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Research on Optimization of Dual Regulation Switching of Library Occupancy Management during Epidemic Situation

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Abstract: With the end of epidemic prevention and control, universities and city libraries have been opened one after another. However, in order to maintain the reader seat distance, the current library seat capacity has been greatly reduced. Based on the inadequacy of the current general reservation regulation operation and the consideration of the seat usage habits of the main body of the library, this project intends to implement a new seat management regulation. The implementation time of the busy-time regulation will depend on the real-time situation. Therefore, the author builds an optimal stopping time model to describe the best time to implement the busy-time regulation, so as to minimize the waste of resources occupied by the seat. By solving the optimal stopping time problem, this paper finally obtains the real-time dynamic strategy implemented by busy-time regulation, which is simple and intuitive, and has strong operability. This research will provide quantitative decision-making basis for maximizing the use of library seating resources during the outbreak.

Keywords: occupancy management; decision timing; optimal stopping time

1 Introduction

As the situation of the epidemic continues to improve in China, the social and economic order is being restored at a faster pace. Governments at all levels continue to accelerate the full restoration of production and living order in the normal epidemic prevention and control process, and strive to minimize the losses caused by the epidemic. As universities around the country announced their opening dates, the Ministry of Education also stressed in the video conference on the epidemic prevention and control schedule of the resumption of colleges and universities, in accordance with the principle of "speaking slowly, thinking kindly and acting wisely" to promote the opening of colleges and the prevention and control of the epidemic. "Speaking slowly" means that we should plan before acting, analyze and judge carefully, plan carefully, scheme carefully and arrange carefully. "Thinking kindly" means that we should always put the life safety and health of teachers and students in the first place, and attach great importance to the examination, admission, employment and other work related to students' vital interests. "Acting wisely" means that we need to strictly implement all prevention and control measures and respond in a timely manner according to the situation of epidemic prevention and control.

At present, some universities that have returned to school still adopt online teaching, closed campus management, limited open public teaching resources such as studios, laboratories and libraries to avoid crowd gathering. With the continuous restoration of teaching order, the library is the main place for daily self-study of students. How to open the self-study room of the library in an orderly manner, avoid excessive gathering of personnel and optimize the allocation of seat resources is an urgent problem to be solved at present. Library seat reservation management system is favored by colleges and universities management system in recent years, relying on the student campus card or WeChat campus card, combining with the large data cloud computing technology, providing effectively for students related services of library information, online booking to choose, to some

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extent the phenomenon of “looking for a seat hard, occupying seats in disorder”, especially in the epidemic prevention and control under normal times. The reservation management system has significant advantages in the reasonable allocation of seat resources, the control of visitor flow, and the traceability of students’ behavior trajectory. While promoting the reservation management system vigorously, some scholars [3, 9, 10] believe that the low utilization rate of reservation management system is due to the audience’s subjective adherence to the rule of “first come, first served” rather than reservation management, and the difference in cost expectations for the implementation of different rules leads to the low efficiency of the system. Literature [4, 5, 8] deeply investigated students’ behavioral preferences for self-study in the library, and pointed out that the introduction of effective seat management system or reservation system would help improve the use efficiency of library seats and alleviate the problem of seat occupation. In addition, many scholars [6, 7] also conducted quantitative analysis from the perspective of economics in terms of resource allocation and game decision theory. At present, in the context of normal epidemic prevention and control, reservation reservation management system has great advantages in the controllability of the flow of people and the traceability of visitors’ information, so the use of reservation reservation mechanism has become the first choice at present. The core problem of the reservation mechanism is that readers who have made an appointment enjoy a certain amount of reservation time, and readers will rely on this exemption time. If they are late or break the contract, there will be a certain amount of empty seats in a certain period of time, resulting in a waste of resources.

