

Team Control Number

201974509

Problem Chosen

A

2019

ShuWei Cup

Summary Sheet

Summary

The paper utilizes gray prediction, multivariate nonlinear regression, clustering and other methods in order to make reasonable predictions for medical indicators and provides suggestions for the development of the medical industry.

Task 1: *Samples were selected from four different indicators (age, population, per capita GDP and residents' disposable income) to establish a model combining grey G (1, n) and regression to predict China's aging trend and residents' medical needs*

Task 2: *Taking sichuan province as an example, 15 common diseases were selected. By calculating the mean and changing trend of the incidence in the past 17 years, the k-means clustering model was established to divide the disease into four diseases with different characteristics, so as to make Suggestions on the development of the hospital.*

Task 3: *First determine the hospital outpatient service, check the site, the second of its general outpatient queuing model is set up respectively and the checkpoint queuing model based on mechanism of greed, through matlab simulation, and the results compared with the results of the general stochastic queuing mechanism, the results show that the average waiting time 1.8 minutes, less service strength increased by 8%.*

Task 4: *According to the objective characteristics of hospitals and the subjective needs of patients, the indicators that affect the cooperation and competition between hospitals are determined. Based on this, cluster analysis was conducted for 20 sample hospitals of private hospitals and public hospitals respectively. Finally, according to the clustering results, the cooperation and competition strategies between different types of hospitals are proposed.*

Task 5: *Based on the analysis of the Chinese social medical system, we give advice for the relevant departments.*

Key word: *Grey prediction; Regression model; k-means clustering; Queuing Theory; Principal Component Analysis;*

Content

1. Introduction.....	4
1.1 Background.....	4
2. Problem analysis.....	4
2.1 Analysis of task one	4
2.2 Analysis of task two	4
2.3 Analysis of question three	5
2.4 Analysis of question four.....	5
2.5 Analysis of question five.....	5
3. Symbol and Assumptions.....	5
3.1 Symbol Description	5
3.2 Fundamental assumptions	6
4. Task one	6
4.1 Modeling preparation.....	6
4.2 Modeling and solving for predictions of the aging trend.....	6
4.2.1 Grey prediction model $G(1,n)$	6
4.2.2 Analysis of prediction results	7
4.3 Modeling and solving for predictions of medical needs	9
4.3.1 Analysis of medical needs and influencing factors	9
4.3.2 Multivariate nonlinear regression model	9
4.3.3 Prediction for future medical needs.....	9
5. Task two	10
5.1 Modeling preparation.....	10
5.2 Modeling and solving for classification of common diseases	10
5.2.1 Data processing	10
5.2.2 K-means clustering for common diseases	11
5.3 Suggestions for the overall development of hospitals	11
6. Task three	13
6.1 Model of Greedy-Queuing.....	13
6.1.1 Determination of various parameters of hospital queuing system	13
6.1.2 Establishment of queuing model of greedy mechanism	14
6.1.3 Calculation of the internal operating index of the system.....	16
6.2 Model solving and algorithm design.....	16
6.2.1 Algorithm design.....	16
6.2.2 Model's calculation result	17
6.3 Test the model	18
7. Task four	19
7.1 Modeling preparation.....	19
7.2 Modeling and solving for classification of hospitals	19
7.2.1 Hospital - patient subjective and objective needs analysis	19
7.2.2 The index system describing hospital characteristics	20
7.2.3 Selection of hospital samples	20

7.2.4 PCA for the main indicators of the hospital.....	20
7.3.5 K-means clustering for hospital samples based on 1-2 principal components.....	22
7.3.6 Discrimination and characteristic analysis of clustering results	22
7.3.7 Analysis on the status quo of private and public hospitals	23
7.3 Propose cooperation and competition strategies	23
8. Task five	23
9.Strengths and Weakness	24
References.....	25
Appendix.....	25
1. Multiple regression grey prediction Code.....	25
2. Draw the aging population growth rate Code.....	27
3. Multiple nonlinear regression	27
4. K-mean clustering and classification of diseases Code.....	28
5. Principal component analysis dimension reduction Code.....	29
6. Drawing of hospital space network Code	31
7. Simulation of greedy queuing model.....	32

1. Introduction

1.1 Background

With the rapid development of China's economy and society, and the aging trend, the demand for hospital health service continues to increase. At the same time, along with the rapid industrialization and urbanization process, ecological and food safety are subject to different levels of challenges. These overall developments have also brought a series of new challenges to medical and health work. The rapid growth and diversified developments of medical demand have led to an increase in the number of private hospitals. At present, private hospitals and public hospitals have formed different levels of competition and cooperation. For public hospitals, how to satisfy the growing demand for universal medical care for residents so as to improve comprehensively the residents' demand for hospitals is the main direction of efforts. For private hospitals, how to effectively meet the peak demand in public hospitals and the demand for special diseases is the main direction of their efforts. Please try to solve the following five problems in combination with network related resources.

2. Problem analysis

2.1 Analysis of task one

For China's aging trend forecast, this paper determine the relevant indicators, the population from 0-14 years old, the population aged 15-59, the aging population, disposable income, and per capita GDP. On the basis of fully considering the random data and abnormal factors, this paper constructs the Gray prediction $G(1,n)$ Model.

For residents' medical demand forecast, medical demand can be measured in the following aspects: the number of medical institutions, the number of medical personnel. And then establish a nonlinear regression model of three variables(Per capita incidence、Total population、Elderly population). For the above three variables, use gray prediction model to predict their future values, finally, the predictive variables are substituted into the established regression model to calculate future medical demand value.

2.2 Analysis of task two

Taking Sichuan Province as an example, this paper extracts the mean and morbidity growth rates of the 15 diseases in 2007-2017 for the 15 diseases with the highest incidence in Sichuan Province. Then K-means clustering of the disease according to the above two indicators. Furthermore, the clustering results of the disease are analyzed and divided into four categories according to the current trend of the disease and the future trend of the incidence rate. Finally, in terms of the characteristics of different diseases, give advice on future development for major public hospitals in Sichuan Province.

2.3 Analysis of question three

First of all, we conduct various project inspections for different types of patient groups, and assign locations in hospitals to propose a queuing system. Then determined various parameters and operational rules in the queuing system. Finally the Greedy-Queuing Model is established. The operational indexes of the Greedy-Queuing Model are solved by simulation in matlab, and it is compared with the ordinary queuing model so that to analyze the superiority of the greedy queuing mechanism.

2.4 Analysis of question four

For the requirements of question four. Firstly, we analyze the objective characteristics of the hospital and the subjective needs of the patients. and then list the indicators affecting the cooperation and competition between hospitals. According to these indicators, different private and public hospitals are clustered,. Finally, Considering the characteristics of different types of hospitals, propose cooperation and competition strategies between them.

2.5 Analysis of question five

Based on the analysis of the Chinese social medical system, we give advice for the relevant departments.

3. Symbol and Assumptions

3.1 Symbol Description

<i>Symbols</i>	<i>Definitions</i>	<i>Symbols</i>	<i>Definitions</i>
P_t	Total population (10,000)	$P_{p(0-14)}$	Proportion of 0-14 years old population (%)
$P_{a(0-14)}$	Population aged 0-14 (10,000)	$P_{p(15-59)}$	Proportion of population aged 15-59 (%)
$P_{a(15-59)}$	Population aged 15-59 (10,000)	P_{p_over60}	Proportion of population over 60 years old (%)
P_{a_over60}	Population aged over 60 (10,000)	I_c	Incidence (%)
H_{di}	Household disposable income (RMB)	I_p	Predicted incidence (%)
G_{pc}	GDP per capita (2010 constant dollar price)	P_{ft}	Forecast total population (10,000)
I_m	Number of beds in medical institutions (10,000)	P_A	Aging population (10,000)
H_n	Number of hospitals in China	S_n	Number of medical staff

3.2 Fundamental assumptions

(1) The data of the National Bureau of Statistics and the EPS data platform are true and reliable, so that the data is sufficient to reflect future trends.

(2) One bed only serves one patient, regardless of serving multiple patients at the same time.

(3) The number of medical institutions, the number of medical personnel, and the number of hospital beds are sufficient to reflect the medical needs of residents.

4. Task one

4.1 Modeling preparation

1) Data Sources

- ✓ National Bureau of Statistics (<http://www.stats.gov.cn/tjsj/>)
- ✓ EPS data platform (<http://olap.epsnet.com.cn/>)

2) Data processing

First of all, we arrange the data according to the year, and then use Excel to calculate the population of 0-14 years old (10,000 people), 15-59 years old population (10,000 people), and 60 years old population (10,000 people). Process it and calculate the proportion of its population (%).

4.2 Modeling and solving for predictions of the aging trend

4.2.1 Grey prediction model $G(1,n)$

(1) Model establishment of gray GM (1,n)

The basic principle of the GM(1,n) model is to accumulate the random original sequence by time, and then use the root obtained by the first-order linear differential equation to approximate the data trend law presented by the accumulated sequence. The steps for building the model are as follows:

- ✓ **Setp1:** The system's feature data sequence: $X_1^{(0)} = (x_1^{(0)}(1), x_1^{(0)}(2), \dots, x_1^{(0)}(n))$;

Related factor sequence:

$$X_2^{(0)} = (x_2^{(0)}(1), x_2^{(0)}(2), \dots, x_2^{(0)}(n)) \dots \dots X_N^{(0)} = (x_N^{(0)}(1), x_N^{(0)}(2), \dots, x_N^{(0)}(n))$$

- ✓ **Setp2:** make $X_i^{(0)} (i = 1, 2, \dots, N)$ its 1-AGO sequence is $X_i^{(1)}$,

$$X_i^{(1)}(k) = \sum_{k=1}^n x_i^{(0)}(k), (i = 1, 2, \dots, n)$$

- ✓ **Setp3:** Calculate $X_i^{(1)}$ Adjacent mean sequence

$$Z_i^{(1)}, x_1^{(0)}(k) + aZ_1^{(1)}(k) = \sum_{i=2}^N b_i x_1^{(1)}(k) \text{ is GM}(1,n) \text{ model.}$$

- ✓ **Setp4:** Let $\beta = (a, b_1, b_2, \dots, b_N)^T$, By least squares parameter estimation, we can get $\beta = (\beta^T \beta)^{-1} \beta^T Y$ Its approximation is:

$$\hat{x}_1^{(1)}(k+1) = \left[x_1^{(0)}(1) - \frac{1}{a} \sum_{i=2}^N b_i x_i^{(1)}(k+1) \right] e^{-ak} + \frac{1}{a} \sum_{i=2}^N b_i x_i^{(1)}(k+1)$$

✓ **Setp5:** Subtraction reduction $\hat{x}_1^{(0)}(k+1) = \hat{x}_1^{(1)}(k+1) - \hat{x}_1^{(1)}(k)$

✓ **Setp6:** Differential analog $\hat{x}_1^{(0)}(k) = -aZ_1^{(1)}(k) + \sum_{i=2}^N b_i \hat{x}_i^{(1)}(k)$

4.2.2 Analysis of prediction results

$G(1,n)$ model accuracy test result as shown in the table. $C=1$, which describe it has high precision. Other indicators are also good.

Table 1: Model accuracy test result

Relative residual Q test	Variance ratio C test	Small error probability P test
$Q=0.0076$	$C=0.00647$	$P=1$

Prediction for the number of elderly people between 2005-2025 is shown in the figure below:

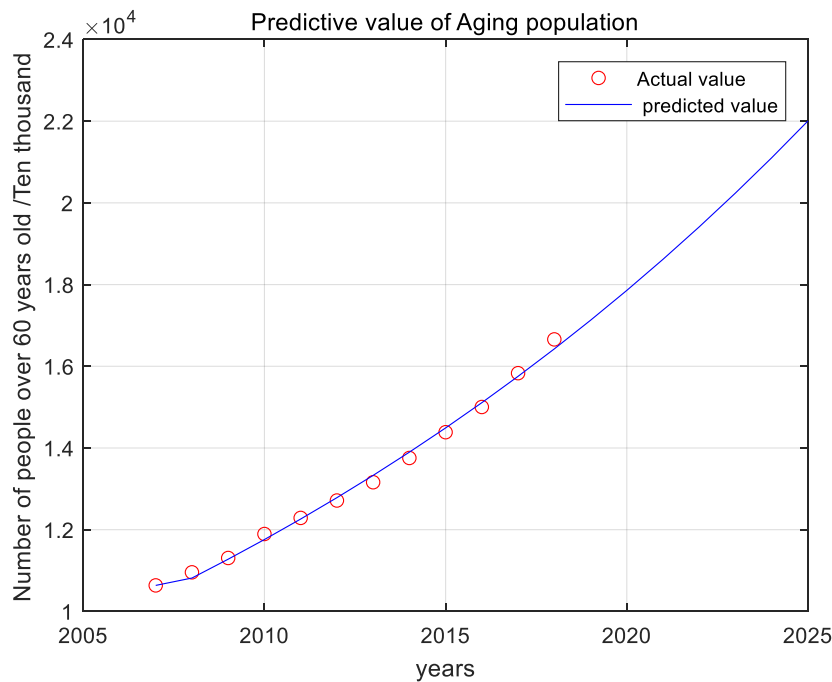


Figure 1: Predictive value of aging population

And the specific amount per year is in the appendix file 5. Further, we analyze the data to show the growth rate of aging population (shown in the figure 2), and The proportion of the aging population (shown in the figure 3).

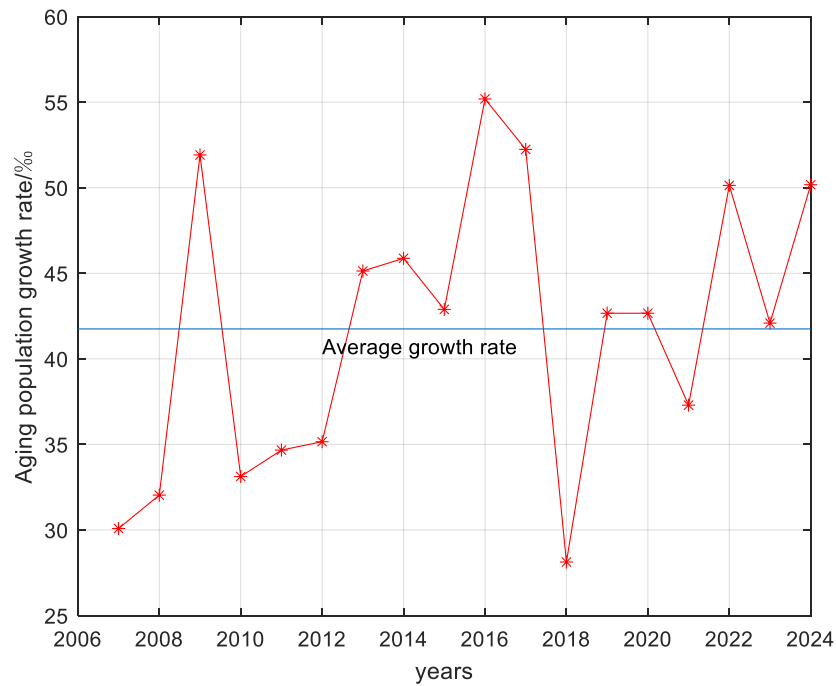


Figure 2: Growth rate of aging population

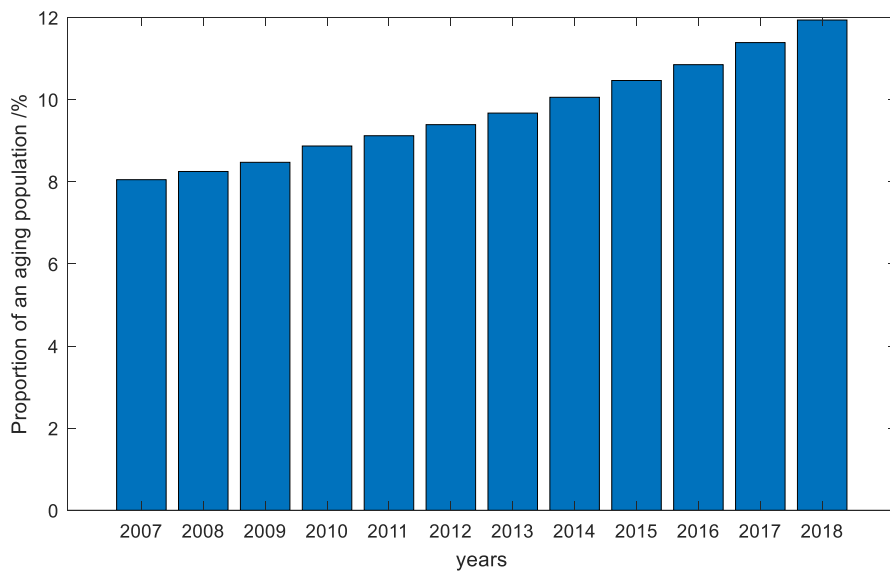


Figure 3: The proportion of the aging population

It can be seen that the proportion of aging population growth after 2017 has maintained a steady growth trend for a long period of time, and the proportion of the aging population is gradually increasing.

4.3 Modeling and solving for predictions of medical needs

4.3.1 Analysis of medical needs and influencing factors

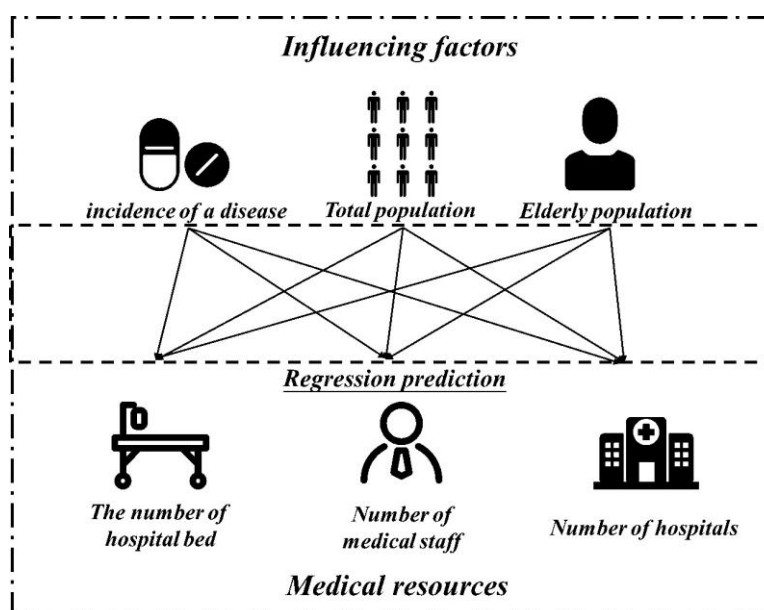


Figure 4: Medical needs and influencing factors

4.3.2 Multivariate nonlinear regression model

$$Y_i = a_1^i + (a_{i2}x_1 + a_{i3}x_2 + a_{i4}x_3) + (a_{i5}x_1^2 + a_{i6}x_2^2 + a_{i7}x_3^2) + (a_{i8}x_1x_2 + a_{i9}x_2x_3 + a_{i10}x_1x_3) \quad i = 1, 2, 3$$

In the multivariate nonlinear regression model, x represents the three influencing factors, Y_i represents the three aspects of medical needs. a_{in} ($n = 1, 2, \dots, 10$) represents 10 regression coefficients. (They are in the [appendix file 6](#))

