adverse weather conditions and other factors, each tour group cloud rest on a camping tent for one night only.
c) Each tour group day trip is as uniform as possible, but the distance from the camping sites reached the last night to the end of this journey is not the same as previous spans.
d) Camping sites are uniformly distributed throughout the river, the distance between any two camping sites is a fixed constant.
e) Two tour groups can not occupy simultaneously the same camping tent.
f) For convenience, we treat a night as a unit and propose to take 6-18 nights expenditure on whole trips.
g) The river recommends two transport tools, an average of 4 m/h oar boat and 8 m/h motor boast.
h) A tour group adopts just either motor boat or oar boat, and do not replace the transport tool on half-way.
i) Assume the number of two transport tools is sufficient to meet the daily needs.

1.2 Symbols Definition

N_i—number of tour groups in the river in the i-th day;

$\Delta N_{i,1}$—number of newly tour groups in the river in the i-th day;

$\Delta N_{i,2}$—number of tour groups of end trip in the river in the i-th day;

$X_{i,j,t}$—the series number of camping sites occupied by the j-th tour group starting on the i-th day and expenditure on t nights;

$v_{i,j,r}$—the average speed of the r-th transport toll adopted by the j-th tour group starting on the i-th day;

$\Delta t_{i,j}$—the total time spend by the j-th tour group in the i-th day (viz. sailing time);

α_r—selected speed factor, α_r=0,1;

S—span between any two adjacent camping sites.

2. THE MODEL BASED ON MAXIMUM EFFECTIVE COEFFICIENT

In the i-th day of the tourist season (i=1, 2, …, 180) , the number of tour groups in the river is not only related with the account of new launching groups and ending trips groups in the i-th day, but also with the number of tour groups yesterday (the i-1th). Similarly, the number of tour groups in the river in the i-1-th day also is not only related with the account of newly groups and ending trips groups in the i-1-the day, but also with the number of tour groups yesterday (the i-2th). With continues iteration, the number of tour groups in the river in the 2-th day still is not only related with the account of newly groups and ending trips groups in the 2-the day, but also with the number of tour groups yesterday (the 1-th). Finally, the number of groups in the river is the number of new launching group in the first (the 1-th).

In order to attain the target maximum utilization camping sites every day, the park managers are required to allow more number of groups and to make possible use of the camping tent. Our models consist of two parts. Firstly, we maximum utilization camping sites in the 1-th, then consider to reach maximum in any day.

2.1 Consider Only the First Day of Operation

Definition: Effective coefficient $\rho_i=\frac{N_i}{Y}$, the number of camping sites is a constant Y.

Considering the maximum utilization of the camping sites as the objective function max ρ_1. Suppose the oar-boating tour number is $N_{1,1}$ and motor-boating tour number is $N_{1,2}$ respectively.

Then, the total tour number in the 1-th day is:

$$N_1=N_{1,1}+N_{1,2}\,.$$

Throughout the whole trip, passengers can choose two transport tools: 4mph ora-boating and 8 mph motor-boating. The average speed for the j-th tour group adopting the r-th tool in the 1-th is defined as $V_{1,j,r}$

$$V_{1,j,r} = 4\alpha_r + 8(1 - \alpha_r)\ ,$$

where α_r is selected speed factor.

As two groups can not occupy the same camping tent at the same time, it is available

$$X_{1,m,1} \neq X_{1,l,1}\ \ (m,l = 1,2,\cdots N_1,\ m \neq 1)\ ,$$

where $X_{1,k,1}$ and $X_{1,l,1}$ are the series number of camping sites occupied by the K-th tour group and l -th tour group respectively.

For each tour group, daily travel distance should be balanced as much as possible. Since $\Delta t_{1,j}$ is the total time spend by the j-th tour group in the l-th day, the voyage of the first day of the j-th tour group is $\Delta t_{1,j}\cdot v_{1,j,r}$. The whole trip takes 6-18 nights (In fact 7-19 days, for easy to remember here, Still notes for 6-18 days)

$$6 \le \frac{225}{\Delta t_{1,j} \cdot v_{1,j,r}} \le 18\ .$$

Each group a day trip can be divided by the span between the adjacent two camping sites.

$$\Delta t_{1,j} \cdot v_{1,j,r} = k\frac{225}{Y+1}\ ,$$

then, we can get

$$\left[\frac{Y+1}{18}\right] \le k \le \frac{Y+1}{6}.$$

Due to inter k, then

$$k \in \left[\left[\frac{Y+1}{18}\right], \left[\frac{Y+1}{6}\right]\right].$$

In summary, we get the following models:

$$\max \quad \rho_1 = \frac{N_1}{Y},$$

$$\begin{cases} N_1 = N_{1,1} + N_{1,2} \\ V_{1,j,r} = 4\alpha_r + 8(1-\alpha_r) \quad (j = 1,2,3,\cdots N_1, r = 1,2) \\ X_{1,m,1} \ne X_{1,l,1} \quad (m,l = 1,2,\cdots N_1, m \ne l) \\ 6 \le \dfrac{225}{\Delta t_{1,j} \cdot v_{1,j,r}} \le 18 \\ \Delta t_{1,j} \cdot v_{1,j,r} = k\dfrac{225}{Y+1} \quad (k \in N^+) \\ k \in \left[\left[\dfrac{Y+1}{18}\right], \left[\dfrac{Y+1}{6}\right]\right] \end{cases}. \quad (1)$$

2.2 Consider Any Given Day

Because the number of tour groups in the river is not only related with the account of new launching groups and ending trips groups in the i-th day, but also with the number of tour groups yesterday (the i-1th), we attain

$$N_i = N_{i-1} + \Delta N_{i,1} - \Delta N_{i,2}.$$

Where N_{i-1} is the tour number in the river in i-1th day, $\Delta N_{i,1}$ is the newly tour number and $\Delta N_{i,2}$ is the number of end tour.

Visitors need to have rest after end of a day trip, therefore, therefore each group a day trip can be divided by the span between the adjacent two camping sites,

$$\frac{\Delta t_{i,j} \cdot v_{i,j,r}}{s} \in N^+.$$

Where

$$s = \frac{225}{Y+1}.$$

Since there two transport speed: v = 4 mph, v = 8 mph and 6-18 trip days, we can compute the min and max speed per day as: 12.5 mph and 37.5 mph. In the view of easy management, daily trip as far as possible the same, we sail away on every day with the following restrictions:

$$12 < \Delta t_{i,j} \cdot v_{i,j,r} < 38.$$

The series number of camping tent occupied by the j-th group at t night is denoted as X_{i-t+1}, j, t, then

$$X_{i-t+1,j,t} = X_{i-t+1,j,t-1} + \frac{\Delta t_{i-t+1,j} \cdot v_{i-t+1,j,r}}{s}.$$

The series number of camping tent occupied by newly launching tour group is defined as $X_{i,j\,1}$, then

$$X_{i,j,1} = \frac{\Delta t_{i,j} \cdot v_{i,j,r}}{s}.$$

Similar to $V_{1,j\,r}$, the average speed for the j-th tour group adopting the r-th tool in the i-th defined as $V_{i,j,r}$

$$V_{i,j,r} = 4\alpha_r + 8(1-\alpha_r).$$

Every day there may be newly launching tour group in the river, but also some groups end their trips. If the series number of camping sites and the span between the two adjacent camping sites are known, we can compute the j-th tour voyage at i-th night $X_{i-t+1,j,t} \cdot S$. Suppose the tour group starting in the i-t+1-th day, after t days, we wonder to know whether the tour group leave the rives in i-th day, defined as $m_{i-t+1,j,t}$. If the total length which contains i days trip and the next day's journey is greater than the length of the river, the tour group is to leave the river after the i-th night, denoted as $m_{i-t+1,j,t}$=1, otherwise $m_{i-t+1,j,t}$=0,

$$m_{i-t+1,j,t} = \begin{cases} 1, & X_{i-t+1,j,t} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} \ge 225 \\ 0, & X_{i-t+1,j,t} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} < 225 \end{cases}.$$

Sum up all the $m_{i-t+1,j,t}$ in the i-th day, the number of tour group reaching the ending after i nights is computed as

$$\Delta N_{i,2} = \sum_{t=1}^{18} \sum_{j=1}^{\Delta N_{i-t+1}} m_{i-t+1,j,t}.$$

Gathering up above analysis we get the following model:

$$\max \quad \rho_i = \frac{N_i}{Y}$$

$$\begin{cases} N_{\mathrm{i}} = N_{\mathrm{i-1}} + \Delta N_{i,1} - \Delta N_{i,2} \\ \dfrac{\Delta t_{i,j} \cdot v_{i,j,r}}{s} \in N^+ \\ 12 < \Delta t_{i,j} \cdot v_{i,j,r} < 38 \\ X_{i-t+1,j,t} = X_{i-t+1,j,t-1} + \dfrac{\Delta t_{i-t+1,j} \cdot v_{i-t+1,j,r}}{s} \quad ,1 < t \le 18 \\ X_{i,j,1} = \dfrac{\Delta t_{i,j} \cdot v_{i,j,r}}{s} \\ V_{i,j,r} = 4\alpha_r + 8(1-\alpha_r) \\ m_{i-t+1,j,t} = \begin{cases} 1, X_{i-t+1,j,t\text{-}1} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} \ge 225 \\ 0, X_{i-t+1,j,t\text{-}1} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} < 225 \end{cases} \\ \Delta N_{i,2} = \sum_{t=1}^{18} \sum_{j=1}^{\Delta N_{i-t+1}} m_{i-t+1,j,t} \\ X_{i,j,t} \ne X_{I,J,T} \quad , \ I \ne iorJ \ne jorT \ne t \end{cases}. \quad (2)$$

Obviously, model of any given day is reduced to model of the first day if we let i = 1, *i.e.* model of the first day is a special cases of model of any given day.

2.3 Improved Model: With Minimal Contact With Other Groups of Boats on the River

In river trip，one group of trip wants minimal contact number with the other groups, *i.e.* the contact times of the former trip are caught up with by the other trips to the reaches minimum. By comparing the location relationship of two different touring parties, we can determine whether they can meet with each other. Then, we propose the following model

$$\text{Min } C_i$$

Denote the number of touring parties at day i as N_i, the total number of touring parties in the first i days as DN_i.

Then, we have $DN_i = \sum_{t=1}^{i} \Delta N_{t,2}$. Nest, we number every trip in 180 days (throughout the whole tourist season) by a one dimensional variable. Let q be the j-th touring parties beginning at the i-th day, which can be expressed as $q = \sum_{t=1}^{i-1} \Delta N_{t,1} + j$.

Denote the touring parties numbered q beginning at i-th day as $X_{i,q}$, and let Kp be a 0-1 variable, $e1 = q + 1$, $e0 = q$. When $X_{i,e1} > X_{i,e0}$, two different touring parties meet with one time. Then, let $Kp = 1$. Otherwise, let $Kp = 0$. The number of ascending order is disorganized when one touring party exceeds the other one. To guarantee the ascending order, we exchange the subscripts of $X_{i,q}$, *i.e.* if $X_{i,e1} > X_{i,e0}$, we have $e1 \leftrightarrow e0$,

$$Kp = \begin{cases} 1, & X_{i,e1} \geq X_{i,e0} \quad (e1 \leftrightarrow e0) \\ 0, & X_{i,e1} < X_{i,e0} \end{cases},$$

where $p = 1, 2, \cdots, N_i - 1$. Then, the number of contact on i-th day can be expressed as

$$C_i = \sum_{p=1}^{N_{i-1}} Kp .$$

Then, the optimization models for the utilization rate and contact number on i-th day

$$\text{Max } \frac{N_i}{Y},$$

$$\text{Min } Ci,$$

$$\begin{cases} N_i = N_{i-1} + \Delta N_{i,1} - \Delta N_{i,2} \\ \dfrac{\Delta t_{i,j} \cdot v_{i,j,r}}{s} \in N^+ \\ 12 < \Delta t_{i,j} \cdot v_{i,j,r} < 38 \\ X_{i-t+1,j,t} = X_{i-t+1,j,t-1} + \dfrac{\Delta t_{i-t+1,j} \cdot v_{i-t+1,j,r}}{s} \quad ,1 < t \leq 18 \\ X_{i,j,1} = \dfrac{\Delta t_{i,j} \cdot v_{i,j,r}}{s} \quad t = 1 \\ V_{i,j,r} = 4\alpha_r + 8(1-\alpha_r) \\ m_{i-t+1,j,t} = \begin{cases} 1, X_{i-t+1,j,t-1} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} \geq 225 \\ 0, X_{i-t+1,j,t-1} \cdot d + v_{i-t+1,j} \cdot \Delta t_{i-t+1,j} < 225 \end{cases} \\ \Delta N_{i,2} = \sum_{t=1}^{18} \sum_{j=1}^{\Delta N_{i-t+1}} m_{i-t+1,j,t} \\ X_{i,j,t} \neq X_{I,J,T} \quad , I \neq i or J \neq j or T \neq t \\ DN_i = \sum_{t=1}^{i-1} \Delta N_{t,2} \\ q = \sum_{t=1}^{i-1} \Delta N_{t,1} + j, \quad q \in N^+ \\ Kp = \begin{cases} 1, X_{i,e1} > X_{i,e0} (e1 \leftrightarrow e0) \\ 0, X_{i,e1} < X_{i,e0} \end{cases}, \quad p = 1, 2, \cdots, N_i - 1 \\ C_i = \sum_{p=1}^{N_{i-1}} Kp \end{cases} \quad . \quad (3)$$

