Team Control Number

201923284

Problem Chosen

A

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ShuWei Cup

Improve the overall level of the hospital

Summary

This paper mainly studies the aging trend, residents' medical needs, analyzes the common diseases in Sichuan Province in the future, solves the problem of queuing, provides the optimal cooperation and competition strategy between hospitals, and writes proposals for the relevant medical management departments.

For the first question, firstly, we summarize the residents' income, population age structure, economic development level, aging and residents' medical needs. According to the characteristics of the data, we establish the multiple linear regression model of aging and residents' income, population age structure, economic development level, residents' medical needs and residents' income, population age structure and economic development level 。 Then, according to the residents' income, population age structure and economic development level, the aging trend and residents' medical needs are predicted. With the continuous growth of residents' income, population age structure and economic development level, the proportion of residents' aging is larger, and the demand for medical care is larger.

For the second question, take Sichuan Province as an example. This paper analyzes the incidence of diseases in Sichuan Province, establishes K-means clustering algorithm model, and uses SPSS software to find that the incidence of viral diseases, palmary tuberculosis, hand foot mouth disease is relatively higher than that of other diseases, and then provides suggestions for the overall development of major public hospitals in Sichuan Province.。

For the third question, consult the relevant information, for different types of patients may need to do different inspections in the hospital; different inspection items may be distributed in different places, and the number of people in line may have a big gap, commonly used m| m|c queuing model; classify and summarize the average number of doctors in charge of diagnosis and treatment every day, solve m|m|c queuing model, and prove that the model is consistent with the topic Required.

For the fourth question, first of all, consult the relevant materials, find out the main influencing factors between the cooperation and competition between public hospitals and private hospitals, establish a multi-objective planning model for the income function between hospitals, analyze and point out the focus of the interests of public hospitals and private hospitals, and understand the relationship between public hospitals and private hospitals by combining the relevant statistical analysis data of the National Bureau of statistics, And provide strategies.

For the fifth question, consult the relevant materials, make a summary table, and write proposals, so as to provide reference for the relevant medical management departments to formulate the 14th five year plan.

Key word: multiple regression *K-Means* clustering $M|M|C$ queuing model multi-objective programming

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 services is increasing. At the same time, with the acceleration of industrialization and urbanization, ecological security and food safety face different levels of challenges. These comprehensive developments have also brought a series of new challenges to health care. The rapid growth and diversified development of medical demand has 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 meet the growing medical needs of the residents and improve the residents' demand for hospitals is the main direction. For private hospitals, how to effectively meet the peak demand and special disease needs of public hospitals is the main direction of their efforts.

1.2 Known conditions

Relevant statistical analysis data of the National Bureau of Statistics.

1.3 Problem Description

Task 1: According to the statistics of residents' income, population age structure and economic development level in the relevant statistical analysis data of the National Bureau of Statistics (http://www.stats.gov.cn/tjsj/), reasonably predict the aging trend and residents of China Medical needs.

Task 2: Take a province as an example to analyze the most common diseases in the province in the future and provide advice on the overall development of major public hospitals in the province.

Task 3: Different types of patients may need to do different tests in the hospital; different inspection items may be distributed in different locations, and there may be a large gap in the number of queues. Aiming at this kind of queuing problem, a common queuing theory and its related optimal queuing method are proposed.

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

Task 5: Write a 1-2 page proposal for the relevant medical management department to provide reference for the formulation of the “14th Five-Year Plan”.

2. