Team Control Number

201931654

Problem Chosen

A

Summary

With the rapid development of China's economy and society, the demand for health care is increasing, which brings challenges to the development and reform of China's health care.This paper analyzes the age structure of population, common diseases, cooperation and competition of public hospitals, which provides a certain direction for the reform and development of hospitals in China.

In view of question one, firstly, this paper collects the population structure and growth situation of China in 2005-2016, constructs the population forecast model of China in the future by using Leslie model, forecasts the population and population structure of China in the next 30 years, and gets the result that the aging problem of China will become more and more serious in the future. By 2045, the aging population will reach about 20% of the total population, while the working population will decline year by year. By 2045, only 60% of the total population, and the population welfare will be reduced, Secondly, this paper collected the number of medical and health institutions, the total cost of health care, the number of people in health care and the number of medical institutions in China from 2005 to 2017. According to the change of people's demand for medical care, it predicted the per capita demand for medical care in the future. Combined with the prediction of population, it predicted the demand for medical care in the future. By 2030, the total cost of health care will be 1643.33 billion yuan, with 18.6692 million health workers, 1.076 million medical institutions and 13.8694 million beds.

In view of the question two, this paper takes Sichuan Province as an example, consulted the statistical yearbook of Sichuan Province, and obtained the total amount of various diseases and the incidence of each kind of diseases from 2005 to 2011.By using statistical methods, the number of patients with various diseases was counted, and the diseases of circulatory system, tumor and Diseases of the Respiratory System were the most, accounting for 30.67%, 26.96% and 23.68% respectively. Then according to the incidence of each kind of disease in each year, we draw the change chart of incidence of each kind of disease, and find that the incidence of circulatory system, cancer is increasing year by year, and the incidence of Trauma and Toxicosis, respiratory system, urinary and reproductive system diseases fluctuates greatly.

In view of the question three, In order to reduce the waiting time of patients, improve the service quality and reduce the service cost, we first establish the MMN queuing model of patients' queuing inspection, Then, taking the inspection service desk of each project as the hospital's parameters to be optimized, and taking the system's idle probability, the average queue length of patients, the system's service intensity and the average waiting time as the optimization objective function, the hospital's optimal queue model is established.

In view of the question four, this paper establishes a comprehensive evaluation model of public hospitals and private hospitals by AHP， We got a comprehensive score of 0.91459 for public hospitals and 0.79824 for private hospitals, so we are more competitive than private hospitals. In conclusion, public hospitals and private hospitals should strengthen technical cooperation and bed sharing.

Key word: Leslie model, MMN queuing model, public hospital, private hospital.

Content

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.

1.2 Work

Task 1:Make reasonable predictions of the aging trend of China and the medical needs of the residents according to the data of residents' income, age structure of the population and the economic development level etc. in the relevant statistical analysis data of the National Bureau of Statistics.

Task 2:Take a certain province as an example， analyze the most common disease in the future in the province, and provide suggestions for the overall development of major public hospitals in the province.

Task 3:Different types of patients may need to do different inspections in the hospital; different inspection items may be distributed in different locations and there may be a large gap in the number of people in the queue. Please propose a common queuing theory and its related optimal queuing method forth is kind of queuing problem.

Task 4:Combining the complex cooperation and competition between private hospitals and public hospitals, please propose the optimal cooperation and competition strategies among multiple hospitals.

Task 5:Write a(n) 1-2 page(s) proposal for the relevant medical management department, and provide a reference for its preparation of the“14th Five-Year Plan”.

2. Problem analysis

2.1 Analysis of question one

In order to predict the trend of aging and the medical needs of residents in China, it is necessary to study the trend of population development and the input of medical and health resources of the whole society, and to establish a mathematical model symbolizing the actual situation of China, so as to predict the trend of aging and medical needs in China in the future. The mature models for population prediction are logistic model, model and Leslie model. Because the population structure, aging and medical needs need to be predicted in the problem, Leslie population prediction model can accurately predict the population structure based on the birth rate and mortality rate, so as to reflect the total population and structural characteristics of the future society. Therefore, this paper first uses Leslie model to predict the future population structure of China. Then, according to the predicted population structure, the main diseases of residents and the input of medical and health resources, the future medical demand is predicted.

2.2 Analysis of question two

In view of the question two we need to take a province as an example to analyze the most common diseases in the future and provide suggestions for the overall development of key public hospitals in the province. This paper takes Sichuan Province as an example, obtains the annual incidence of several kinds of diseases with high incidence in recent years by consulting the literature, and then analyzes the changes of the incidence of various diseases and the proportion of the total incidence of various diseases by using statistical methods. Finally, according to the changes of all kinds of diseases, suggestions are put forward for the hospital.

2.3 Analysis of question three

Different types of patients may need to do different tests in the hospital, different test items may be distributed in different places, and the number of people in line may vary greatly Therefore, how to reduce the waiting time of patients as much as possible in order to improve the quality of service and reduce the cost of service is an important issue in the realization of modern hospital management.

If more than one item needs to be examined for a patient's physical examination, all items must be examined before they are completed, that is to say, they can only be served through a series of service stages. If a patient has N items to be checked, and there is no order in the N items, then the queue that the patient can currently choose to queue has N columns, and each column corresponds to the queue of a check item.

2.4 Analysis of question four

According to the complex relationship between private hospitals and public hospitals, the bes t cooperation and competition strategy between hospitals is proposed For the way of competition, AHP is used to evaluate public hospitals and private hospitals, and the comprehensive scores of pu blic hospitals and private hospitals are obtained, so as to obtain their advantages and disadvantage s in various aspects,For the cooperation mode, we can share and guide the resources of public hos pitals and private hospitals according to the corresponding ratio of indicators in various aspects of comprehensive evaluation of public hospitals and private hospitals.

2.5 Analysis of question five

Through the inquiry and analysis of the data, this paper comes up with some valuable suggestions for the relevant medical management departments to write a proposal, and provide a reference for the preparation of the 14th five year plan.

3. Symbol and Assumptions

3. 1 Symbol Description

Table 3.1.1 symbol description

Symbol	Symbol description
a_i	Fertility in group i of women
m_{xi}	Proportion of women born in group i
m_{yi}	Proportion of men born in group i
d_{xi}	Mortality in group i women
d_{yi}	Mortality in group i men
s_{xi}	Survival rate of female sex component i
s_{yi}	Survival rate of male component i， $s_{vi} = 1 - d_{vi}$
$x_i^{(t)}$	Population of women in stage i and t year
i	Group i after population age is divided into 101 groups
y_i^t	Survival rate of female sex component i

3.2 Fundamental assumptions

1. All data are true and reliable with statistical analysis value.
2. Social stability, no disaster or war.
3. It is assumed that the survival rate of the population at all ages is stable.
4. The age range of women of childbearing age is 15-49 years old.
5. Age range of labor force: 15-64.