3. BLOCK SINGLE TRIPS MODEL FOR THE OPTIMIZATION OF USING CAMP SITES

3.1 Conditions, Assumes and Symbol Introduction

(a) Traveling Miles $S = 225$ m.

(b) Tourist season $T = 180$ days, which come from the camping night.

(c)The number of camping sites satisfies $Y \geq 18$. For the sake of computation, the number of camping sites is might as well chosen as $Y = 45$.

(d) Distributed fairly uniformly throughout the river corridor and numbered by 1, 2, $\cdots$ Y, from the initial entry point to the terminating point.

(e) A camping site can only be used by one trip on one day

(f) A camping site cannot be used by a trip more than one night.

(g) The camping sites are divided into different types according to the camping nights (d=6, 7,$\cdots$, 18) and the means of trip (motorized boats or rubber rafts). For example, motorized d-trip is the trip using motorized boat and take d nights, and the rest can be done in the same manner.

(h) The speeds of motorized boats and rubber rafts are respectively denote by $V_{\text{mot}} = 8$ and $V_{\text{hum}} = 8$

(i) For a special trip, the time limits tmax and tmin satisfy $t_{\max} = 5 > t_{\min}$, and $t_{\min}$ must long enough to guarantee the trip can reach the next camping sites. Therefore, anyone trip cannot stay in a camping site more than one night.

(j) As to motorized d-type, the upper limit of travel time can be transfer to the upper limit of the crossed camping sites

$$s\max_{\text{mot}} = fix\left(\frac{V_{\text{mot}} \cdot t_{\max}}{S/(Y+1)}\right)$$

and the lower limit is $s\min_{\text{mot}} = 1$.

(k) To guarantee the trip be successfully finished. The maximal number of crossed camping sites cannot be less than Y in d days, *i.e.* $d \cdot s\max_{mot} \geq Y$, $d \cdot s\max_{\text{hum}} \geq Y$

(l) The maximal number of trips starting off the initial point is not more than smax. Otherwise, there must exist two trips camp in the same site or some a trip must waste time to avoid contacting with the other one.

Remark: The 0 value in table means the empty cell or the corresponding term does not make sense.

3.2 Single Type Trip

Maximizing the number of trips implies the using of camping sites achieves the upper limit, and optimizing the using of camping sites means the utilization rate of each sites should be closed as far as possible. To make the camping sites are used more times, the days of all the sites are occupied by trips should be as much as possible, reaching the saturated state should be as early as possible, and keeping this state should be as long as possible. Being the tourist season is fixed (T=180), the number of available camping sites $Q=T\cdot Y$ is invariable. If the saturated state cannot be kept, more camping sites (Res) are left unused, *i.e* .the less sites are used ($C=Q$-Res). Then, it is reasonable to consider the scheme which can keep the saturated state long time; Furthermore, seen from the administrative cost, fixed arrangement is acceptable. Otherwise, if the daily arrangement different from each other, it is not good to the propaganda and generalization. Of cause, some people may be like it. Therefore, the single type trip is firstly considered, *i.e.* only the trips with the same kinds of boats and the identical camping days are arranged.

Conclusion 1 The camping days (N) reaching the saturated state satisfies $N>d$-1 if only the single type trips are arranged.

Proof. Suppose the state is saturated when $N=d$-1, the Y th camping sites has been used by certain a trip. Then, this trip cannot occupy this site any more, and the trip finished. The whole trip lasts for d-1 days, which is contradictory to the assumption of this section.

Conclusion 2 Let Xset=[X_1,X_2,$\cdots$, X_d] be any a integer sequence with length d. Then, Xset can be used to denote the number of d-trips starting from the initial state. If $1\le X_i\le s\max$, $\sum_{i=1}^{d} X_i = Y$ are satisfied, the arrangement is described in Table 1. The saturated state is reached in d th day, kept without contact with the other trips. Each of positive integer in Table 1 expresses the number of a certain trip on some day defined in Conditions and assumptions.