4.3.3 Prediction for future medical needs

- ✓ **Step1:** Grey prediction for the influencing factors, using $G(1,1)$ model, just as the figure below shows:

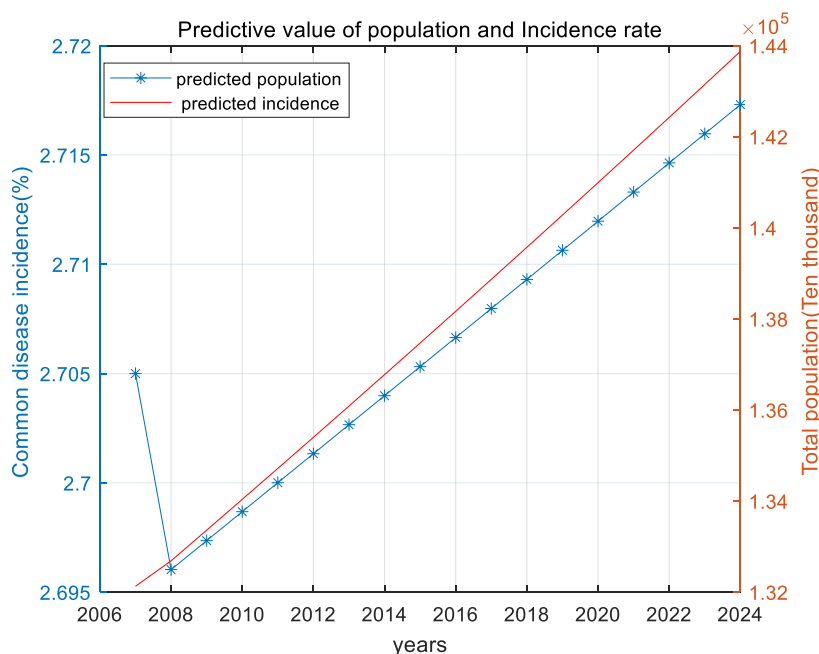


Figure 5: Predictive value of population and incidence rate

- ✓ **Step2:** Bringing parameters into a regression model to calculate the future medical needs. (the complete data in the appendix file 1)

Table 2: Prediction of medical resources for the next five years

	2020	2021	2022	2023	2024
The number of hospital bed (Ten thousand)	1004.32	1080.64	1162.72	1251.03	1346.04
Number of medical staff(thousand)	35878.85	37820.86	39868.00	42025.94	44300.68
Number of hospitals	13856122.27	14583536.41	15349138.1	16154932.11	17003028.42

5. Task two

5.1 Modeling preparation

- (1) **Data Sources:** Sichuan Provincial Bureau of Statistics website (<http://tjj.sc.gov.cn/>)
- (2) **Content of the data:** incidence of various diseases from 2000 to 2017(a total of 15 categories)

5.2 Modeling and solving for classification of common diseases

5.2.1 Data processing

For the 15 most common diseases in Sichuan Province from 2000 to 2017, use Excel to calculate the mean incidence and morbidity growth of incidence over the

18-year period. The formula for calculating the average morbidity and morbidity growth are as follows:

$$\text{Mean}(inc)_i = \frac{\sum_{j=1}^{\text{years}} Inc_i^j}{\text{years}} \quad ; \quad \text{Mean}(growth)_i = \frac{\sum_{j=1}^{\text{years}} (Inc_i^j - Inc_i^{j-1})}{\text{years}}$$

5.2.2 K-means clustering for common diseases

(1) K-means clustering process

- ✓ **Step1:** Initialize the cluster center, select C suitable samples from the sample set as the initial cluster center, and randomly divide all samples into C categories.
- ✓ **Step2:** Initial clustering: The samples are classified into the classes represented by each cluster center according to the principle of proximity.
- ✓ **Step3:** Recalculate the sample mean, update the cluster center, then take the next sample and repeat until all the samples are in the corresponding class.

(2) Clustering result

Clustering common 15 diseases according to the indicators (mean incidence and morbidity growth of incidence), divide them into four categories:

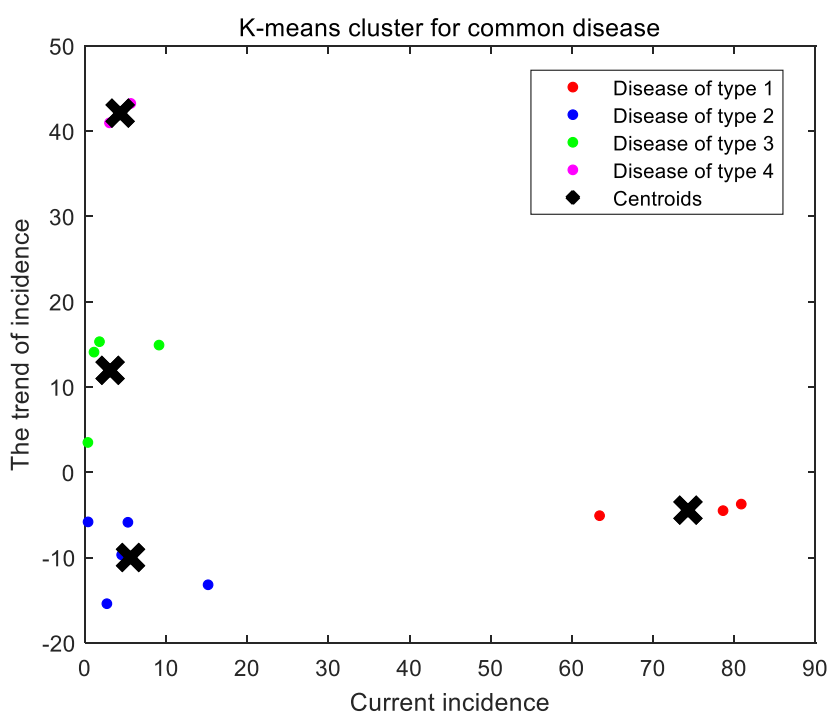


Figure 6: K-means cluster for common diseases

5.3 Suggestions for the overall development of hospitals

Analysis of disease classification results, give suggestions based on the characteristics of different diseases:

Table 3: Characteristics of diseases of type 1-4

Type	Characteristics
1	✓ Current incidence is low ✓ High growth rate
2	✓ Current incidence is in medium level ✓ Low growth rate
3	✓ Current incidence is high ✓ Little change in incidence
4	✓ Current incidence is high ✓ Negative growth

Suggestions:

1. For the disease type-1 related departments, there may be a high incidence rate in the future. Therefore, it is necessary to gradually expand the scale of relevant departments, strengthen the technical level, increase capital investment, and prepare for the future.
2. For the disease type-2 related departments, the incidence rate is slowly increasing, and the future incidence rate will not change so much. However, the patient base is still large. Therefore, the relevant department's scale should be maintained, the technical level should be strengthened, and adopt new treatments .
3. For the disease type-3 related departments, the incidence rate in the future may not change much, so the department scale should be kept as current.
4. For the disease type-4 related departments, the incidence is increasing, so the relevant departments should consider reducing the size of the staff and gradually transferring their resources to other departments.
5. For other uncommon diseases related departments, the hospital should maintain its current scale and strengthen its technical reserves to prevent unexpected increases in incidence .

6. Task three

6.1 Model of Greedy-Queuing

6.1.1 Determination of various parameters of hospital queuing system

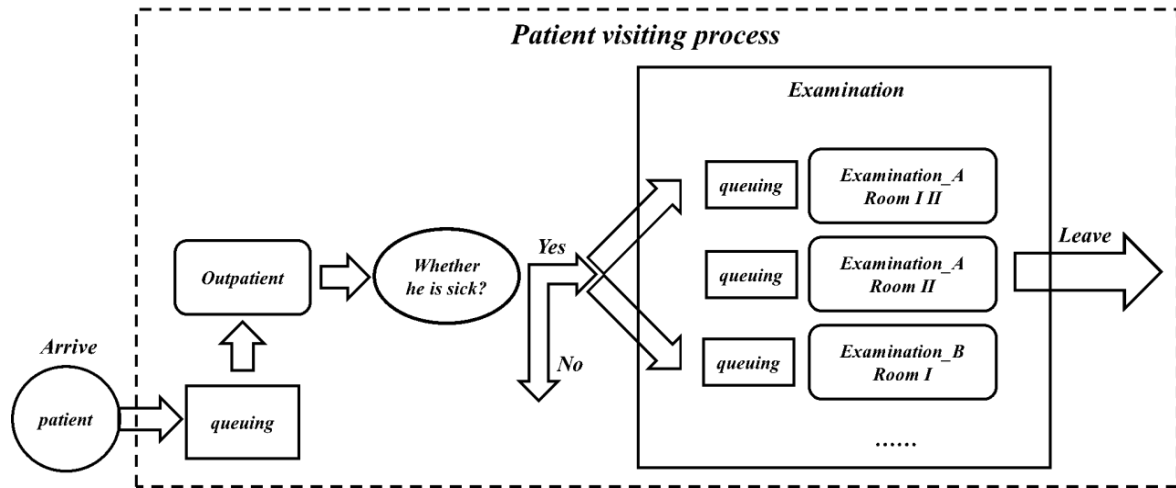


Figure 7: Schematic diagram of queued operation system

(1) Determine the distribution of patient arrival time

For the distribution of patients arriving at the outpatient service, this paper, based on the operational research theory. This paper found in the time of the $[t_i, t_{i+1}]$, The distribution of patient arrivals X_a^i was roughly Poisson distribution. For this reason, this paper determined the number of patients X_a^i arriving in the time $[t_1, t_2]$ by using the Poisson distribution of parameters $\lambda = 0.2$, (the average time taken by each patient to arrive).

$$P(X_a^i = k) = \frac{e^{-0.2} 0.2^k}{k!}, \quad k = 0, 1, 2, \dots$$

Accordingly, the patient to time is generated by matlab. (see the appendix for the code).