This paper takes the library seat reservation management mechanism currently implemented by Jiangsu University Library during the epidemic period as a reference, and takes it as the regulation of leisure time. According to the reservation management system, students can reserve a seat on the same day or the next day through the location selection machine, the homepage reservation system or the official WeChat. Reservations can not be cancelled after success on that day. The next day can be cancelled before 8:00 on the effective day. Sign in or sign out the rules after the success of the reservation must be within 30 minutes into the hall sign in, temporary system default reservation for 30 minutes, lunch hour(11:30-12:30) and dinner hour(17:00-18:00) can temporarily reserved an hour, students are given 30 minutes or an hour, and it no longer accepts seat selection after 21:00. In addition, the library also carries out identity and health-related information registration for visitors, and restricts or prohibits readers who fail to meet the requirements of epidemic prevention and control.

With the increasing number of students returning to school, especially with the coming of the full back-to-school pressure of the fall semester of 2020, the design and implementation of the busy-time regulation is the focus of the research. On the other hand, from the previous data, the daily visitor flow of university library has a certain tidal nature, that is, there will be a peak flow of library in the morning, before and after the lunch break and before the library closes. In terms of monthly flow fluctuation, there will be a peak flow of library near the mid-term and final learning periods, it has obvious periodicity. In the face of the peak flow of people, too long reservation time will lead to too long queuing time, and the system operation efficiency is low. For the consideration of normal epidemic prevention and control, the main issues to be considered in this paper are how to steadily open the library study room, adjust the current reservation seat reservation mechanism according to the current situation, determine the timing of the change of management mechanism, and ensure the utilization efficiency of seat resources to the maximum extent.

The busy-time plan design mainly on the following two issues to do appropriate improvement. First, if the reservation is held for 30 minutes, it will waste 30 minutes after opening the library. More reserved readers will rely on this exemption time to arrive 20 minutes late than in the case of no reservation, thus wasting seat resources. In the past peak period of the end of the term, all the seats were filled within five minutes of opening during the peak period without reservation. Second, the 90 minutes reserved during lunch put more students in a dilemma. Compared with the situation of no reservation, even in the peak period of the end of the term, many people did not take a seat for lunch and could still find a seat in the afternoon. But under the reservation system, giving up a seat at noon and sign out mean it is almost impossible to find a seat in the afternoon, so more people will have to rush back to the library. This has caused trouble to many students who have the habit of taking a nap. They could have taken a nap in the dormitory, but now only come to the library and lie on the table, contributing to the false seat utilization rate. But readers who do not need a nap and want to read and study at this time have no seats. The designers of the system do not want to see is that “bad money drives out good money,” but it happened.

Based on the above two problems, we design to implement a shorter seat retention time on a day near the peak period of the end of the term. It seems to be stricter control, but it is expected to solve the above two problems and achieve a more full use of seat resources. The new rules are: cancel the reservation if you don’t arrive within 10 minutes of opening, cancel the extension of reservation time during mealtimes, and leave the seat for a maximum of 30 minutes at any time of the day.

Therefore, readers who leave the seat at noon will give up their seats, and students who need seats more during this period will make reservations. It is noted that the above regulations mainly consider the situation of the peak period of the end of the term, and the current reservation situation is extremely loose (see Table 1 below, the summary of the data in Table 1 of reservation information), so it is not necessary to change the regulations now. However, once the regulations are changed, it is unlikely that it will be changed again in the short term, so it is vital that the date is set carefully. In addition, the regulation change needs to be announced at least three working days in advance. Therefore, the date we need to make a decision is set as the third working day before the regulation change, and any information beyond that date cannot be used as a decision-making basis. For this reason, we introduce the optimal stopping time (see [1], [2]), it is a stochastic analysis tool, and it can analyze and quantify the date of the regulation change.

Table 1: Data summary of main table 1 for reservation information

Reservation behavior	Sign in and sign out	Sign in but absent	Sign in but not sign out	Sign in and be present
50414 person-time	45626 person-time	1253 person-time	3535 person-time	49161 person-time

2 Model Hypothesis

This project plans to build a random model for the operation status of the leisure-time regulation and the selective implementation of the busy-time regulation (cancel the reservation if you don't arrive within 10 minutes of opening, cancel the extension of reservation time during mealtimes, and leave the seat for a maximum of 30 minutes at any time of the day). Model assumptions:

Hypothesis 1: Take May 20 as the first working day, there will be about 30 working days before the end of the semester. Each working day has 720 minutes (12 hours). There are 4000 seats in the library.