Conclusion 3 For any reasonable sequence Xset, the cyclic utilization of the arrangement in Table 1, the saturated state are kept.

For $C=Q$-Res, maximizing C means minimizing Res. Then, the optimization problem (P1)

$$\begin{aligned} &\min \quad Res\left(T, Y, d, X_1, X_2, \cdots, X_d\right) \\ &s.t. \\ &\sum_{i=1}^{d} X_i = Y, \\ &X_i \in \{1, 2, \cdots, s\max\}, i = 1, 2, \cdots, d \end{aligned}$$,

where $s$max can be respectively chosen as $s\max_{mot}$ and $s\max_{hum}$ according to the motorized trips and the rubber trips.

Table 1
The Arrangement of Trips Under the Control of Some Sequence Xset

Trips \ Time	1	2	3	…	d
1	1	1+$X$2	1+$X$2+$X$3	…	1+$X$2+…+Xd
2	2	2+$X$2	2+$X$2+$X$3	…	2+$X$2+…+Xd
…			…		
$X$1	$X$1	$X$1+$X$2	$X$1+$X$2+$X$3	…	$X$1+$X$2+…+Xd
$X$1+1		1	1+$X$3	…	1+$X$3+…+Xd+$X$1
$X$1+2		2	2+$X$3	…	2+$X$3+…+Xd+$X$1
…				…	
$X$1+$X$2		$X$2	$X$2+$X$3		$X$2 +$X$3+…+Xd+$X$1
…					
$X$1+…+X(d-1)+1					1
$X$1+…+X(d-1)+2					2
…					…
$X$1+…+X(d-1)+Xd					Xd

Conclusion 4 Let r = mod (T - d+1, d). Then, Res = (d-1)Y if r =0 and $Res = \left(d + r - 1\right)Y - d\sum_{i=1}^{r} X_i$ if $r > 0$.

Proof.

a) r =0

Then, the numbers camping sites left unused are $(1 \to d - 1)$

$$\begin{aligned} &Y - X_1 \\ &Y - X_1 - X_2 \\ &\cdots \\ &Y - X_1 - X_2 - \cdots - X_{d-1} \end{aligned}$$

The numbers camping sites left unused are $(d \to T - d + 1)$

$$\begin{aligned} &Y - X_d \\ &Y - X_d - X_{d-1} \\ &\cdots \\ &Y - X_d - X_{d-1} - \cdots - X_2 \end{aligned}$$

Being $\sum_{i=1}^{d} X_i = Y$, we have

$$Res = \sum_{k=1}^{d-1}\left(Y - \sum_{i=1}^{k} X_i\right) + \sum_{k=1}^{d-1}\left(Y - \sum_{i=1}^{k} X_{d+1-i}\right) = 2\left(d-1\right)Y - \left(d-1\right)\sum_{i=1}^{d} X_i = \left(d-1\right)Y .$$

b) $r > 0$. The results can be obtained in the similar way as case 1.

Thus, minimizing Res can be achieved by maximizing $\sum_{i=1}^{r} X_i$ for certain a sequence Xset. Further, the result is independence to order of X_1, X_2,$\cdots$, X_r. The sequence Xset in Proposition 2 leads to the same Res if $r = 0$, and (P1) can be solved.

In the same time, (P1) is equivalent to optimization problem (P2) when $r > 0$

$$\min \quad S_r\left(d, X_1, X_2, \cdots, X_d\right) = \sum_{i=1}^{r} X_i$$

$$s.t.$$

$$\sum_{i=1}^{d} X_i = Y,$$

$$X_i \in \{1, 2, \cdots, s\max\}, i = 1, 2, \cdots, d.$$

By the formulae of r in conclusion 4, we have Table 2 and 3.

Table 2
***r* - *d* (*T* = 180)**

d	6	7	8	9	10	11	12	13	14	15	16	17	18
r	1	6	5	1	1	5	1	12	13	1	5	11	1

It is easy to see that $r > 0$ for any integer d, i.e. the sequence Xset affects Res.