4.Problem 1 model establishment

4.1 Preparation of population prediction model

Because Leslie population model is a kind of discrete matrix based on age and gender. The model is divided into groups by gender. The initial column vector is constructed by the number of women in different age groups in a certain initial period. The Leslie matrix is constructed by the fertility rate and mortality rate of women in different age groups. Then, the product of Leslie matrix and the number vector of women in different age groups is obtained by MATLAB We first predict the number matrix of female population, and then we calculate the total population size through the ratio of men and women, so as to reflect the total population and structural characteristics of the future society.

First of all, the female population is divided into 101 groups according to the size of age, with the interval of one year old, and those over 100 years old are one group; second, the time is discretized into: T = 0,1,2,3 (t=0 is our initial year, for example, the t=0 behind is 2000). The total number of women in the age group *i* is $x_i^{(t)}$, $x_i^{(t)}=[x_1^{(t)}, x_2^{(t)}\dots x_{101}^{(t)}]^T$ The model further studies $x^{(t)}$ the change rule of the total population and other indicators by studying the change relationship with *t* time.

Let the fertility rate of age group i be a_i , a_i is the average number of children per woman in the i age group per unit time; the mortality rate in the i age group is d_{xi} hat is to say, the survival rate of the ratio between the number of female deaths and the total number in the i age group per unit time is $s_{xi}=1-d_{xi}$ Let a_i 、 S_{xi} not change with time t , According to the definition of a_i 、 S_{xi} and $x_i^{(t-1)}$, the relationship between $x_i^{(t-1)}$ and $x_1^{(t)}$ can be obtained：

$$x_i^{(t)}=\sum_{i=0}^{100}x_i^{t-1}a_i m_{xi} \qquad (4\text{-}1\text{-}1)$$

The number of females in group *i* + 1 in year *t* + 1 is the number of females surviving in group I in year t:

$$x_{i+1}^{(t+1)}=x_i^{(t)}s_{xi} \qquad (4\text{-}1\text{-}2)$$

The number of women:

$$x^{(t+1)}=\begin{pmatrix} x_1^{(t+1)} \\ x_2^{(t+1)} \\ x_3^{(t+1)} \\ \cdots \\ x_{101}^{(t+1)} \end{pmatrix}=\begin{pmatrix} a_1m_1 & a_2m_2 & \cdots & \cdots & a_{101}m_{101} \\ s_1 & 0 & \cdots & \cdots & 0 \\ 0 & s_2 & \cdots & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & \cdots & \cdots & s_{100} & 0 \end{pmatrix}\begin{pmatrix} x_1^{(t)} \\ x_2^{(t)} \\ x_3^{(t)} \\ \cdots \\ x_{101}^{(t)} \end{pmatrix} \tag{4-1-3}$$

$$L=\begin{pmatrix} a_1m_1 & a_2m_2 & \cdots & \cdots & a_{101}m_{101} \\ s_1 & 0 & \cdots & \cdots & 0 \\ 0 & s_2 & \cdots & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & \cdots & \cdots & s_{100} & 0 \end{pmatrix} \tag{4-1-4}$$

L is the Leslie matrix：

$$x^{(t+1)}=Lx^{(t)} \tag{4-1-5}$$

In the above formula, when l, is known, for any t = 0,1,2 ：

$$x^{(t)}=L^t x^{(0)} \tag{4-1-6}$$

Therefore, only the Leslie matrix needs to be solved, and the initial vector of female population distribution in different age groups can be obtained $x^{(0)}$, Then we can get the population distribution vector of any t time period $x^{(t)}$.

4.2 Test of population prediction model

After the above models are established, they are not used directly. Instead, they are used to predict the total population of China in 2001-2009 and compare with the actual population of China in 2001-2009 to evaluate and modify the model. Finally, the total population of China in 2017-2030 is predicted.

First of all, in the China Demographic Yearbook and the National Bureau of statistics of China, the population data in 2000 are calculated, and the female population distribution vectors of all age groups are established (see Annex I). Then, the established Leslie model is used to predict the total population in 2001-2009. Secondly, the prediction data is analyzed based on the actual data, and then the model is modified.

Specific forecast steps:

1. Find out the number of female population in each age group in the National Bureau of statistics of China, and then divide by the sampling ratio to find out the vector of female population distribution in each age group in 2000.

2.Count the number of fetuses born by women of all ages, and then calculate the average number of children born by each woman in the I age group, so as to obtain the birth rate a_{xi}.

3.Count the number of deaths at all ages, and then you can figure out the mortality rate d_{xi} So we can get the survival rate $s_{xi}=1-d_{xi}$.

4.Modify the fertility rate, and then use MATLAB programming to predict the population of women after t years $x^{(t)}$,Then the total population is calculated according to the proportion of men and women, and the population quantity and characteristics in the next t years are obtained.

5.According to the census data, the data from 2001 to 2009 are listed and compared with the predicted data to verify the accuracy of the model.

Table 4.2.1 comparison of 2001-2009 real population based on Leslie model

Year	**real population （ten thousand）**	**forecast population （ten thousand）**	**error rate**
2001	127627	128217	0.004626609
2002	128534	128707	0.001814100
2003	129227	129127	0.000773680
2004	129988	129127	0.003394107
2005	130756	131235	0.003670843
2006	131448	131638	0.003670843
2007	132129	132050	0.001449317
2008	132802	132471	0.000600935
2009	133450	132472	0.002489467

4.3 Model adjustment

According to the data in Table 4.2.1:

With the change of time *t*, there is a certain error between the predicted population and the real population in a certain range. The reason is that the model assumes that the proportion of men and women is approximately the same, and then the prediction of the total population size is calculated by the prediction of the number of women population; however, considering the actual situation, the proportion of men and women in different years has been in dynamic change. It can be seen from the data of the Bureau of statistics that the proportion of men and women in China was seriously unbalanced around 2000. With the development of time, the proportion of men and women has improved.

According to the actual situation of our country, after the implementation of the new policy, with the passage of time, the proportion of men and women in China will tend to a balanced proportion of 1:1; not only that, the analysis of the data from the National Bureau of statistics shows that the average life expectancy of women is higher than that of men, and under the condition of normal childbearing, there may be more women than men. Therefore, in the annual population forecast of 2017-2030, according to the trend and speed of the change of the ratio of men to women in recent years, we will reduce the ratio of men to women appropriately. Every five years, we will slightly adjust the ratio of men to women.

The following table shows the proportion of men and women in the past six years:

Table 4.3.1 relationship between men's and women's ratio and time in 2010-2016

Year	sex ratio	Total number （ten thousand）
2010	105.20	134091
2011	105.17	134732
2012	105.12	135404
2013	105.10	136072

2014	105.04	136782
2015	105.02	137349

4.4 Solution of population prediction model

Using the Leslie population prediction model established in this paper, then using the population statistics in 2016 as the initial data, using different fertility rates, using MATLAB to bring in the model calculation, the population table of 2017-2030 is predicted.