Hypothesis 2: If the library is full at time t in the first 30 minutes after opening (8:00am-8:30am), it will be full until 8:30am. If the library is full at any time t between 11:00am to 13:00pm, it will be full until 13:00pm.

Hypothesis 3: During the 30 working days, the daily reservation volume increases day by day, which can be approximately seen as an increase of 200 reservation person-times per day.

3 Establishment and Solution of Model

2.1 Definition of model variables

In order to facilitate variable description and model establishment, the following variables and functions are first defined in this paper.

(1) The first 30 minutes after the opening of the library is recorded as the time period s_1, and 11:00am to 13:00pm is recorded as the time period s_2.

(2) Note that the tth day ($t \in \{1, 2, ..., 30\}$), the time length of the seats are filled of the time period s_1 is recorded as $a(t)$, the time length of the seats are filled of the time period s_2 is recorded as $b(t)$.

(3) The average empty seat occupancy time is e_{11} before the reform time period s_1, the average empty seat occupancy time is e_{12} before the reform time period s_2; the average empty seat occupancy time is e_{21} after the reform time period s_1, the average empty seat occupancy time is e_{22} after the reform time period s_2.

(4) For any seat, the state F is defined as the current state when the whole library is full but some seats are empty.

(5) Record the tth day($t \in \{1, 2, ..., 30\}$), the sum of the average duration of the state F in two time periods of s_1 and s_2 is $A(t)$(before the reform) or $B(t)$(after the reform).

(6) Record the number of reservation of the tth day($t \in \{1, 2, ..., 30\}$) is $R(t)$.

(7) Record the date of the decision to change the regulation is $\tau(\tau \in \{1, 2, ..., 27\})$, so the date of the implementation of the reform regulation is τ+3.

2.2 The overall idea of the model construction

In this model, the cumulative duration of the state time F (the current state when the whole library is full but some seats are empty) which is most likely to waste resources by occupying seats is taken as the object of investigation, and the optimal determination of the time by changing the use of the busy-time regulation is made to minimize the waste of seat resources. The solution of the model realizes the dynamic decision of the busy-time regulation based on the real-time date and the number of reservation made on the day.

2.3 Estimation of average empty seat occupancy time of two time periods before the reform s_1 and after the reform s_2.

Taking the library of Jiangsu University as an example, the answer sheets of the questionnaire (see appendix) were counted. According to the statistical results of the answers to the first two questions, the average value was obtained as follows:

Table 2: Survey results of average empty seat occupancy time before and after the reform

e_{11}	e_{12}	e_{21}	e_{22}
18.92	82.19	14.78	21.63

2.4. Estimation of the time when the library is full in two time periods of s_1 and s_2

Obviously, the time for the whole library to enter the full state is closely related to the number of visitors. Since it is difficult to calculate the number of visitors, the existing information table is a statistical table of reservation behavior, so as to obtain the statistics $R(t)$, and make a regression with the time when the library is full in two time periods, so $R(t)$ express the time when the library is full. Record the tth day ($t \in \{1, 2, ..., 30\}$) the time period s_1 at the i minute to enter the full state, the time period s_2 at the j minute to enter the full state. At present, the samples are as follows:

Table 3: Statistical table of reservation behavior

The serial number	$R(t)$	i	j
1	962	—	—
2	1052	—	—
3	1521	27	—
4	1740	24	87
5	2200	19	61
6	2451	17	50
7	2504	16	48

Note: "-" means that the seat is not full during the time period s_1 or during the time period s_2

Using MATLAB tools for regression $i = 57.1 \times e^{-0.0005 \times R(t)}$; $j = 303 \times e^{-0.0006 \times R(t)} - 19.6$ namely

$$a(t) = 30 - 57.1 \times e^{-0.0005 \times R(t)};$$

$$b(t) = 139.6 - 303 \times e^{-0.0006 \times R(t)}.$$

2.5. The sum of the average duration of the state F in two time periods of s_1 and s_2

The average empty seat occupancy time is e_{11} before the reform time period s_1. Suppose that the continuous empty seat occupation time of a certain seat during the time period s_1 is e_{11}. The starting time of this period follows $[0, s_1 - e_{11}]$, which is uniform distribution, so that the average duration of the state F during the time period s_1 can be calculated. When $e_{11} < 30 - a(t)$, the average duration of the state F during the time period s_1 is

$$\int_{30-e_{11}-a(t)}^{30-e_{11}} \frac{e_{11} + a(t) + y - 30}{30 - e_{11}} dy = \frac{a(t)^2}{2(30 - e_{11})},$$

When $e_{11} \geq 30 - a(t)$, the average duration of the state F during the time period s_1 is

$$\int_{0}^{30-e_{11}} \frac{e_{11} + a(t) + y - 30}{30 - e_{11}} dy = \frac{e_{11}}{2} + a(t).$$

Similarly, When $e_{11} < 120 - a(t)$, the average duration of the state F during the time period s_2 is

$$\int_{120-e_{11}-b(t)}^{120-e_{11}} \frac{e_{11}+b(t)+y-120}{120-e_{11}}dy = \frac{b(t)^2}{2(120-e_{11})},$$

When $e_{11} \geq 120 - a(t)$, the average duration of the state F during the time period s_2 is

$$\int_{0}^{120-e_{11}} \frac{e_{11}+b(t)+y-120}{120-e_{11}}dy = \frac{e_{11}}{2} + b(t).$$

As a result:

$$\begin{aligned} A(t) = &\frac{a(t)^2 I(a(t) < 30 - e_{11})}{2(30-e_{11})} + (\frac{e_{11}}{2} + a(t) - 15)I(a(t) \geq 30 - e_{11}) \\ &+\frac{b(t)^2 I(b(t) < 120 - e_{12})}{2(120-e_{12})} + (\frac{e_{12}}{2} + b(t) - 60)I(b(t) \geq 120 - e_{12}), \end{aligned}$$

$$\begin{aligned} B(t) = &\frac{a(t)^2 I(a(t) < 30 - e_{21})}{2(30-e_{21})} + (\frac{e_{21}}{2} + a(t) - 15)I(a(t) \geq 30 - e_{21}) \\ &+\frac{b(t)^2 I(b(t) < 120 - e_{22})}{2(120-e_{22})} + (\frac{e_{22}}{2} + b(t) - 60)I(b(t) \geq 120 - e_{22}). \end{aligned}$$

2.6 Objective function $V(s,z)$

The objective function $V(s,z)$ is defined as the sum of the duration of the state F in two time periods of s_1 and s_2 each day from the sth day to the 30th day (the given observation value is the number of reservation on that day), which is expressed as follows:

$$V(s,z) = min_{\tau \in [s,27]} E[\sum_{t=s}^{\tau+2} A(t) + \sum_{\tau+3}^{30} B(t) | R(s) = z]. \quad (1)$$

It can be seen that an optimal stopping time problem is defined, and the acquisition of the optimal stopping time will realize the seat use optimization with the goal of minimizing the cumulative duration of state F in two time periods of s_1 and s_2.However, in general, it is difficult to obtain an analytical solution to the optimal stopping time problem, so it is necessary to design an algorithm to solve the optimal stopping time problem.

In the optimal stopping time model (2), there is a random process $R(t)$, and when the probability is calculated, it is approximately believed that, under the condition of $R(s) = z$, for each $t \in \{s+1, s+2, ..., 30\}$, the approximate value of $R(t)$ is $z + (t-s) \times 200$ (according to Hypothesis 3). When designing the algorithm, we firstly discretize the value of z, and consider the value of z as $\{z_1, z_2, ..., z_{10}\}$. According to Equation (1) :

$$V(s,z) = min\{E[\sum_{t=s}^{s+2} A(t) + \sum_{s+3}^{30} B(t) | R(s) = z], E[V(s+1, R(s+1)) | R(s) = z]\}. \quad (2)$$

So we can only build a backward recursion relationship, and the initial value is

$$V(27,z) = E[A(27) + A(28) + A(29) + B(30) | R(27) = z].$$

Since then by

$$V(26,z) = min\{E[A(26) + A(27) + A(28) + B(29) + B(30) | R(26) = z], E[V(27, R(27)) | R(26) = z]\},$$

We can calculate all of them.