Table 3
***d* - *s*max (*T*=180, *Y*=45)**

d	6	7	8	9	10	11	12	13	14	15	16	17	18
$s\max_{mot}$	8	8	8	8	8	8	8	8	8	8	8	8	8
$s\max_{hum}$							4	4	4	4	4	4	4

Solve (P2) and compute idle variable $Res = (d + r - 1)Y - d{\cdot}Sr$, we can get the maximum tour group number $n$trip $= T \cdot Y - R$es, optimal sequence $X\text{set} = [X_1, X_2, \cdots X_d]$ and the following Table 4, 5 and 6.

Table 4
Relations *d* and *R*es for Single Type of Tour Trip (*T*=180, *Y*=45)

d	6	7	8	9	10	11	12	13	14	15	16	17	18
Res_{mot}	222	232	220	333	370	246	444	508	554	555	356	552	666
Res_{hum}							492	508	554	615	580	552	738

Table 5
Relations *d* and *N*trip For Single Type of Tour Trip (*T*=180, *Y*=45)

d	6	7	8	9	10	11	12	13	14	15	16	17	18
$ntrip_{mot}$	1313	1124	985	863	773	714	638	584	539	503	484	444	413
$ntrip_{hum}$							634	584	539	499	470	444	409

Table 6a
Relations *d* and *X*set for Single Type of Motor-Boating Tour Trip (*T*=180, *Y*=45)

d	$Xset_{mot}$																	
6	8	8	8	7	7	7												
7	7	7	7	7	7	7	3											
8	6	6	6	6	6	5	5	5										
9	6	5	5	5	5	5	5	5	4									
10	6	5	5	5	4	4	4	4	4	4								
11	6	6	6	6	6	3	3	3	2	2	2							
12	6	4	4	4	4	4	4	3	3	3	3	3						
13	4	4	4	4	4	4	4	4	3	3	3	3	1					
14	4	4	4	4	4	3	3	3	3	3	3	3	3	1				
15	6	3	3	3	3	3	3	3	3	3	3	3	2	2	2			
16	6	6	6	6	6	2	2	2	2	1	1	1	1	1	1	1		
17	4	4	4	4	4	4	3	3	3	3	3	1	1	1	1	1	1	
18	6	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2

Table 6b
Relations *d* and *X*set for Single Type of Oar-Boating Tour Trip (*T*=180, *Y*=45)

d	$X\text{set}_{\text{hum}}$																	
12	4	4	4	4	4	4	4	4	4	3	3	3						
13	4	4	4	4	4	4	4	4	3	3	3	3	1					
14	4	4	4	4	4	3	3	3	3	3	3	3	3	1				
15	4	3	3	3	3	3	3	3	3	3	3	3	3	3	2			
16	4	4	4	4	4	3	3	3	2	2	2	2	2	2	2	2		
17	4	4	4	4	4	4	3	3	3	3	3	1	1	1	1	1	1	
18	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2

The following conclusion is easy to attain with previous results and Table 3 and 4.

Conclusion 5: If there are enough motor-boating, we can arrange 6-type motor-boating tour group and get the optimal series *X*set [8,8,8,7,7,7] with maximum group number 1,313, idle number 222. The number of each camping tents occupied is 175. Any two group can not meet each other for the whole trip. The scheme for tour groups arrangement is contained in data file optrip.xls.

3.3 Further Discussion in Single Type Case

Define (Single type of group policy): *Y* nodes into several groups, and each group was arranged for the same single type of group

Conclusion 6: If $Y_1 + Y_2 = Y$, the idle variables $R\text{es}_{\text{mot}}$ and $R\text{es}_{\text{hum}}$ satisfy

$$R\text{es}_{\text{mot}}\left(d, Y_1\right) + R\text{es}_{\text{mot}}\left(d, Y_2\right) \geq R\text{es}_{\text{mot}}\left(d, Y\right),$$

$$R\text{es}_{\text{hum}}\left(d, Y_1\right) + R\text{es}_{\text{hum}}\left(d, Y_2\right) \geq R\text{es}_{\text{hum}}\left(d, Y\right).$$

The results for $n\text{trip}_{\text{mot}}$ and $n\text{trip}_{\text{hum}}$ are similar.