(2) Determine the distribution of outpatient diagnosis time and examination time

As stated in (1), according to the operational research theory, it is known that for the outpatient diagnosis time distribution and checkpoint inspection time distribution. In this paper, the negative exponential distribution of parameters $\mu_1 = 0.3$ and $\mu_2 = 0.1$ (the number of customers served per minute) was used to simulate the number of people who completed outpatient service and the number of people who completed checkpoint service in a time $[t_i, t_{i+1}]$, respectively.

$$P(X_b^i) = \lambda e^{-\lambda X_b^i}, X_b^i \geq 0, P(X_c^i) = \lambda e^{-\lambda X_c^i}, X_c^i \geq 0$$

Accordingly, matlab generated the patient in the outpatient diagnosis time t_{aw}^i , the patient in the examination time t_{bw}^i . (see the appendix for the code)

(3) Determine the spatial relationship inside the hospital

The distribution of each department of the hospital is shown in figure 1.2.

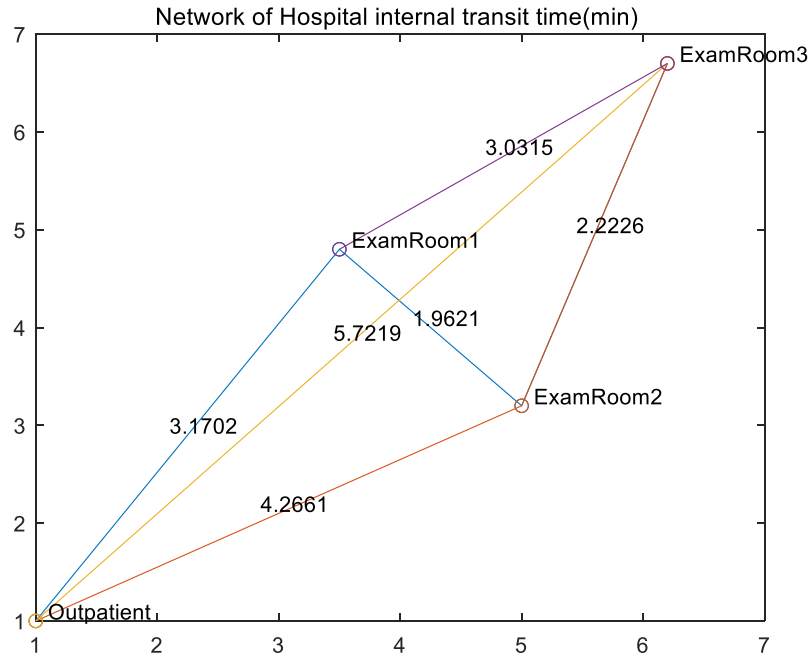


Figure 8: Spatial relationship inside the hospital

(4) Determine the distribution of the probability of illness

By analyzing the statistical data of the incidence of the second question, the types of diseases and their probabilities of the patients in the first question were shown in Table 4.

Table 4: Disease probability distribution table.

Type of disease	disease A	disease B	disease C	Not sick
Probability of illness	0.2	0.3	0.3	0.2
Examination room	I, II	II, III	I, III	Leave

6.1.2 Establishment of queuing model of greedy mechanism

As shown in figure 1.1, for the outpatient queuing model, the input source is Poisson distribution, the service time is negative exponential distribution, and it is a single service desk, and the queuing capacity is infinite. Based on this, this paper established an $M/M/1/\infty$ outpatient queuing model.

(1) Establishment of outpatient $M/M/1/\infty$ queuing model

The state transition model of outpatient queuing system is shown below:

When the i^{th} patient arrives at the clinic, if there is no queue in the clinic, queue directly, otherwise, the diagnosis cannot start until everyone leaves.

$$l_d^i = t_d^i + t_{aw}^i, \quad t_d^i \geq \max (t_{aw}^{i-1})$$

$$l_d^i = \max (t_{aw}^{i-1}) + t_{aw}^i, \quad t_d^i < \max (t_{aw}^{i-1})$$

The maximum departure time earlier the i^{th} former patient is $\max (t_{aw}^{i-1})$, The arrival time of the i^{th} patient is t_d^i , leave time is l_d^i .

(2) The establishment of greedy choice queuing mechanism model

The i^{th} patient leaves the clinic and gets the results ds_i , The patient's checkpoint

$$d_i \text{ is as follows : } d_i = \begin{cases} [1, 2], & ds_i = A \\ [2, 3], & ds_i = B \\ [1, 3], & ds_i = C \end{cases}$$

During this time, for the selection of the checkpoint, select the checkpoint d_1^i with the shortest queue time at present. After the current inspection is completed, the next checkpoint d_2^i will be checked.

$$l_e^i(o, d_1^i) < l_e^i(o, d_2^i), \quad d_1^i, d_2^i \subseteq d_i$$

Among them, $l_e^i(o, d_1^i)$ indicates the time of d_1^i after completion of the inspection, $l_e^i(o, d_2^i)$ indicates the time of d_2^i after completion of the inspection. Thus, in the checkpoint queuing model, the arrival time of the patient is the time of departure after the outpatient diagnosis plus the intermediate journey time.

$$t_f^i = l_d^i + R(o, d_1^i)$$

The i^{th} patient arrived at the checkpoint is t_f^i , The distance from the clinic o to the checkpoint d_1^i is $R(o, d_1^i)$.

It can be seen from this that the arrival time of patients is generally random distribution, the service time of checkpoints is negative exponential distribution, and there are all checkpoints. The queuing capacity is ∞ . The queuing model is $G/M/3/\infty$.

(3) Establishment of checkpoint $G/M/3/\infty$ queuing model

As 1.2.1, for the checkpoint d_1^i queuing model, the state transition model of checkpoint queuing system is shown below:

$$l_f^i = t_f^i + t_{bw}^i, \quad t_f^i \geq \max (l_f^{i-1})$$

$$l_f^i = \max (l_f^{i-1}) + t_{bw}^i, \quad t_f^i < \max (l_f^{i-1})$$

The time the i^{th} patient left is l_f^i , the maximum departure time earlier the i^{th} former patient is $\max (l_f^{i-1})$.

For the queuing model of the checkpoint d_2^i , *ibid*.

6.1.3 Calculation of the internal operating index of the system

In the above queuing model, the average queuing time T_a of the outpatient department and the average queuing time T_b of the checkpoint,

$$T_a = \text{sum} (l_d - t_d) / n, T_b = \text{sum} (l_f - t_f) / n$$

Where n is the total number of patients.

Outpatient service intensity P_a , Checkpoint service intensity P_b (The ratio of working time to total time):

$$P_a = \text{sum} (t_{aw}) / \max(l_d), P_b = \text{sum} (t_{bw}) / \max(l_f)$$

Maximum departure time for clinic and checkpoint are $\max (l_d)$, $\max (l_f)$.

At this point, the hospital queuing model system was established.

6.2 Model solving and algorithm design

6.2.1 Algorithm design

For the hybrid queuing model, computer simulation was carried out according to the queuing mechanism in figure 7, and then the optimal queuing scheme with the shortest predicted time was carried out for each patient in advance.

- ✓ **Step1:** Initialize the patient arrival interval t_reach , outpatient service hours t_book , time at the checkpoint t_check , Initial diagnosis time a station bg_book , time to start checking at a station bg_check , departure time at a station l_book , time to leave at the checkpoint l_check , hospitals are geographically distributed p_map , average walking speed v ;
- ✓ **Step2:** Define variable outpatient wait captain W_book , current number of outpatient N_book , Inspection waiting captain W_check , current number of inspectors N_check ;
- ✓ **Step3:** Calculate the patient's arrival time $t_reach = \text{consum}(t_reach)$, hospital location and time transfer distribution $t_map = p_map/v$;
- ✓ **Step4:** Calculate the type of patient with disease ds , for all patients loop, initialize the random number $rand$, If $rand$ less than 0.2, Suffering from a disease $ds=1$, Otherwise if $rand$ less than 0.5, develop 2 disease, $ds=2$, otherwise, if $rand$ less than 0.8, develop 3 disease, $ds=3$; otherwise, this

- person has something to leave without checking, $ds = 0$;
- ✓ **Step5:** The i^{th} patient was simulated to queue up and set up a loop,
for $i = 1 : 10000$;
 - ✓ **Step6:** Judge whether there is someone in station at this time, if there is no direct service,
if $t_reach(i) > \max(l_book(1, 1:i-1))$, $W_book(1, i) = 0$,
 $N_book = 1$, $bg_book = t_reach$, $l_book = bg_book + t_book$;
 - ✓ **Step7:** To simulate the patient inspection process, determine what patients suffer from disease, required to generate the checkpoint, if suffering from one disease, need to check 1, 2, checkpoints, case 1, $ch = [1, 2]$, time needed for choosing the smallest checkpoint queued, and record the checkpoint number,
 $[t_min, flag] = \min(\max(l_check^1), \max(l_check^2))$ and to
flag checkpoints to line up, $bg_check^{flag} = l_book + t_map(1, flag)$,
queuing algorithm with station queuing algorithm, record its departure time plus transfer time is the start time to another checkpoint, queuing algorithm is the same as above;
 - ✓ **Step8:** If case 2 or case 3, the algorithm is the same as Step7, if case 0,
directly leave the hospital.
 $W_check(1, i) = 0$, $N_check(1, i) = N_check(1, i-1)$,
 $l_check(1, i) = l_book(1, i)$. End the layer judgment.
 - ✓ **Step9:** If station 1 is unattended,
if $t_reach(1, i) < \max(l_book(1, 1:i-1))$, need to queue.
 $bg_book(1, i) = \max(l_book(1, 1:i-1))$, the waiting
time $W_book(1, i) = bg(1, i) - t_reach(1, i)$, wait for the
captain $num = \sum(l_book < t_reach(1, i))$,
 $N_book(1, i) = num + 1$,
 $l_book(1, i) = bg_book(1, i) + t_book(1, i)$;
 - ✓ **Step10:** Continue to simulate the patient examination process, the algorithm is completely the same as A station no one in service after the examination process algorithm;
 - ✓ **Step11:** End the current process, return to the loop, perform Step5 until the end, and output relevant indicators;

The above algorithm was simulated by matlab for 1000 times, and the results of 6.2.2 the operation indexes were shown in Table5.