Table 4.4.1 population forecast 2017-2030

Year	number of women (ten thousand)	number of men （ten thousand）	Total forecast
2017	71646.30	75945.08	147591.40
2018	72205.82	76538.17	148744.00
2019	72720.67	77083.90	149804.60
2020	73185.59	77576.73	150762.30
2021	73521.48	77932.77	151454.20
2022	73796.13	78223.90	152020.00
2023	74013.66	78454.48	152468.10
2024	74181.12	78632.00	152813.10
2025	74296.75	78754.56	153051.30
2026	74325.37	78784.89	153110.30
2027	74320.89	78780.15	153101.00
2028	74277.16	78733.79	153011.00
2029	74202.28	78654.42	152856.00
2030	74100.69	78546.73	152647.00

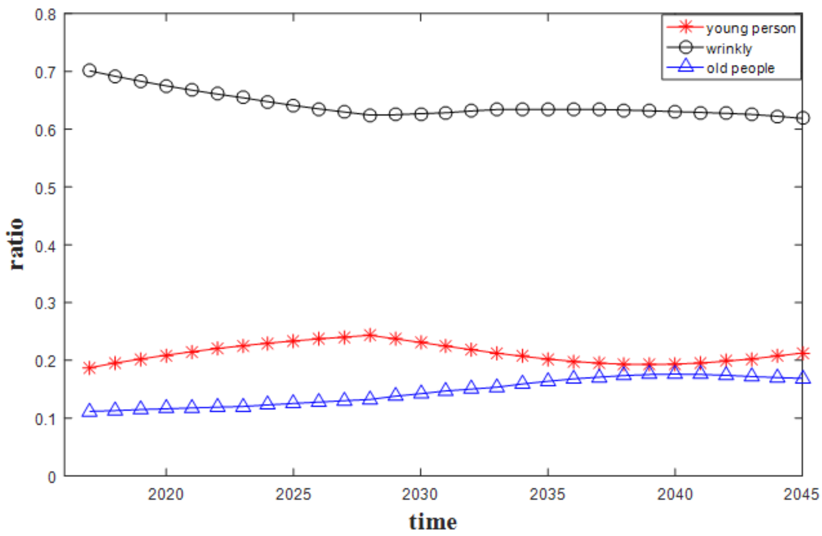

Figure 4.4.1 The age ratio

According to the population prediction model, the proportion of young population, middle-aged population and old population in 2017-2045 is shown in the Figure 4.4.1.

It can be seen from the Figure that the proportion of the working population, that is, the middle-aged population, decreases year by year. The proportion of the elderly population first increases and then decreases, reaching a maximum of 24.8% in 2028, and then tends to stabilize at about 20%. The proportion of young people has also increased, but at a slower rate.

The detailed composition of population in 2020 and 2030 is shown in the Figure below:

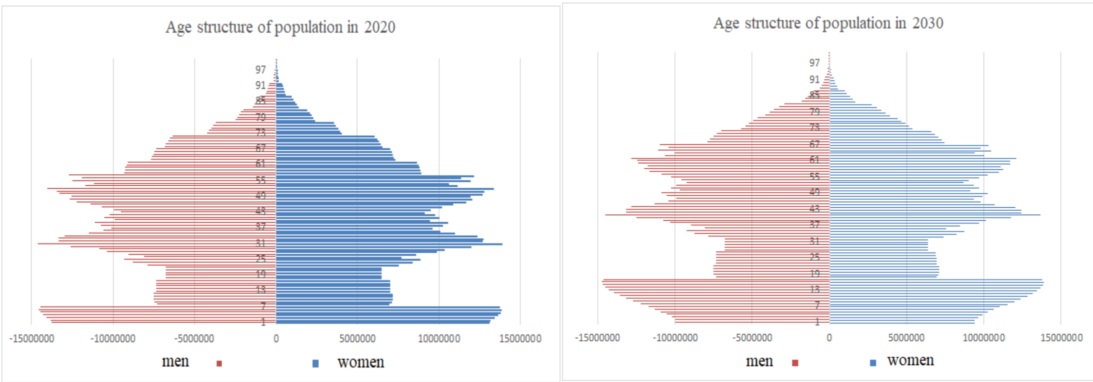

Figure 4.4.2 age structure of population in 2020 and 2030

4.5 Prediction of residents' medical needs

The data of the total population and the number of beds, the total cost, the number of people and the number of medical and health institutions in China from 2005 to 2017 are as follows:

Table 4.5.1 Medical needs data sheet

Year	2005	2006	2007	2008	2009	2010
Population(ten thousand)	130765	131448	132129	132802	133450	134091
Beds in medical institutions (ten thousand)	336.75	351.18	370.11	403.87	441.66	478.68
Total health cost (One hundred million yuan)	8659.91	9843.34	11573.9	14535.4	17541.9	19980.4
Health population (ten thousand)	644.72	668.12	696.44	725.18	778.14	820.75
Number of medical institutions	882203	918097	912263	891480	916571	936972

Year	2011	2012	2013	2014	2015	2016
Population(ten thousand)	134735	135404	136072	136782	137462	138272
Beds in medical institutions (ten thousand)	515.99	572.48	618.19	660.12	701.52	741.05
Total health cost (One hundred million yuan)	24345.9	28119	31668.9	35312.4	40974.6	46344.8
Health population (ten thousand)	861.60	911.57	979.05	1023.42	1069.39	1117.29
Number of medical institutions	954389	950297	974398	981432	983528	983394

4.5.1 Prediction of beds in medical and health institutions

Calculate the ratio $x_b(t)$ between the number of beds per year and the corresponding total population by referring to the data:

$$x_b(t) = \frac{W(t)}{N(t)} \tag{4-5-1}$$

$W(t)$ ---Beds of medical and health institutions in t year

$N(t)$ ---Total population in t year

Use MATLAB to draw the scatter diagram of bed number and population ratio from 2005 to 2016, as shown in the Figure 4.5.1.