$G(s,z)$ is defined as follows:

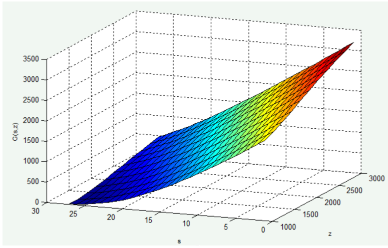

Figure 1: The curved surface of $G(s,z)$

$$G(s,z) = E[\sum_{t=s}^{s+2} A(t) + \sum_{s+3}^{30} B(t)|R(s) = z]. \tag{3}$$

By running code 2, make the following figure 1:

Substitute equation (3) into equation (2) to get

$$\begin{aligned} V(s,z) &= min\{G(s,z), E[V(s+1, R(s+1))|R(s) = z]\} \\ &\cong min\{G(s,z), V(s+1, z+200)\}. \end{aligned}$$

All the codes are calculated immediately:

```
function rs = vvaluef(s,z)
if s==27
    rs=vvalue(27,z);
else
    rs=min(gvalue(s,z),vvaluef(s+1,z+200));
end
end
```

The function vvalue () is shown in code 1, and gvalue () is shown in code 2. Based on this, the following figure is made with code 3.

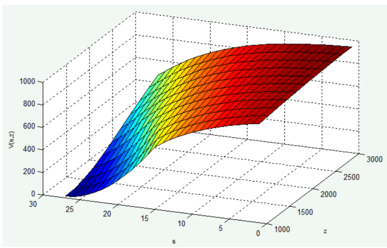

Figure 2: The curved surface of $V(s,z)$

Similarly, the following figure 3 can be obtained:

There is a boundary between the curved surface and the zero horizontal plane, i.e.

$$b(s) := max\{z : G(s,z) = V(s,z)\}. \tag{4}$$

The curve of $b(s)$ when s is $\{1, 2, ..., 27\}$ is shown in Figure 4 below:

So far, we have obtained the free boundary $b(s)$ of the optimal stopping time problem (2), which is the final form of the solution of the optimal stopping time problem. According to the classical theory of the optimal stopping time problem, the upper part of $b(t)$ is called the continuous area and the lower part (including the curve of $b(t)$) is called the stop area. Its operation meaning is: the state in the continuous waiting area will continue to wait, once entering the stop area, the stop will be triggered immediately.

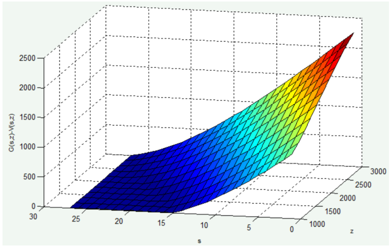

Figure 3: The curved surface of $G(s, z) - V(s, z)$

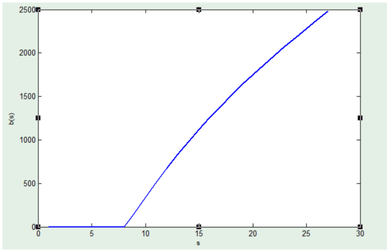

Figure 4: The free boundary $b(s)$ of the optimal stopping time problem

Therefore, the regulation operator observes the reservation volume $R(s)$ of each day $s \in \{1, 2, ..., 27\}$ to detect $(s, R(s))$ whether it enters the stop area (the lower part of $b(s)$). Once entering the stop area, it decides to adopt the busy-time regulation, and it will be formally implemented in 3 days later $(s + 3)$.