6.2.2 Model's calculation result

Table 5: Results of system simulation in several times

	<i>Average queuing time of outpatient service</i>	<i>Average queue time at checkpoints</i>	<i>Service intensity of registration station</i>	<i>Checkpoint service intensity</i>
One	6.46	4.75	0.67	0.78
Two	5.97	5.45	0.65	0.84
Three	5.94	4.31	0.66	0.75
Four	7.04	5.18	0.68	0.76
Five	6.59	4.46	0.67	0.82
Six	6.39	6.87	0.67	0.82
Seven	6.49	4.53	0.67	0.77
...
Population mean	6.66	4.80	0.67	0.75

The statistics of various operating indicators are shown in Figure 9 :

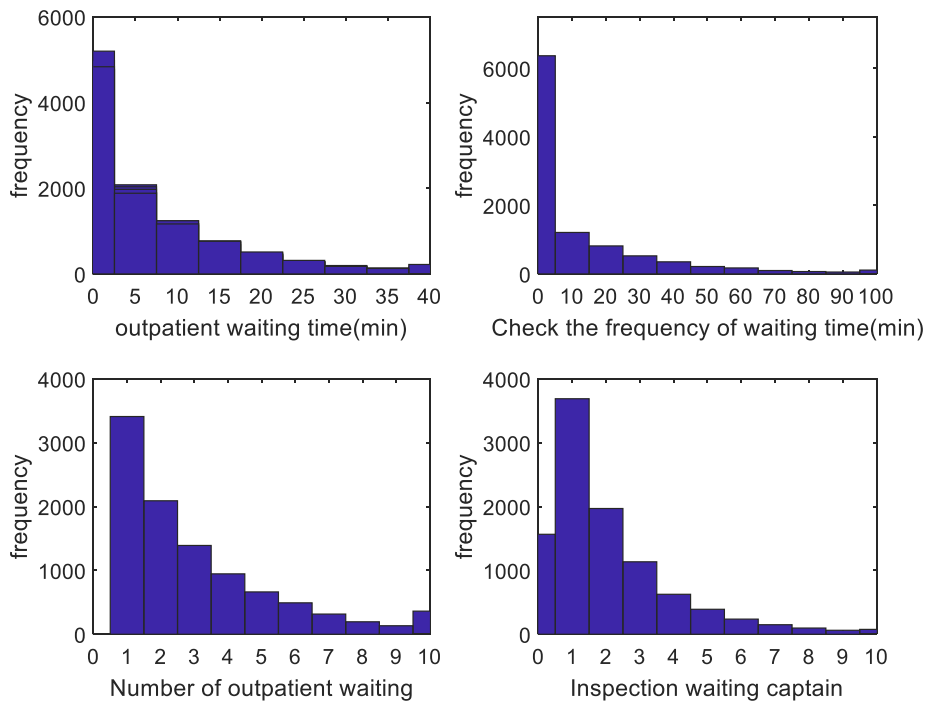


Figure9: Frequency of system operation indicators

6.3 Test the model

In order to test the optimization effect of the greedy mechanism queuing model, this paper simulated the ordinary random queuing mechanism model for several times, and obtained the comparison data as shown in Table 6, in which the ordinary random queuing mechanism represents the probability adopted in the checkpoint selection.

Table6: Comparison of system output parameters

indicator	Checkpoint service intensity	Average queuing time of outpatient service	Average queue time at checkpoints	Service intensity of registration station
Normal queuing mechanism	6.68min	6.61min	0.67	0.62
Greedy queuing and waiting mechanism	6.66min	4.80min	0.67	0.75

According to the data analysis in the table, the average waiting time of the checkpoint with ordinary random queuing mechanism is about 1.8 min different from that of the checkpoint with greedy queuing mechanism, and the service intensity is improved by 8 percentage points, which has a significant improvement effect.

7. Task four

7.1 Modeling preparation

1. Select sample data of 10 public and private hospitals in Chengdu from the hospital information platform.
2. Access to information on the current status of public and private hospital operations.

7.2 Modeling and solving for classification of hospitals

7.2.1 Hospital - patient subjective and objective needs analysis

In real life, patients will consider the relationship between the objective characteristics of the hospital and their own supervisory needs when choosing a hospital. Among them, the main demand factors of patients include expenses, speed of admission, hospital reputation and so on, and the objective characteristics of the hospital mainly include medical resources, fee levels, hospital admission rate and so on. The diagram below details the relationship between patients and hospitals:

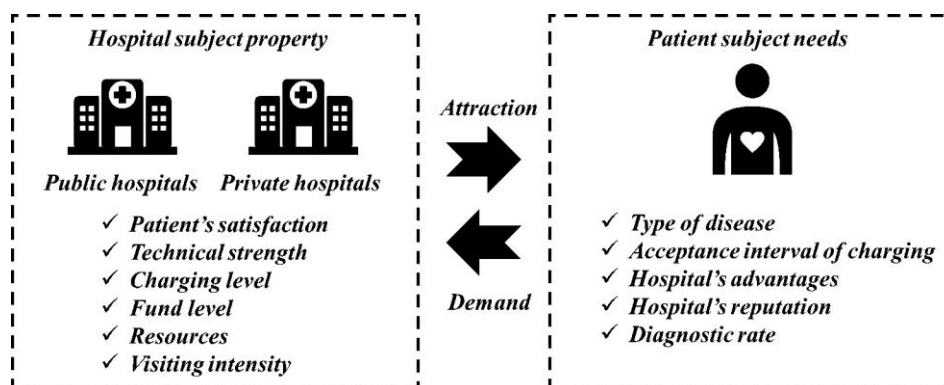


Figure 10: Hospital-patient demands analysis

7.2.2 The index system describing hospital characteristics

To describe the characteristics of any hospital, we selected six indicators (Satisfaction, Charging level, Technical strength, Fund level, Resources, Visiting intensity, Resource utilization index) to portray the hospital. Further, the hospital's medical resource utilization index can be obtained by dividing the hospital's average frequency of consultations by the resource allocation.

Considering the different numerical ranges between the different types of values, in order to better compare the vertical values of the values, we standardized the data of each index so that the value range is 1~1, thus the numerical scales are unified. The specific numerical processing method is:

$$Val_i^j = \frac{val_i^j - \min(val_i^j)}{\max(val_i^j) - \min(val_i^j)} \times 10, \quad i = 1, 2 \dots 7; j = 1, 2 \dots 20$$

Among them, i represents the type of indicator, j represents the serial number of the hospital, val_i^j represents the absence of pre-standardized data on indicators, Val_i^j represents standardized processed index data.

7.2.3 Selection of hospital samples

We selected 10 private hospitals and 10 public hospitals as samples, calculate 7 characteristic indicators and resource utilization index of each hospital.. The results obtained are shown in the table (only Show some data, see Appendix n for the complete form)

Table 7: The indicators of hospital samples

	1	2	11	12
Public or private	Public	Public	private	private
Satisfaction	7.5	6.3	9.2	7.4
Charging level	7.2	6.4	8.8	7.7
Technical strength	7.0	7.1	8.3	8.3
Fund level	7.6	7.8	7.9	8.2
Resources	8.0	7.9	8.2	8.3
Visiting intensity	6.0	6.1	8.2	8.1
Resource utilization index	0.75	0.77	1.00	0.98

7.2.4 PCA for the main indicators of the hospital

(1)The main purpose of principal component analysis

Use less variables to explain most of the mutations in the original data, and convert existing related variables into independent variables. Typically, several new variables

are selected that are smaller than the original variables to represent the information contained in the original variables. These newly selected variables are called principal components. Thus, principal component analysis is a way to reduce the data dimension. The specific steps are:

- ✓ **step1:** For the original multidimensional data matrix X , Calculate the covariance matrix $CorX$
- ✓ **step2:** Through the eigenvalue equation $(\lambda I - CorX)\Phi = 0$, Find each eigenvalue λ_i and each eigenvector Φ of the covariance matrix $CorX$, Arrange them in descending order to get the eigenvalue matrix $M_\lambda = [\lambda_1, \lambda_2, \dots, \lambda_i]^T$, And get the corresponding eigenvector matrix M_Φ
- ✓ **step3:** Take the PCA transformation matrix $A = M_\Phi^T$
- ✓ **step4:** PCA transformation $Y = AX$
- ✓ **step5:** Extract the transformed principal components $PCA_i = Y(i, :)$

(2) PCA and Result analysis

The matlab program was written to conduct principal component analysis on five indicators of 20 hospitals in the sample set, and extract the principal component representing the original data appropriately according to the amount of information contained.