Then the function relation between $x_b(t)$ and time is obtained by polynomial interpolation:

$$x_b(t) = -1.9114\times10^6 t^3 + 4.5241\times10^5 t^2 - 3.5272\times10^5 t + 0.0025693 \tag{4-5-2}$$

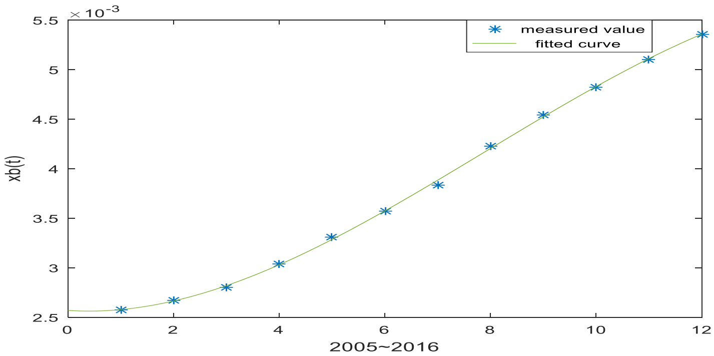

Figure 4.5.1 The scatter diagram of bed number and population ratio

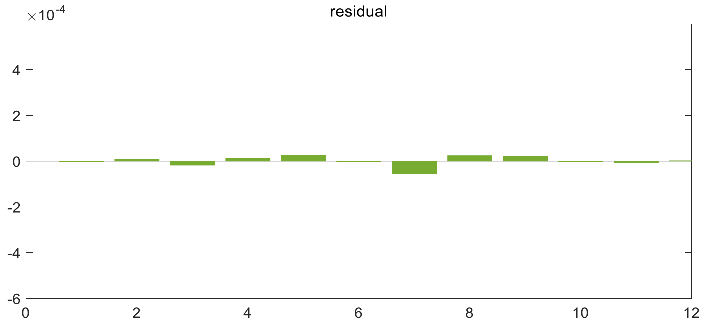

Figure 4.5.2 The residual plot of bed number and population ratio

According to the fitting function of $x_b(t)$ and time, the number of beds and the proportion of population in each year from 2017 to 2030 are calculated, and then the future population is predicted according to Table 4.4.1.Use formula to calculate the bed forecast value from 2017 to 2030, as shown in the table:

Table 4.5.2 Prediction of beds in medical institutions

Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Beds in medical institutions (ten thousand)	823.02	869.60	916.24	962.80	1008.11	1052.94	1097.18
Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Beds in medical institutions (ten thousand)	1140.92	1184.02	1225.80	1267.07	1307.63	1347.57	1386.94

4.5.2 Prediction of total health expenditure (100 million yuan)

Use the total annual health expenditure and the total annual population in the Table 4.5.1 to calculate the annual per capita medical cost.

$$m(t)=\frac{M(t)}{N(t)} \tag{4-5-3}$$

$M(t)$ -Total health expenditure in *t* year

$N(t)$ -Total population in *t* year

Use MATLAB to draw the scatter chart of per capita medical expenses from 2005 to 2016, as shown in the figure.

Then, polynomial interpolation is used to obtain the functional relationship between per capita medical expenses and time as follows:

$$m(t)=11.378t^2+98.174t+521.53 \tag{4-5-4}$$

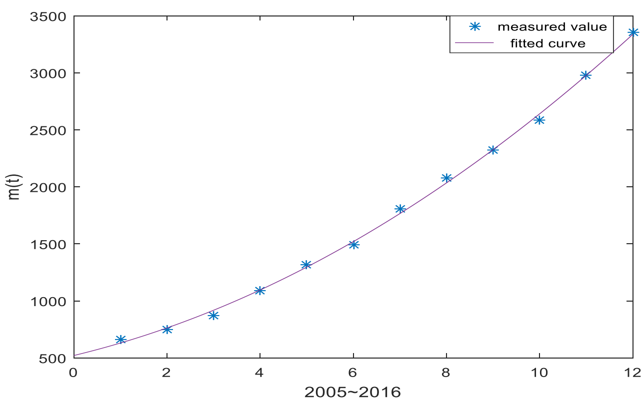

Figure 4.5.3 The scatter diagram of total health expenditure and population ratio

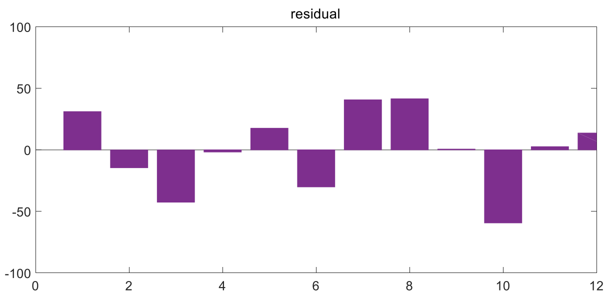

Figure 4.5.4 The residual plot of total health expenditure and population ratio

According to the fitting function relationship between the per capita medical expenses $m(t)$ and time, the per capita medical expenses from 2017 to 2030 are calculated. Then combined with Table 4.4.1, the predicted future population Use formula to calculate the Total health cost forecast value from 2017 to 2030, as shown in the table.

Table 4.5.3 Prediction of total health expenditure

Year	2017	2018	2019	2020	2021	2022	2023
Total health cost (One hundred million yuan)	54913.9	61372.5	68223.9	75457.8	82977.7	90833.9	99017.3

Year	2024	2025	2026	2027	2028	2029	2030
Total health cost (One hundred million yuan)	107522	116333	125371	134706	144311	154188	164333

4.5.3 prediction of health population

Calculate the proportion between the number of health population and the total number of corresponding population every year by consulting data $x_a(t)$:

$$x_a(t) = \frac{N_a(t)}{N(t)} \tag{4-5-5}$$

$N_a(t)$ -Health population in *t* year

$N(t)$ -Total population in *t* year

Use MATLAB to draw a scatter diagram of the proportion of the number of health workers to the total population in 2005-2016, as shown in the figure. Then the function relation between $x_a(t)$ and time is obtained by polynomial interpolation.

$$x_a(t) = 0.0030087t + 0.0044077 \tag{4-5-6}$$

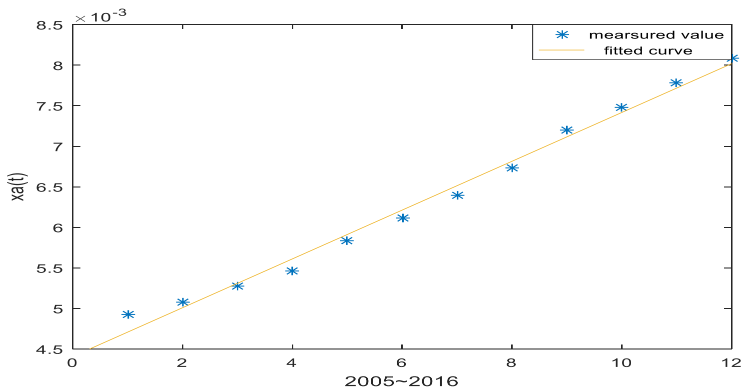

Figure 4.5.5 The scatter diagram of health population and population ratio

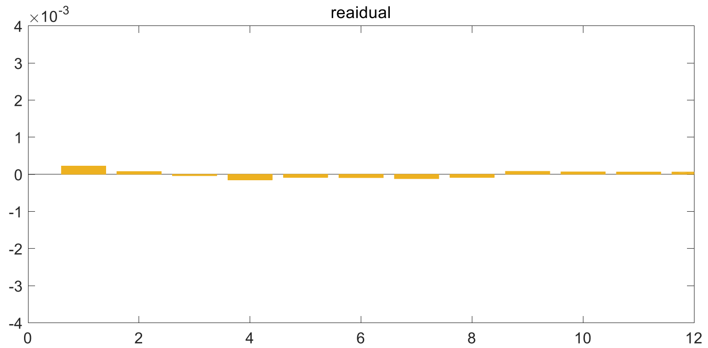

Figure 4.5.6 The residual plot of health population and population ratio

According to the fitting function relationship between the per capita medical expenses $x_a(t)$ and time, the per capita medical expenses from 2017 to 2030 are calculated. Then combined with Table 4.4.1, the predicted future population Use formula to calculate the Health population forecast value from 2017 to 2030, as shown in the table.