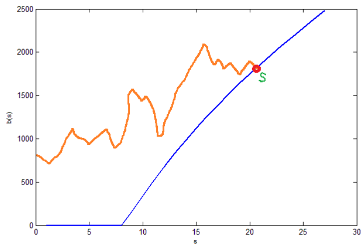

Figure 5: Decision simulation

Figure 5 simulated and demonstrated the decision of the free boundary $b(s)$ based on the optimal stopping time. The state of the first 19 days $(s, R(s))$ are all in the waiting area(s is the sth day and $R(s)$ is the number of reservation on the sth day), and the state of the 20th day (20,1749) is the first time to enter the lower stop area of $b(s)$. Therefore, it is decided to use the busy-time regulation on the 20th day, and formally use the busy-time regulation on the 23rd day, so as to minimize the waste of resources occupied by seats.

4 Conclusions and Prospects

The use of reservation seat management system has become the first choice to restore the opening of university libraries, whether in the reader information traceability, or in the control of the flow of visitors, the system has significant advantages. The hysteresis of reservation management mechanism can not be adjusted according to the current conditions, which greatly restricts its operational efficiency. From subjective perspective, readers want to be able to obtain the right to make an reservation of time in order to satisfy their inertia, but improve the operational efficiency of reservation system must be shortened reservation waiting time leads to the occupancy time of "empty seat", so this article proposes a regulation of free-busy time conversion. Establishing the optimal stopping time model and quantitative analysis the best time of decision conversion. The model takes the cumulative duration of state time F,which is the most likely time to waste resources by occupying a seat,(the current state when the whole library is full but some seats are empty) as the object of investigation, and by changing the use of busy-time regulation time to determine the optimization, the waste of seat resources can be minimized. From the perspective of simulation effect, the solution of this model realizes the dynamic decision of busy-time regulation based on the real-time date and the number of reservation on the day. In general, this model has the following advantages:

(1)The model can quantify and compare the situation of library seat waste under different management regulations through optimization, and the university library can adjust the reservation management time according to the current conditions, so as to optimize the allocation of seat resources and meet the needs of visiting readers to the maximum extent.

(2)By using the optimal stopping model can effectively calculate the optimal restructuring period and the period of transition, this paper set up the transition period of 3 days, namely the change on the third day after the date in determining the restructuring management regulation, which provides the reader with moderate buffer time, also avoid the waste of resources and management confusion caused by the mechanism transformation. We did think before acting.

(3)When constructing the busy-time regulation, the author combined the questionnaire survey and the historical data of the library to comprehensively investigate the psychological expectations and behavioral characteristics of various readers on the waiting time of reservation. The model constructed has certain flexibility in the adjustment of time regulation and can meet the needs of various readers.

In addition, the improvement of the method and model adopted in this paper can be expanded from the following aspects:

(1)The more global targets of all weather can be considered, so as to measure the empty and waste situation of seats in a more comprehensive way, and further optimize relevant parameters in combination with the characteristics of tide and periodicity of the flow of people in space and time.

(2)The reservation time set by the busy-time regulation can be optimized, the seat reservation time can be systematically adjusted from the perspective of readers' subjective feelings and the proportion of libraries' objective resources and other aspects. And the corresponding positive information feedback mechanism can be established through questionnaire survey or scoring system to adjust and optimize resource allocation in a timely manner.

(3)The use of big data technology to provide real-time and accurate monitoring data, combined with the optimal stopping time technology demonstrated in this paper, focus on improving the use efficiency of the management system, flexibility and timeliness of regulation decisions.

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Appendix:

The questionnaire

Dear readers, hello! In order to optimize the service and management of the library during the busy period of the end of the term, and optimize the utilization efficiency of the seats in the library.Thank you for your participation. We will keep personal information confidential and will not disclose it. We promise that it will not be used for commercial purposes.

1. Under the existing reservation system, if you have reserved a seat before the opening of the library, how long can you sit on the seat after the opening of the library:( ).How long will the seat be occupied between 11:00 and 13:00:( ).