All results show that single type of group policy is less than single type of fixed policy.

$$\begin{aligned}
&\min \quad n\text{trip}_{\text{mot}}\left(d_1, Y_1\right) + n\text{trip}_{\text{hum}}\left(d_2, Y_2\right) \\
&s.t. \\
&Y_1 + Y_2 = Y, \\
&n\text{trip}_{\text{mot}}\left(d_1, Y_1\right) \leq A, \\
&n\text{trip}_{\text{hum}}\left(d_2, Y_2\right) \leq A + B - n\text{trip}_{\text{mot}}\left(d_1, Y_1\right). \\
&X\text{set}_{\text{mot}} = \left[2,2,2,2,2,2\right] \\
&X\text{set}_{\text{hum}} = \left[3,3,3,3,3,3,3,3,3,3,3\right]
\end{aligned}$$

distribution of camping sites:

pqqpqqpqqpqqpqqpqqpqqpqpqpqpqpqpqpqpqpqpqpqpqpq

Where, Y_1=12, Y_2=33, evenly distributed.

The optimal sequence:

$$\begin{aligned}
&X\text{set}_{\text{mot}} = \left[3,2,2,2,2,2,2,2,2\right] \\
&X\text{set}_{\text{hum}} = \left[2,2,2,2,2,2,2,2,2,2,2,2,2,2\right]
\end{aligned}.$$

4. MODEL BASED ON THE DISTRIBUTION OF CAMPING SITE FOR MOTORIZED BOATS

The models discussed in above sections owns a key assumption that the number of the camping sites *Y* is a determined value. However, the number of camping sites take play an important role in the making of tourism plan. In the present section, we suppose the number of camping sites can be reset.

Because the trips range from 6 to 18 nights of camping on the river from the initial site to the terminating site, the number of camping sites satisfies $Y \geq 6$. It is worth to note that there are only two kinds of boats, i.e. rubber rafts, motorized boats, can be used, and the speed of the latter is faster than that of the former. Then, we prefer to use the motorized boats to improve the utilization rate of camping sites.

Definition: The evaluation coefficient of camping site $\gamma_Y = \dfrac{X}{Y}$, where *X* is the total number of touring parties in a tourist season, and *Y* is the number of camping sites.

4.1 The Case of Six Camping Sites for Motorized Boats

Firstly, establish the approximate isometric motor-boating camping sites. Suppose the tour group spends 6 nights on whole trip, there needs 6 uniformly distributed camping sites. The distance between any adjacent camping sites is 32. Each tour group spends about 4 hours in the river every day. Subsequently, we want to add several camping sites (either oar-boating or motor-boating) between two adjacent motor-boating sites.

(a) We evenly add a camping site between two adjacent motor-boating sites, one gets 13 camping sites on the whole river, and the river is divided into 14 intervals. After computation, only two motorized trips or one rubber trip can be arranged to enjoy the river trip. Obviously, this arrangement is a single trip, *i.e.* the motorized trip and the rubber trip is not arranged simultaneously. In this section, we mainly focus on the arrangements owning both of the two kinds of trips.

(b) On the basis of (a), adding a new camping site to each of the 14 intervals, we get 27 camping sites on the whole river, which are respectively numbered by 1,2,…, 27 from the initial entry point to the destination. Then, the whole river is divided into 28 intervals, and the length for which is nearly 9 miles. In view of the physiological limit, the distance of travel by rubber rafts is not more than 24 miles one day. To avoid two campers occupy the same site at the same time, we assume that rubber raft ran about 16 miles or 24 miles one day. Then, the total number of trips in six months can be obtained by the following equation

$$X=174+2\times170=514\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{514}{27}=19.037.$$

(c) On the basis of (b), adding a camping site to each of the 28 intervals, one gets 55 camping sites on the whole river, which are respectively numbered by 1,2,…, 55 from the initial entry site to the terminating site. Then, the whole river is divided into 56 intervals, and the length of which is nearly 4 miles. After computation, we get the arrangement for trips described in Table 2.

In a tourist season, the total number of trips in six months is

$$X=2\times174+4\times170=1028,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{1028}{55}=18.691.$$

(a) Adding evenly two camping sites to each of the 7 intervals, one gets 20 camping sites on the whole river. After computation, only two motorized trips and one rubber trip can be arranged to enjoy the river trip. The slowest trip needs 12 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=174+168=34\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{342}{20}=17.200.$$

(b) On the basis of (a), adding a camping site to each of the 21 intervals, one gets 41 camping sites on the whole river. After computation, only two motorized trips and two rubber trips can be arranged to enjoy the river trip. The slowest trip needs 13 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=2\times174+2\times167=682,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{682}{41}=16.630.$$