Table 4.5.4 Prediction of health population

Year	2017	2018	2019	2020	2021	2022	2023
Health population (ten thousand)	1227.81	1282.16	1336.37	1390.27	1442.22	1493.35	1543.62
Year	2024	2025	2026	2027	2028	2029	2030
Health population (ten thousand)	1593.09	1641.62	1688.32	1734.28	1779.30	1823.49	1866.92

4.5.4 Prediction of the number of medical and health institutions

The proportion of the number of medical and health institutions per year to the corresponding total population is $x_h(t)$ calculated by using the total annual number of medical and health institutions and the total annual population in the table.

$$x_h(t) = \frac{N_h(t)}{N(t)} \tag{4-5-7}$$

$N_h(t)$ -Number of medical and health institutions in t year

$N(t)$ -Total population in t year

Use MATLAB to draw a scatter diagram of the proportion of the number of health workers to the total population in 2005-2016, as shown in the figure. Then the function relation between $x_h(t)$ and time is obtained by polynomial interpolation as follows:

$$x_h(t) = -1.1471\times10^{-7}t^3 + 2.2052\times10^{-6}t^2 - 8.1116\times10^{-6}t + 0.00069067 \tag{4-5-8}$$

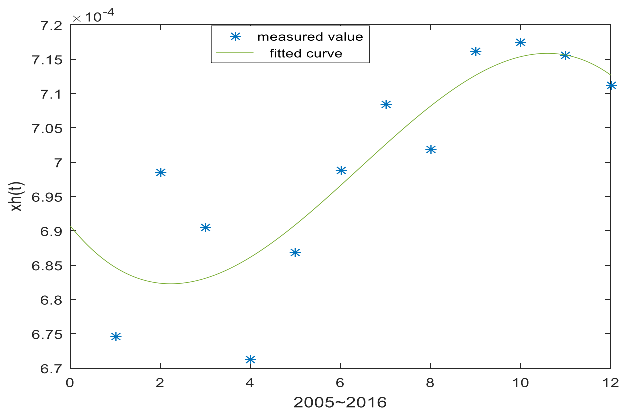

Figure 4.5.7 The scatter diagram of medical and health institutions and population ratio

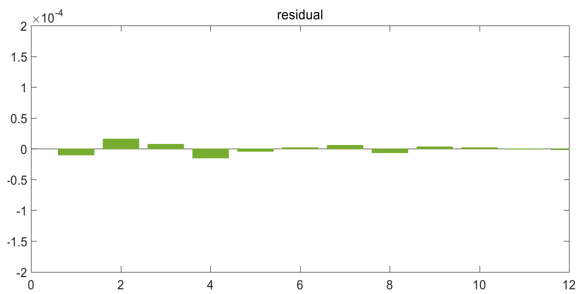

Figure 4.5.8 The residual plot of medical and health institutions and population ratio

According to the fitting function relationship between the per capita medical expenses $x_h(t)$ and time, the per capita medical expenses from 2017 to 2030 are calculated. Then combined with Table 4.4.1, the predicted future population Use formula to calculate the Number of medical institutions forecast value from 2017 to 2030, as shown in the table.

Table 4.5.5 Prediction of the number of medical and health institutions

Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Number of medical institutions	984944	997926	1010217	1021725	1031244	1039780	1047381
Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Number of medical institutions	1054146	1060037	1064505	1068367	1071524	1074090	1076142

5. Problem 2 model establishment

In this paper, taking Sichuan Province as an example, by consulting the statistical yearbook of Sichuan Province, we get the incidence of various diseases from 2005 to 2017, and calculate the number of cases of various diseases in the past 13 years. Then calculate the proportion of the number of patients with each disease in all diseases. Draw the sector statistical chart as shown in the Figure:

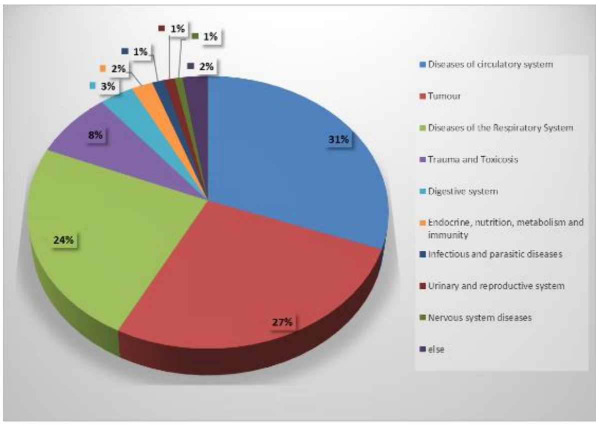

Figure 5.1 Disease plot of Sichuan province

It can be seen from the figure that the most frequent diseases are Diseases of circulatory system, tumor and Diseases of the Respiratory System , accounting for 30.67%, 26.96% and 23.68% of the total disease incidence respectively; the next most frequent diseases are Trauma and Toxicosis、digestive system diseases and immune diseases, accounting for 7.84%, 3.33% and 2.09% of the total disease incidence respectively. The incidence of infectious diseases and parasitic diseases, urinary and reproductive system and nervous system diseases are relatively low, accounting for 1.16%, 1.05% and 0.76% of all diseases, respectively.

The Top 10 diseases are Diseases of circulatory system、Tumour、Diseases of the Respiratory System、Trauma and Toxicosis、Digestive system、Endocrine, nutrition, Metabolic and Immune Diseases、Infectious and parasitic diseases、Urinary and reproductive system、Nervous system diseases and Mental disorder .Corresponding to the annual incidence of various diseases (see attached table). Using the data in the attached table, the ratio of various diseases to all diseases is calculated as follows.

5.1 Study on the incidence of common diseases

According to the data of Sichuan statistical yearbook, the annual incidence of various diseases from 2005 to 2017 was obtained. Using MATLAB to draw the incidence changes of 9 common diseases, as shown in the figure.