2. If the new rules are adopted, the reservation will be cancelled if you fail to arrive within 10 minutes after the opening of the library, and the extension of the reservation time during the meal period will be cancelled. The maximum reservation time of leaving the seat at any time of the day is 30 minutes.Suppose you have made a reservation before the opening of the library, how long can you sit on the seat after the opening of the library:( ).How long will the seat be occupied between 11:00 and 13:00:( ).

The questionnaire was sent to several class groups and grade groups through mobile phone WeChat and QQ platform. A total of 129 valid answers were received from undergraduate and graduate students of Finance 1602, 1703, MPACC16 and other classes.

Program code:

Code 1 (Matlab code, only calculate V(27,z))

```
function rs = vvalue(s,z)
e11=18.92; e12=82.19; e21=14.78; e22=21.63;
rs=A(s)+A(s+1)+A(s+2)+B(s+3);
    function r1=Rtf(t)
        r1=z+(t-s)*200;
    end
    function r1=atf(t)
        r1=30-57.1*exp(-0.0005*Rtf(t));
    end
    function r1=btf(t)
        r1=139.6-303*exp(-0.0006*Rtf(t));
    end
    function r1=A(t)
        at=atf(t); bt=btf(t);
        if at<30-e11
            p1=at*at/(60-2*e11);
        else p1=e11/2+at-15;
        end
        if at<120-e12
            p2=bt*bt/(240-2*e12);
        else p2=e12/2+at-60;
        end
        r1=p1+p2;
    end
    function r1=B(t)
```

```
        at=atf(t); bt=btf(t);
        if at<30-e21
            p1=at*at/(60-2*e21);
        else p1=e21/2+at-15;
        end
        if at<120-e22
            p2=bt*bt/(240-2*e22);
        else p2=e22/2+at-60;
        end
        r1=p1+p2;
    end
end
```

Code 2 (Matlab code, calculate G(s,z) and make a curved surface, see figure 1)

```
xx=1000:200:3000; nx=length(xx);
tt=1:27; nt=length(tt);
matx=zeros(nx,nt);
for ix=1:nx
    for it=1:nt
        ux=xx(ix); ot=tt(it);
        matx(ix,it)=gvalue(ot,ux);
    end
end
        surf(xx',tt',matx');
        xlabel('z','fontsize',8);
        ylabel('s','fontsize',8);
        zlabel('G(s,z)','fontsize',8);
```

Use the following functions:

```
function rs = gvalue(s,z)
e11=18.92; e12=82.19; e21=14.78; e22=21.63; rs=0;
for i=s:s+2
    rs=rs+A(i);
end
for i=s+3:30
    rs=rs+B(i);
end
    function r1=Rtf(t)
        r1=z+(t-s)*200;
    end
    function r1=atf(t)
        r1=30-57.1*exp(-0.0005*Rtf(t));
    end
    function r1=btf(t)
        r1=139.6-303*exp(-0.0006*Rtf(t));
    end
    function r1=A(t)
        at=atf(t); bt=btf(t);
        if at<30-e11
            p1=at*at/(60-2*e11);
        else p1=e11/2+at-15;
        end
        if at<120-e12
            p2=bt*bt/(240-2*e12);
        else p2=e12/2+at-60;
```

```
        end
        r1=p1+p2;
    end
    function r1=B(t)
        at=atf(t); bt=btf(t);
        if at<30-e21
            p1=at*at/(60-2*e21);
        else p1=e21/2+at-15;
        end
        if at<120-e22
            p2=bt*bt/(240-2*e22);
        else p2=e22/2+at-60;
        end
        r1=p1+p2;
    end
end
```

Code 3 (Matlab code, making curved surface V(s,z), see figure 2)

```
xx=1000:200:3000; nx=length(xx);
tt=1:27; nt=length(tt);
matx=zeros(nx,nt);
for ix=1:nx
    for it=1:nt
        ux=xx(ix); ot=tt(it);
        matx(ix,it)=vvaluef(ot,ux);
    end
end
        surf(xx',tt',matx');
        xlabel('z','fontsize',8);
        ylabel('s','fontsize',8);
        zlabel('V(s,z)','fontsize',8);
```