The following table shows that the five eigenvalues in principal component analysis represent the amount of information contained:

Table 8: Eigenvalues and their contribution

	<i>Eigen value</i>	<i>contribution</i>	<i>Cumulative contribution</i>
1	2.4497	0.8083	0.8083
2	0.5222	0.1723	0.9806
3	0.0390	0.0129	0.99335
4	0.0114	0.0038	0.9973
5	0.0082	0.0027	1.0

Since the first two principal components already included 98.06% of the original amount of information, we extracted the 1 and 2 principal components to summarize the original indicator information. In addition, the meaning of the original information represented by the 1 and 2 principal components can be obtained by the value of the feature vector, as shown in the following table:

Table 3: Information contained in the principal components

	<i>Satisfaction</i>	<i>Charging level</i>	<i>Technical strength</i>	<i>Fund level</i>	<i>Resource utilization index</i>
PCA_1	79.8%	/	/	/	53.1%
PCA_2	59.96%	7.69%	24.43%	16.67%	/

7.3.5 K-means clustering for hospital samples based on 1-2 principal components

The main components of 1 and 2 were used as new indicators to represent the characteristics of the hospital, and K-means clustering was carried out for 20 sample hospitals, so that all sample hospitals were divided into 4 categories:

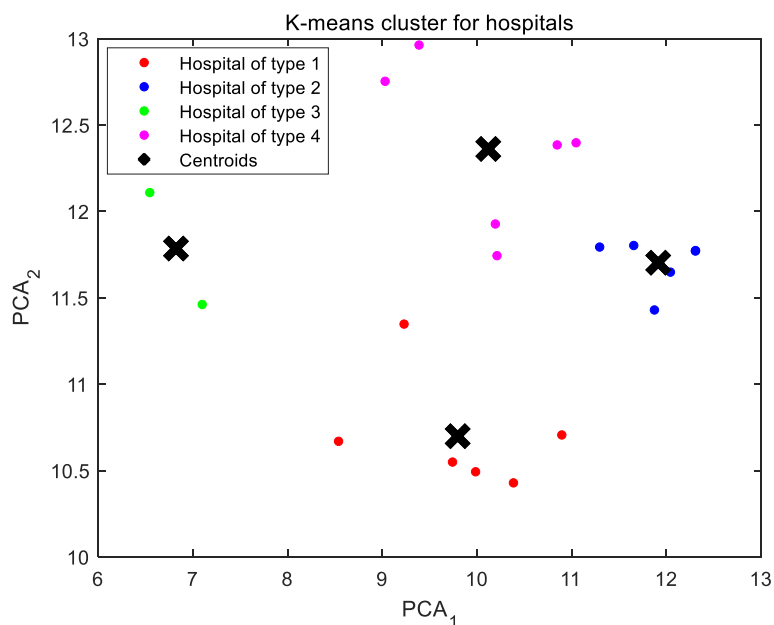


Figure 11: K-means cluster for hospitals

Finally, among the 20 hospitals, there are 6 classified into category 1, 6 in category 2, 6 in category 3, and 2 in category 4.

7.3.6 Discrimination and characteristic analysis of clustering results

After completing the classification of 20 sample hospitals, combining the original feature description index information to analyze the classified results, the characteristics of the four types of hospitals can be obtained, as shown in the following table:

Table 9: Characteristics description for hospital of type 1-4

The type of hospital	Characteristics
1	<ul style="list-style-type: none"> ✓ Adequate capital investment ✓ Strong technical strength ✓ Too Busy
2	<ul style="list-style-type: none"> ✓ High satisfaction ✓ Other indicators are general
3	<ul style="list-style-type: none"> ✓ Low capital investment ✓ Relatively low level of technology ✓ Low attendance rate
4	<ul style="list-style-type: none"> ✓ Low satisfaction

✓ *Relatively Busier*

7.3.7 Analysis on the status quo of private and public hospitals

Through the above sample hospital classification results, the characteristics of private and public hospitals can be seen separately: most public hospitals such as 1, 2 have sufficient funds and strong technical strength, but the problem of excessive utilization of medical resources is widespread. Private hospitals such as 13, 15 and so on generally have low technical level and low capital investment, and their medical resources are low in utilization, however, they have high development potential.

7.3 Propose cooperation and competition strategies

According to the above background, the conditions of talents, technology, scientific research, etc. in private hospitals are not comparable to those of large hospitals, but the advantage lies in the small number of people and the large amount of medical resources. Therefore, the two can have the following cooperation and development ideas:

1. Public hospitals provide technical guidance for private hospitals;
2. Sharing of medical resources (turning idle beds and other medical resources to hospitals with excessive access);
3. Operational experience sharing (for hospitals with high user satisfaction, their hospital staff can share experiences for other hospitals)
4. Improve the existing situation, strengthen the advantageous medical field, and develop special medical fields to gain market survival space.

Table 10: Feasible cooperation program between hospitals

The type of hospital	1	2	3	4
1	/	1→2 Technical assistance	1→3 Technical assistance	1→4 Technical assistance
2	2→1 Experience sharing	/	2→3 Experience sharing	2→4 Experience sharing
3	3→1 Medical resource sharing	3→2 Medical resource sharing	/	
4	/	/	/	/

8. Task five

Analysis of the current situation: At present, the trend of aging of China's social population is gradually accelerating, and the expanding elderly group has caused a great burden on social medical care. In addition, in recent years, private hospitals have been unable to compete with public large hospitals in terms of technology and

talent credibility, resulting in small outpatients and vacant beds, resulting in unnecessary waste of medical resources. Public large hospitals rely on the government's strong investment, technology, talent, scientific research and management level have obvious advantages. Public hospitals have a large number of outpatients, "difficult hospitalization", and "difficult surgery."

- ✓ **Suggestion 1:** *The medical management department should formulate incentive policies to promote cooperation between private hospitals and public hospitals, and effectively utilize various medical resources of private hospitals with low resource utilization.*
- ✓ **Suggestion 2:** *Medical authorities should strengthen market supervision to prevent the occurrence of vicious competition to ensure the fair development of private hospitals and public hospitals.*
- ✓ **Suggestion 3:** *The government should increase support for private hospitals, strengthen the scientific research and technical strength of private hospitals, improve the status of private hospitals in the medical system, and effectively drain patients in the patient population, effectively alleviating the current difficult problem of public hospitals.*
- ✓ **Suggestion 4:** *In view of the fact that the current social aging phenomenon is gradually increasing, the medical management department should set up more small medical institutions in the community to provide more convenient medical services for the elderly and relieve the pressure of hospital visits.*

9. Strengths and Weakness

Table 11: Strengths and weakness of models

	Strengths	Weaknesses
GM(1,n) model	<i>Based on the characteristics of time series and accumulation, the model weakens the randomness of original data and eliminates the interference of abnormal factors.</i>	<i>There are many complex factors, which cannot be considered comprehensively, resulting in some inconsistencies with the actual situation.</i>
Multiple nonlinear regression model	<i>It is a multi-dimensional model integrated with various factors, which can effectively eliminate the restriction of single influencing factor, improve data stability and enhance correlation degree</i>	<i>We use the prediction data to simulate the required data, which is equivalent to magnifying the error of the first simulation data for the second time, so as to affect the prediction accuracy.</i>
Greedy queuing mechanism model	<i>Combining with the actual situation, the proposed problem is solved to make the model more practical and universal.</i>	<i>Due to the interference of unknown social factors, the data will fluctuate to a certain extent, so the obtained interval is too long to affect the prediction accuracy.</i>

References

- [1] Ming Li. *China's population aging prediction based on GM1_1 model* [J]. 2014.
 [2] Hua Ze. *Study on Health Resources Allocation Analysis and Demand Forecast in Jiangsu Province* [J]. 2016.
 [3] Yiming Tang. *Investigation and Analysis of Common Diseases and Physical Fitness Evaluation of Adults Aged 20_59 in Hubei Province* [J]. 2004.
 [4] Jing Li. *Analysis of queuing model* [J]. 1991.

Appendix

1. Multiple regression grey prediction Code

```
%Establish symbol variables a(development coefficient) and b(grey effect)
syms a b;
c = [a b]';

%The original sequence A
A = [10636 10956 11307 11894 12288 12714 13161 13755 14386
     15003 15831 16658];
n = length(A);

%You add up the original sequence A to get sequence B
B = cumsum(A);

%I'm going to do adjacent mean generation to B
for i = 2:n
    C(i) = (B(i) + B(i - 1))/2;
end
C(1) = [];

%Construct data matrix
B = [-C;ones(1,n-1)];
Y = A; Y(1) = []; Y = Y';

%Using the least square method to calculate the parameters a(development
coefficient) and b(grey effect)
c = inv(B*B')*B*Y;
c = c';
a = c(1); b = c(2);

%Forecast follow-up data
```

```
F = []; F(1) = A(1);
for i = 2:(n+7)
    F(i) = (A(1)-b/a)/exp(a*(i-1))+ b/a;
end

%The sequence F is reduced and the predicted data is obtained
G = []; G(1) = A(1);
for i = 2:(n+7)
    G(i) = F(i) - F(i-1); %Get the predicted Numbers
end

disp('The predicted data are : ');
G

%Model test

H = G(1:12);
%Compute the residual sequence
epsilon = A - H;

%Method one : Relative residual Q test
%Calculate the relative error sequence
delta = abs(epsilon./A);
%Calculate the relative error Q
disp('Relative residual Q test: ')
Q = mean(delta)

%Method 2 : Variance over C
disp('Variance over C: ')
C = std(epsilon, 1)/std(A, 1)

%Method 3 : Small error probability P test
S1 = std(A, 1);
tmp = find(abs(epsilon - mean(epsilon)) < 0.6745 * S1);
disp('Small error probability P test: ')
P = length(tmp)/n

%Plot a graph
t1 = 2007:2018;
t2 = 2007:2025;

plot(t1, A, 'ro'); hold on;
plot(t2, G, 'b-');
xlabel('years'); ylabel('Number of people over 60 years old /Ten thousand');
```

```

legend('Actual value ',' predicted value');
title('Predictive value of Aging population');
grid on;