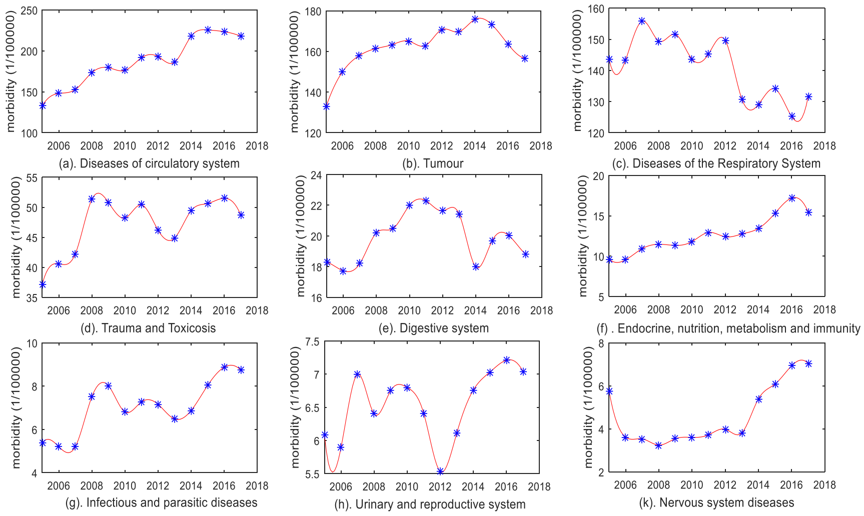

Figure 5.1.1 Changes of common diseases

It can be seen from the figure that the incidence of circulatory system diseases is the highest, with more than 150 cases in 100000 people each year The incidence of nervous system diseases is the lowest, about 4-6 out of every 100000 people. Due to the improvement of environment and quality of life, the incidence of respiratory system diseases and endocrine, nutritional and immune system diseases has decreased. The incidence of the other seven common diseases has increased to varying degrees, he incidence of nervous system diseases and mental disorders is increasing rapidly. Hospitals should strengthen the means of treatment in this regard, increase the number of medical staff and treatment drugs to treat these diseases, so that patients can get effective treatment as soon as possible, In addition, we should also pay attention to other kinds of disease hospitals. Hospitals can improve the treatment level of hospitals by increasing medical equipment, drugs and improving the comprehensive quality of medical staff.

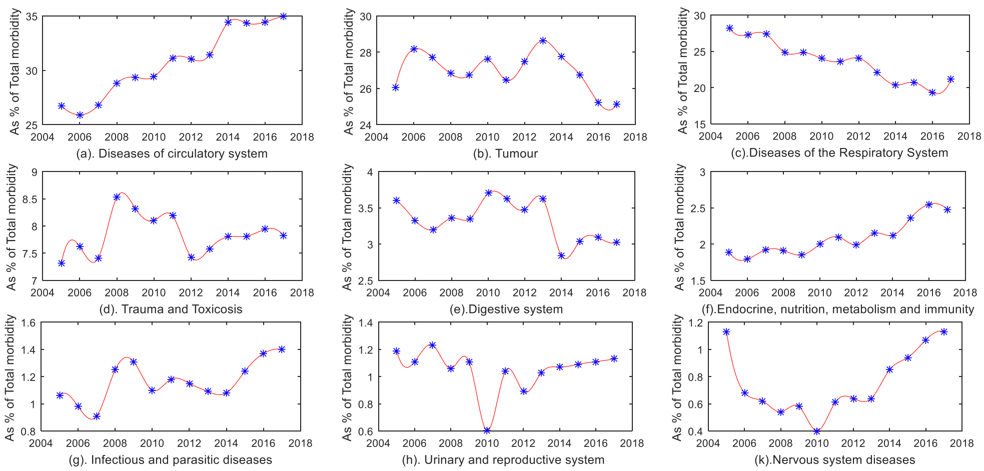

Figure 5.1.2 Changes in the proportion of common diseases

It can be seen from the figure that in recent years, the incidence of tumor, respiratory system and endocrine diseases, metabolic and immune system diseases has decreased in all common diseases, Provincial public hospitals can appropriately reduce the treatment measures and medical resources invested in such diseases. The Trauma and Toxicosis, poisoning and nervous system diseases is relatively stable in all common diseases. Hospitals should keep the existing medical resources investment. At the same time, we can also find that the Diseases of the Circulation System, Infectious Disease and Verminosis, the Diseases of the Genitourinary System and other diseases is gradually increasing. Public hospitals should increase the investment in the treatment resources of these diseases, so that patients can get effective treatment in the fastest time, so as to recover as soon as possible. Especially, in recent years, the proportion of mental disorders and other diseases has increased dramatically. Several specialized hospitals should be set up. At the same time, public hospitals can send medical staff to carry out mental health education activities in schools and on the Internet to reduce the incidence of such diseases.

6. Problem 3 model establishment

The whole queuing system is shown in the figure. Figure 6.1 shows that the patient arrives at service desk 2 after completing the examination items provided by service desk 1, and arrives at service desk 3 after receiving the services of the service desk, until leaving the queuing system after the service desk finishes all the items.

For each service desk in Figure 6.1, a queuing system can be formed. The service desk indicated by each arrow in Figure 6.2 represents a department with a medical doctor, a service desk in the queuing theory, which can also form a queuing system.

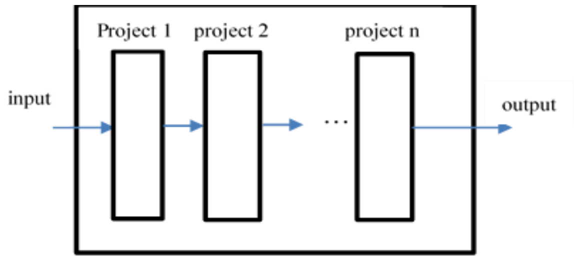

Figure 6.1 queuing system(A)

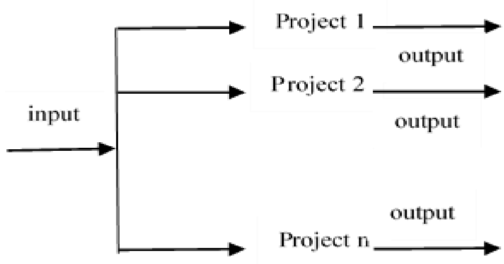

Figure 6.2 queuing system(B)

In order to make the overall queuing time of patients relatively short, and the hospital operation efficiency is the highest, it is necessary to make the time of each service desk in the queuing model of the inspection center shorter, and the patient’s stay time in each service desk is approximately equal. In order to achieve this effect, it is necessary to optimize the design of the service desk of the queuing system model two of the inspection center, In this paper, according to the number of patients with different examination items and the examination time of the item, the service desk of each item is optimized, so that the queuing time of patients in each examination item is approximately the same, which is as short as possible.

6.1 Queuing system model for patient inspection

Queuing theory, also known as stochastic service system theory, is a discipline developed to study and solve queuing problems. It is applied to all service systems, including production management system, transportation system, communication network system, storage system, etc. The general model of queuing theory is shown in Figure 6.1.1. Queuing theory mainly analyzes and studies several quantitative indexes of service system queuing process, provides reference and decision-making, and further discusses optimization problems.