Adding four camping sites to each of the 7 intervals, one gets 34 camping sites on the whole river. After computation, only two motorized trips and one rubber trip can be arranged to enjoy the river trip. The slowest trip needs 13 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=174+2\times167=508\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{508}{34}=14.941.$$

Adding six camping sites to each of the 7 intervals, one gets 34 camping sites on the whole river. After computation, only two motorized trips and three rubber trips can be arranged to enjoy the river trip. The slowest trip needs 11 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=2\times174+3\times168=855\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{855}{48}=17.813.$$

4.2 The Case of Seven Camping Points for Motorized Boats

We choose seven points distributed fairly uniformly throughout the river corridor as the camping sites, which split the whole river into eight parts. Each of them is nearly 28 miles and each trip travels to about 3.5 hours one day.

(a) Adding a camping point to each of the 8 intervals, one gets 15 camping sites on the whole river, and only one motorized trip or one rubber trip can be arranged to enjoy the river trip. This arrangement is also a single trip.

(b) On the basis of (a), adding a new camping site to each of the 16 intervals, one gets 31 camping sites on the whole river. After computation, only one motorized trip or one rubber trip can be arranged to enjoy the river trip. The slowest trip needs 11 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=173+2\times169=511\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{511}{31}=16.484.$$

(a) Adding two camping sites to each of the 7 intervals, one gets 23 camping

sites on the whole river. After computation, only one motorized trip and one rubber trip can be arranged to enjoy the river trip. The slowest trip needs 11 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=173+169=342\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{342}{23}=14.770.$$

(b) On the basis of (a), adding two new camping site to each of the 24 intervals, one gets 47 camping sites on the whole river. After computation, only 2 motorized trips and 3 rubber trips can be arranged to enjoy the river trip. The slowest trip needs 10 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=2\times173+3\times170=856\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{856}{47}=18.213.$$

Adding four camping sites to each of the 7 intervals, one gets 39 camping sites on the whole river. After computation, only two motorized trips and two rubber trips can be arranged to enjoy the river trip. The slowest trip needs 13 nights to finish the route. In a tourist season, the total number of trips in six months is

$$X=2\times173+2\times167=680\ ,$$

and the evaluation coefficient is

$$\gamma_Y=\frac{X}{Y}=\frac{680}{39}=17.430.$$

4.3 The Case of Eight Camping Points for Motorized Boats

We choose eight points distributed fairly uniformly throughout the river corridor as the camping sites, which split the whole river into nine parts. Each of them is nearly 25 miles and every trip travels on to 3.125 hours one day. In the following, some other camping points will be added among the chosen points, initial entry point and the destination for motorized boats or rubber rafts. Similar to above discussion in the cases 1-2, we have the following results:

If $Y = 26$, the evaluation coefficient $\gamma_Y = 12.885$

If $Y = 35$, the evaluation coefficient $\gamma_Y = 14.457$;

If $Y = 44$, the evaluation coefficient $\gamma_Y = 15.410$;

If $Y = 53$, the evaluation coefficient $\gamma_Y = 16.000$.

4.4 Results Analysis

The bigger value of γ_Y is expected for the government agency when Y varies in a reasonable interval. Seen from above discussion, the values of γ_Y are bigger than the others when $Y = 27$, which means these two kinds of arrangement is performable.

When $Y = 27$, there exists another arrangement as two motorized trips and one rubber trip, and $X = 518$, $\gamma_Y = 19.185$. Then, we say $X = 518$ is the carrying capacity of the river as $Y = 27$.

When $Y = 55$, there exist another three kinds of arrangements as three motorized trips and three rubber trips, five motorized trips and two rubber trips, six motorized trips and one rubber trip. Correspondingly, the total number of touring parties and the evaluation coefficient are valued as $X = 1032, 1210, 1214$, $\gamma_Y = 17.764, 22.000, 22.730$, respectively. Then, we say $X = 1214$ is the carrying capacity of the river as $Y = 55$.

CONCLUSION

On the basis of the analysis on the inherent law of river touring, we propose three different models from different views. We employ three different methods to solve the problem. It is easy to verify the accuracy of the models by comparing the data obtained from different methods.

The definitions effective coefficient and evaluation coefficient are proposed. By defining the effective coefficient and evaluation coefficient, we simplify the statement on our variables used in this model.

Our method is simple and easy to be implemented, and it can accomplish the optimization efficiently no matter the number of camping sites or the trip. The using of camping sites can be optimized and the trips can be maximized.

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