```

2. Draw the aging population growth rate Code

```

A=[10636 10956 11307 11894 12288 12714 13161 13755 14386
    15003 15831 16658 17126.56298 17857.27339 18619.15979
    19313.55232 20281.83787 21135.4624922195.93394];
l=length(A);
for i=1:l-1
    D(i)=A(i+1)-A(i);
end
D=D*1000;
for i=1:18
    k(i)=D(i)/A(i);
end

for i=1:l-1
    x(i)=2006+i;
end
plot(x,k,'-r'); %Linearity, color, marking
hold on;
Aver=mean(k);
plot([2006,2024],[Aver,Aver]);
text(2012,Aver-1,'Average growth rate');
xlabel('years');
ylabel('Aging population growth rate/%');
grid on;

```

3. Multiple nonlinear regression

```

%The target function is linear, color, label :
y=a1+(a2x1+a3x2+a4x3)+(a5x1^2+a6x2^2+a7x3^2)+(a8x1*x2+a9x1*x3+a10x2*x
3);
%1The incidence of
x1=[2.7239 2.6801 2.7239 2.6801 2.7239 2.6801 2.7239 2.6801 2.7239
    2.6801 2.7239]';
%2population

```

```

x2=[132129 132802 133475 134148 134821 135494 136167 136840 137513
    138186 138859]';
%3An ageing population
x3=[10636 10816.23139 11277.70944 11758.87659 12260.5729 12783.67425
    13329.09389 13897.78403 14490.73753 15108.98958
    15753.61955]';
%Number of beds
k=size(x1);
y=[370.11 403.87 441.66 478.68 515.99 572.48 618.19 660.12 701.52
    741.05 794.03
    ]';
X=[ones(k) x1 x2 x3 x1.^2 x2.^2 x3.^2 x1.*x2 x1.*x3 x2.*x3];
[b,bint,r,rint,stats] = regress(y,X);

```

4. K-mean clustering and classification of diseases Code

```

%You pick 150 random points
X=[80.85818182 -3.727928712
4.518181818 -9.675245915
63.40272727 -5.085447909
9.123636364 14.91633791
1.111818182 14.09214294
2.697272727 -15.40452791
15.16909091 -13.18503086
5.287272727 -5.858169169
78.61545455 -4.494427596
5.645454545 43.25158734
1.787272727 15.31696136
3.020909091 40.97235165
0.357272727 3.502461296
0.38 -5.812790184
]

opts = statset('Display','final');

%Call the Kmeans function
%X N by P data matrix
%Idx N*1 storing the cluster number of each point
%Ctrs K*P, storing K locations of the center of mass of the cluster
%SumD 1*K The sum vector of is the sum of all the points between the class and the
centroid of the class
%D N*K is matrix, What is stored is the sum of the distances between all the points in
the class and the centroid of the class

```

```
[Idx,Ctrs,SumD,D] = kmeans(X,4,'Replicates',4,'Options',opts);

%Let me draw a cluster of 1. X(Idx==1,1),Is the first coordinate of the sample of the
first class; X(Idx==1,2)Is the second coordinate of the sample of type ii
plot(X(Idx==1,1),X(Idx==1,2),'r.','MarkerSize',14)
hold on
plot(X(Idx==2,1),X(Idx==2,2),'b.','MarkerSize',14)
hold on
plot(X(Idx==3,1),X(Idx==3,2),'g.','MarkerSize',14)
hold on
plot(X(Idx==4,1),X(Idx==4,2),'m.','MarkerSize',14)

%Draw the center of the cluster. Kx represents the circle
plot(Ctrs(:,1),Ctrs(:,2),'kx','MarkerSize',5,'LineWidth',4)
plot(Ctrs(:,1),Ctrs(:,2),'kx','MarkerSize',14,'LineWidth',4)
plot(Ctrs(:,1),Ctrs(:,2),'kx','MarkerSize',14,'LineWidth',4)
title('K-means cluster for common disease');
xlabel('Current incidence');
ylabel('The trend of incidence');

legend('Disease of type 1','Disease of type 2','Disease of type 3','Disease of type
4','Centroids','Location','NW')

Ctrs
SumD
```

5. Principal component analysis dimension reduction Code

```
%PCAtransform(K-L)
bands=5;
% Values for each type are listed in one column
mul=[7.5 7.2 7 7.6 0.75
6.3 6.4 7.1 7.8 0.77
6.8 6.9 7.7 8.1 0.76
7.1 7.3 7.2 7.4 0.86
8.9 8.5 7.8 8 1.12
9.2 8.8 8.3 7.9 0.81
8.4 8.2 8.2 8.1 0.87
8.1 7.9 8.5 8.7 0.99
4.5 5.5 8.4 8.5 1.01
5.1 5.6 7.9 8.1 1.07
9.2 8.8 8.3 7.9 1.00
```

```

7.4 7.7 8.3 8.2 0.98
8.2 8.1 8.5 8.7 1.01
8.7 8.4 8.2 8.1 1.06
7.4 7.7 8.3 7.9 1.00
6.6 6.9 8.7 9.1 0.82
6.8 7.2 9.1 8.9 0.88
7.6 7.7 7.1 7.3 1.12
8.1 7.9 7.3 7.5 0.95
8.9 8.8 7.9 8.2 0.77
];
tempMul = mul;

% Find the average value of each channel
meanValue = mean(mul,1);

% Data decentralization
%B = repmat(A,M,N)Matrix B is A copy of matrix A, where the dimension of B is
[size(A,1)*M, size(A,2)*N]
%Each element minus its band mean
mul = mul - repmat(meanValue,[20,1]);

% Find the covariance matrix
correlation = (mul'*mul)/20;

%Find the eigenvector and eigenvalue
%value--The eigenvalues are arranged from large to small
%vector--An eigenvector corresponds to an array of eigenvalues, and a column is an
eigenvector
[vector ,value] = eig(correlation);

% The eigenvalues and eigenvectors are sorted from large to small
vector = fliplr(vector);
value = fliplr(value);
value = flipud(value);

% Y=AX (X is a sample. If X ACTS as a sample, thenY =XA )
% PCAIs changing
PC = tempMul*vector;

sum_val=sum(sum(value));
for l=1:5
    con(l)=value(l,l)/sum_val;
end

```

```

for l=1:5
    cum_con(l)=sum(con(1:l));
end

```

6. Drawing of hospital space network Code

```

x=[1 3.5 5.0 6.2];
y=[1 4.8 3.2 6.7];
plot(x,y,'-o');hold on;

```

```

x1=[1 5.0 6.2];
y1=[1 3.2 6.7];
plot(x1,y1,'-o');hold on;

```

```

x2=[1 6.2];
y2=[1 6.7];
plot(x2,y2,'-o');hold on;

```

```

x3=[ 3.5 6.2];
y3=[ 4.8 6.7];
plot(x3,y3,'-o');hold on;

```

```

text(x(1)+0.1,y(1)+0.1,'Outpatient');
text(x(2)+0.1,y(2)+0.1,'ExamRoom1');
text(x(3)+0.1,y(3)+0.1,'ExamRoom2');
text(x(4)+0.1,y(4)+0.1,'ExamRoom3');

```

```

dist=zeros(4,4);
for i=1:3
    for j=i+1:4
        dist(i,j)=sqrt((x(i)-x(j))^2+sqrt((y(i)-y(j))^2));
    end
end
end

```

```

for i=1:4
    for j=i+1:4
        X=(x(i)+x(j))/2;
        Y=(y(i)+y(j))/2;
        text(X-0.15,Y+0.1,num2str(dist(i,j)));
        hold on
    end
end

```

```
end
title('Network of Hospital internal transit time(min) ');
```

7. Simulation of greedy queuing model

```
clear
clc
mean_W_1=zeros(6,1000);
for xj=1:1000
    most=10000;
    %The illness[1 2 3]To the doping control station[1 ;2 ; 3],The probability of
    illness[0.2 0.3 0.3 0.2]
    e=rand(1,most);
    ds=zeros(1,most);
    away=zeros(4,most);
    for i=1:most
        if(e(1,i)<0.2)
            ds(1,i)=1;
        else
            if(e(1,i)<0.5)
                ds(1,i)=2;
            else
                if(e(1,i)<0.8)
                    ds(1,i)=3;
                else
                    e(1,i)=0;
                end
            end
        end
    end
end
end
t_walk=[3,5,6];%The walking time from the registration center to the
examination room
n=most;%The number of simulations
lamda=0.2;
mu1=0.3;
mu2=0.1;
%Arrival interval
t_reach=exprnd(1/lamda,1,3*n);
t_reach(1,:)=cumsum(t_reach(1,:));%Time of arrival confirmed
t_book=exprnd(1/mu1,1,3*n);%Registration time
t_exc=exprnd(1/mu2,1,3*n);
%s;%Number of service, queuing scale
W_s=zeros(2,n);%Waiting for captain, current number of service
T=zeros(2,n);%Start service time, leave time
```



```

%The first one simulated
W_s(1,1)=0;%Wait for the captain
W_s(2,1)=1;%Current registered number
T(1,1)=t_reach(1,1);%Time of registration
T(2,1)=T(1,1)+t_book(1,1);%Departure time of registration
begin=zeros(4,most);
W1=zeros(2,most);
W2=zeros(2,most);
W3=zeros(2,most);
W4=zeros(2,most);
%s+1 to n
i=2;
a=1;b=1;c=1;d=1;
while(i<=n)
    t_max=max(T(2,i-W_s(2,i-1):i-1));
    if(t_reach(1,i)>=t_max)%No queue at present
        W_s(1,i)=0;
        W_s(2,i)=1;
        T(1,i)=t_reach(1,i);
        T(2,i)=T(1,i)+t_book(1,i);
        switch ds(1,i)
            case 0%Directly to leave
                away(1,a)=T(2,i);
                W1(1,i)=0;
                W1(2,i)=W_s(2,i);
                begin(1,a)=T(2,i);
                i=i+1;
                a=a+1;
            case 1%With 1 illness, to 1 examination room
                if sum(away(2,:))==0
                    begin(2,b)=T(2,i)+t_walk(1,1);
                    away(2,b)=begin(2,b)+t_exc(1,i);
                    W2(1,b)=0;
                    W2(2,b)=1;%Waiting for the number of
                    i=i+1;
                    b=b+1;
                else
                    T_max=max(away(2,b-W2(2,b-1):b-1));
                    if(T(2,i)+t_walk(1,1)>T_max)
                        begin(2,b)=T(2,i)+t_walk(1,1);
                        away(2,b)=begin(2,b)+t_exc(1,i);
                        W2(1,b)=0;
                        W2(2,b)=1;%Waiting for the number of
                        i=i+1;