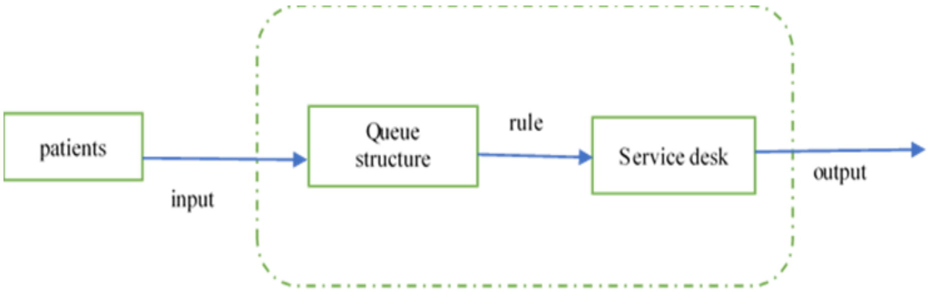

Figure 6.1.1 Queuing system model for patient inspection

In the queuing model shown in Figure 6.1.1, the patient is regarded as the customer, the inspection service desk as the service organization, and the completion of the patient inspection items is regarded as the end of service.

6.2 Establish model constraint relaxation conditions

(1) the input process is random, and the patient's examination law obeys the Poisson distribution of parameters;

(2) the queuing rule is waiting, first come first serve;

(3) multiple service desks provide services at the same time, N service desks are arranged in parallel, and each service desk works independently, with the same average service rate, and each service desk can only serve one patient at a time.

(4) negative exponential distribution of service time.

The whole process of patient inspection is similar to M/M/N queuing model, so this paper uses M / M / N queuing model to analyze patient inspection.

Let the arrival rule of patients obey the Poisson process with parameter λ, the physical examination time of patients obey the negative exponential distribution with parameter μ, and the overall service efficiency is η. refer to the calculation method of M /M /N model of queuing theory.

（1）System service intensity: an indicator to measure the service desk's ability to bear the service and meet the needs of physical examination:

$$\rho=\frac{\lambda}{\eta N\mu} \qquad (6\text{-}2\text{-}1)$$

（2）service desk idle probability: the probability that the service desk is idle:

$$P_0=[\sum_{n=0}^{N-1}\frac{(\mathrm{N}\rho)^n}{n!}+\frac{(\mathrm{N}\rho)^N}{\mathrm{N}!(1-\rho)}]^{-1} \qquad (6\text{-}2\text{-}2)$$

（3）the average waiting team length of patients is:

$$L_q=\frac{(\mathrm{N}\rho)^{\mathrm{N}}\rho}{\mathrm{N}(1-\rho)^2}P_0 \qquad (6\text{-}2\text{-}3)$$

（4）Waiting time: refers to the average waiting time of a patient in physical examination:

$$W_q=\frac{L_q}{\lambda} \qquad (6\text{-}2\text{-}4)$$

（5）average total number of service desks in service:

$$L_p=\frac{\lambda}{\eta\mu} \qquad (6\text{-}2\text{-}5)$$

7. Problem 4 model establishment

In this paper, AHP is used to evaluate the overall competitiveness of public hospitals and private hospitals, and then the advantages and disadvantages of the competition between public hospitals and private hospitals are obtained by comparative analysis of various indicators.

7.1 construction of hospital evaluation system

In order to make the evaluation system more reasonable, this paper reviews the relevant information of hospital evaluation, and constructs the structure chart of hospital evaluation system.

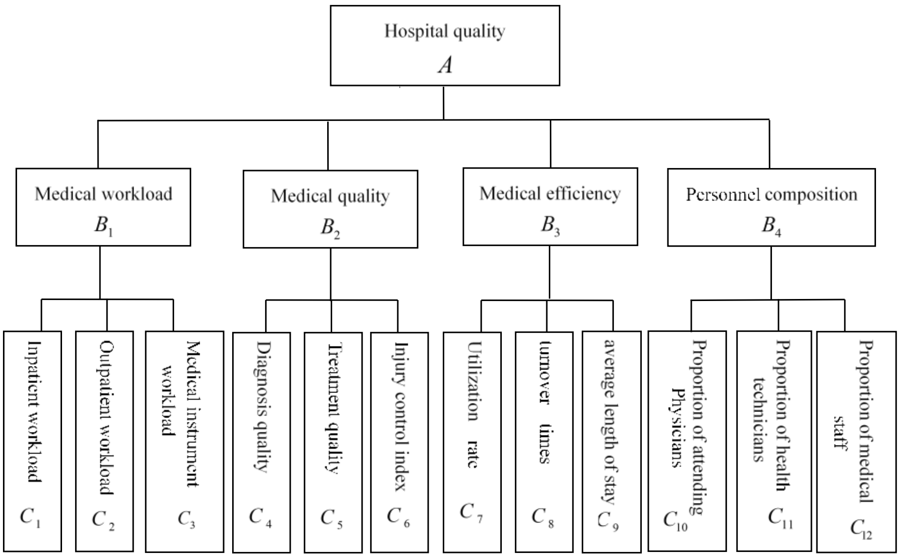

Figure 7.1.1 Hierarchical structure model

7.2 construct pairwise comparison matrix

Let a layer have *N* factors, $X = \{x_1, x_2, \ldots, x_n\}$. compare their influence on a criterion (or target) of the upper layer, and determine the proportion of a criterion in the layer.(Rank the influence degree of *N* factors on a certain target at the upper level),In the above comparison, the two factors are compared, and the scale is 1-9, a_{ij} is the comparison result of factor i with factor j.

$$A = (a_{ij})_{m \times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \quad (7\text{-}2\text{-}1)$$

A — pairwise comparison matrix

7.2.1 establishment of pairwise comparison matrix

Among the factors affecting hospital quality, medical quality obviously has an obvious influence, and medical work efficiency has a certain influence on hospital quality, Secondly, the medical workload also has an impact on the quality of the hospital, and the impact of personnel structure on the quality of the hospital is weaker than the first three. We evaluate the importance of the four factors of hospital quality indicators, determine the comparative scale among the influencing factors, and construct the judgment matrix of the indicators, Then we use the formula calculation to check the consistency, and use the matrix correlation calculation to get the maximum eigenvalue and its corresponding eigenvector, and then normalize the eigenvector to get the corresponding weight vector, All the above processes can be realized by MATLAB programming. See the appendix for the program and Table 7.2.1 for the results.