```

```

        b=b+1;
    else
        num=sum(away(2,:)>T(2,i)+t_walk(1,1));
        begin(2,b)=T_max;
        away(2,b)=begin(2,b)+t_exc(1,i);
        W2(1,b)=begin(2,b)-T(2,i)-t_walk(1,1);
        W2(2,b)=num+1;
        i=i+1;
        b=b+1;
    end
end
case 2
if sum(away(3,:))==0
    begin(3,c)=T(2,i)+t_walk(1,2);
    away(3,c)=begin(3,c)+t_exc(1,i);
    W3(1,c)=0;
    W3(2,c)=1;%Waiting for the number of
    i=i+1;
    c=c+1;
else
    T_max=max(away(3,c-W3(2,c-1):c-1));
    if(T(2,i)+t_walk(1,2)>T_max)
        begin(3,c)=T(2,i)+t_walk(1,2);
        away(3,c)=begin(3,c)+t_exc(1,i);
        W3(1,c)=0;
        W3(2,c)=1;%Waiting for the number of
        i=i+1;
        c=c+1;
    else
        num=sum(away(3,:)>T(2,i)+t_walk(1,2));
        begin(3,c)=T_max;
        away(3,c)=begin(3,c)+t_exc(1,i);
        W3(1,c)=begin(3,c)-T(2,i)-t_walk(1,2);
        W3(2,c)=num+1;
        i=i+1;
        c=c+1;
    end
end
case 3
if sum(away(4,:))==0
    begin(4,d)=T(2,i)+t_walk(1,3);
    away(4,d)=begin(4,d)+t_exc(1,i);
    W4(1,d)=0;
    W4(2,d)=1;%Waiting for the number of

```

```

        i=i+1;
        d=d+1;
    else
        T_max=max(away(4,d-W4(2,d-1):d-1));
        if(T(2,i)+t_walk(1,3)>T_max)
            begin(4,d)=T(2,i)+t_walk(1,3);
            away(4,d)=begin(4,d)+t_exc(1,i);
            W4(1,d)=0;
            W4(2,d)=1;%Waiting for the number of
            i=i+1;
            d=d+1;
        else
            num=sum(away(4,:)>T(2,i)+t_walk(1,3));
            begin(4,d)=T_max;
            away(4,d)=begin(4,d)+t_exc(1,i);
            W4(1,d)=begin(4,d)-T(2,i)-t_walk(1,3);
            W4(2,d)=num+1;
            i=i+1;
            d=d+1;
        end
    end
end
end
else%There's a queue
    num=sum(T(2,:)>t_reach(1,i));
    T(1,i)=t_max;
    T(2,i)=T(1,i)+t_book(1,i);
    W_s(1,i)=T(1,i)-t_reach(1,i);
    W_s(2,i)=num+1;
    switch ds(1,i)
        case 0%Directly to leave
            away(1,a)=T(2,i);
            W1(1,i)=0;
            W1(2,i)=W_s(2,i);
            begin(1,a)=T(2,i);
            i=i+1;
            a=a+1;
        case 1%With 1 illness, to 1 examination room
            if sum(away(2,:))==0
                begin(2,b)=T(2,i)+t_walk(1,1);
                away(2,b)=begin(2,b)+t_exc(1,i);
                W2(1,b)=0;
                W2(2,b)=1;%Waiting for the number of
                i=i+1;
                b=b+1;
            end
        end
    end
end

```

```

else
    T_max=max(away(2,b-W2(2,b-1):b-1));
    if(T(2,i)+t_walk(1,1)>T_max)
        begin(2,b)=T(2,i)+t_walk(1,1);
        away(2,b)=begin(2,b)+t_exc(1,i);
        W2(1,b)=0;
        W2(2,b)=1;%Waiting for the number of
        i=i+1;
        b=b+1;
    else
        num=sum(away(2,:)>T(2,i)+t_walk(1,1));
        begin(2,b)=T_max;
        away(2,b)=begin(2,b)+t_exc(1,i);
        W2(1,b)=begin(2,b)-T(2,i)-t_walk(1,1);
        W2(2,b)=num+1;
        i=i+1;
        b=b+1;
    end
end
case 2
if sum(away(3,:))=0
    begin(3,c)=T(2,i)+t_walk(1,2);
    away(3,c)=begin(3,c)+t_exc(1,i);
    W3(1,c)=0;
    W3(2,c)=1;%Waiting for the number of
    i=i+1;
    c=c+1;
else
    T_max=max(away(3,c-W3(2,c-1):c-1));
    if(T(2,i)+t_walk(1,2)>T_max)
        begin(3,c)=T(2,i)+t_walk(1,2);
        away(3,c)=begin(3,c)+t_exc(1,i);
        W3(1,c)=0;
        W3(2,c)=1;%Waiting for the number of
        i=i+1;
        c=c+1;
    else
        num=sum(away(3,:)>T(2,i)+t_walk(1,2));
        begin(3,c)=T_max;
        away(3,c)=begin(3,c)+t_exc(1,i);
        W3(1,c)=begin(3,c)-T(2,i)-t_walk(1,2);
        W3(2,c)=num+1;
        i=i+1;
        c=c+1;
    end
end

```

```

        end
    end
    case 3
        if sum(away(4,:))==0
            begin(4,d)=T(2,i)+t_walk(1,3);
            away(4,d)=begin(4,d)+t_exc(1,i);
            W4(1,d)=0;
            W4(2,d)=1;%Waiting for the number of
            i=i+1;
            d=d+1;
        else
            T_max=max(away(4,d-W4(2,d-1):d-1));
            if(T(2,i)+t_walk(1,3)>T_max)
                begin(4,d)=T(2,i)+t_walk(1,3);
                away(4,d)=begin(4,d)+t_exc(1,i);
                W4(1,d)=0;
                W4(2,d)=1;%Waiting for the number of
                i=i+1;
                d=d+1;
            else
                num=sum(away(4,:)>T(2,i)+t_walk(1,3));
                begin(4,d)=T_max;
                away(4,d)=begin(4,d)+t_exc(1,i);
                W4(1,d)=begin(4,d)-T(2,i)-t_walk(1,3);
                W4(2,d)=num+1;
                i=i+1;
                d=d+1;
            end
        end
    end
end
end
end
t_mean=mean([W1(1:a-1),W2(1:b-1),W3(1:c-1),W4(1:d-1)]);%Check the
average wait time
p_book=sum(t_book(1,1:i-1))/T(2,i-1);%Work intensity of registration station
p_exc=sum(t_exc(1,1:i-1))/(sum(t_exc(1,1:i-1))+t_mean*most);%Work intensity
of examination room
mean_W_1(1,xj)=mean(W_s(1,1:i-1));
mean_W_1(2,xj)=mean(t_mean);
mean_W_1(3,xj)=mean(W_s(2,1:i-1));
mean_W_1(4,xj)=mean(mean([W1(2:a-1),W2(2:b-1),W3(2:c-1),W4(2:d-1)]));
mean_W_1(5,xj)=mean(p_book);
mean_W_1(6,xj)=mean(p_exc);
end

```

```

fprintf('Average waiting time for registration%6.2f\n',mean(W_s(1,1:i-1)));
fprintf('Average wait time for patient examination%6.3f\n',t_mean);
fprintf('Average      number      of      patients      waiting      for
registration%6.4f\n',mean(W_s(2,1:i-1)));
fprintf('Average      number      of      patients      examined
waiting%6.5f\n',mean([W1(2:a-1),W2(2:b-1),W3(2:c-1),W4(2:d-1)]));
fprintf('Service intensity of registration station%6.6f\n',p_book);
fprintf('Examination room service intensity%6.6f\n',p_exc);
X1=0:5:40;
X2=0:10:100;
X3=0:1:10;
subplot(2,2,1)
hist(W_s(1,1:i-1),X1);
hold on
plot(10,mean(W_s(1,1:i-1)))
axis([0,40,0,6000]);
xlabel('Registration waiting time(min)')
ylabel('frequency')
subplot(2,2,2)
hist([W1(1,1:a-1),W2(1,1:b-1),W3(1,1:c-1),W4(1,1:d-1)],X2);
axis([0,100,0,7500]);
xlabel('Check the frequency of waiting time(min)')
ylabel('frequency')
subplot(2,2,3)
hist([W_s(2,1:i-1),W2(2,1:i-1),W3(2,1:i-1),W4(2,1:i-1)],X3);
axis([0,10,0,20000]);
xlabel('Registration waiting captain')
ylabel('frequency')
subplot(2,2,4)
hist([W1(2,1:a-1),W2(2,1:b-1),W3(2,1:c-1),W4(2,1:d-1)],X3);
axis([0,10,0,4000]);
xlabel('Inspection waiting captain')
ylabel('frequency')

```