Table 7.2.1 B_i judgment matrix for A

A	B_1	B_2	B_3	B_4	w_1
B_1	1	1/3	1/2	2	0.1689
B_2	3	1	2	3	0.4512
B_3	2	1/2	1	2	0.2609
B_4	1/2	1/3	1/2	1	0.1190
CR_1=0.0263					

The four main factors that affect hospital quality are also influenced by the internal factors, Factors influencing medical workload: inpatient workload, outpatient workload and medical instrument workload, The factors that affect the quality of medical treatment are diagnosis quality, treatment quality and injury control index. Factors affecting the efficiency of medical work: utilization rate of hospital bed, times of hospital bed turnover and average length of stay, Factors influencing the personnel structure: proportion of attending doctors, proportion of health technicians and proportion of medical staff, The importance of each index is also determined by the above methods. See the table below:

Table 7.2.2 C_i judgment matrix for B_1

B_1	C_1	C_2	C_3	w_{21}
C_1	1	2	3	0.5396
C_2	1/2	1	2	0.2970
C_3	1/3	1/2	1	0.1634
CR_{21}=0.0079				

Table 7.2.3 C_i judgment matrix for B_2

B_2	C_4	C_5	C_6	w_{22}
C_4	1	1/3	1/2	0.1634
C_5	3	1	2	0.5396
C_6	2	1/2	1	0.2970
CR_{22}=0.0079				

Table 7.2.4 C_i judgment matrix for B_3

B_3	C_7	C_8	C_9	w_{23}
C_7	1	2	3	0.5396
C_8	1/2	1	2	0.2970
C_9	1/3	1/2	1	0.1634
CR_{23}=0.0034				

Table 7.2.5 C_i judgment matrix for B_4

B_4	C_{10}	C_{11}	C_{12}	w_{23}
C_{10}	1	1	1	0.3333
C_{11}	1	1	1	0.3333
C_{12}	1	1	1	0.3333
CR_{24}=0.0034				

From the calculation in the above table, it can be concluded that the pairwise comparison matrix has passed the consistency test, and the weight values of the above factors are reliable.

$$W_2 = \begin{bmatrix} 0.5396 & 0 & 0 & 0 \\ 0.2970 & 0 & 0 & 0 \\ 0.1634 & 0 & 0 & 0 \\ 0 & 0.1634 & 0 & 0 \\ 0 & 0.5396 & 0 & 0 \\ 0 & 0.2970 & 0 & 0 \\ 0 & 0 & 0.5396 & 0 \\ 0 & 0 & 0.2970 & 0 \\ 0 & 0 & 0.1634 & 0 \\ 0 & 0 & 0 & 0.3333 \\ 0 & 0 & 0 & 0.3333 \\ 0 & 0 & 0 & 0.3333 \end{bmatrix} \tag{7-2-2}$$

$$w_1 = \begin{bmatrix} 0.1689 \\ 0.4512 \\ 0.2609 \\ 0.1190 \end{bmatrix} \tag{7-2-3}$$

According to formula:

$$w = W_2 w_1 \tag{7-2-4}$$

By consulting the data, we can get the target program index data of inpatient workload, outpatient workload and medical instrument workload, Then the data are processed dimensionally, and then the index data and weight coefficient are substituted into the formula by using the linear weighted synthesis method:

$$Y = Ew \tag{7-2-5}$$

E - index data

Table 7.2.6 synthesis score

Rank	Hospitals	Score
1	Public hospitals	0.91459
2	Private hospitals	0.79824

Through the comprehensive evaluation score, we can see that the comprehensive score of public hospitals is higher, so it is more competitive than private hospitals.

Through the comparative analysis of the indicators of public hospitals and private hospitals, we found that Public hospitals have obvious advantages in capital investment, technology, talents, scientific research and management level and medical quality. Private hospitals have less flow of people and more resources such as controlled beds, In order to solve the three problems of "large number of outpatient services", "difficult hospitalization" and "difficult operation" in public hospitals, we can strengthen the cooperation between public hospitals and private hospitals, Private hospitals should explore their own development direction, actively learn from large hospitals in the same direction, and explore a better development direction.

8. Problem 5 model establishment

Based on the data query and modeling analysis, the following suggestions are proposed for the relevant medical management departments.

1.According to the scientific prediction of this paper, taking Sichuan Province as an example, during the 14th Five Year Plan period, the proportion of young and middle-aged people in China's population continued to decline, and the proportion of the elderly increased. Therefore, the relevant medical management departments should pay attention to the establishment of more professional hospitals mainly serving the elderly.

2. According to the scientific prediction of this paper, taking Sichuan Province as an example, the proportion of children in China's population will increase during the fourteenth Five Year Plan period, so relevant medical management departments should open more pediatric hospitals, and the demand for pediatricians in hospitals will also increase, and relevant departments should train more pediatricians.

3. The medical management department should master or predict the incidence trend of the main diseases through scientific investigation and analysis. According to the latest information, for the diseases with high incidence, the hospital should strengthen the means of treatment in this respect, increase the number of medical staff and drugs to treat such diseases, and purchase relevant medical equipment in time, so that patients can get effective treatment as soon as possible.

4. In order to improve the working efficiency of the hospital and let the patients get effective treatment in the shortest possible time, we should introduce a more scientific and reasonable way of queuing. In this paper, we use an efficient way of queuing to solve this problem.

5. Public hospitals and private hospitals should strengthen cooperation. Medical management departments can use AHP to establish a comprehensive evaluation system to evaluate the advantages and disadvantages of public hospitals and private hospitals, and then learn from each other according to their advantages and disadvantages. According to the corresponding ratio of the indicators of the comprehensive evaluation of public hospitals and private hospitals, public hospitals and private hospitals All kinds of resources of the hospital should be shared and technical guidance should be provided.

9 Strengths and Weakness

9.1 Advantages of the model

Leslie model can not only get the total number of population in the future, but also get the population number and population structure characteristics of all ages, making the results clearer.

After the establishment of Leslie model, we did not directly use it to predict the population and structural characteristics of China in the future years, because there are inevitable deviations in the modeling process, so this paper first uses the data known in 2000 to predict the population and structural characteristics from 2001 to 2012, and then compares the data with the data from the National Bureau of statistics of the people's Republic of China to test the correctness of the model and then make corresponding adjustment to make the prediction model more reliable.

The comprehensive evaluation model of public hospitals and private hospitals is established, and each index of hospitals is quantified. Through the comprehensive score, the comprehensive competitiveness of public hospitals and private hospitals can be seen directly.

The optimization model of patient inspection queue established in this paper is not only suitable for patient inspection queue, but also suitable for station and other queuing problems.

9.2 Disadvantages of the model

In the prediction of population type, this paper first considers the changes of female population development, and then obtains the number of male population and total number according to the proportion of male and female in the past. Although minor adjustments have been made, there are still errors.

The analytic hierarchy process (AHP) is used in the establishment of the comprehensive evaluation model of public and private hospitals, which is subjective. The expert matrix is scored by questionnaire. However, due to the limited time, only 50 samples are selected, and the number of samples is too small.

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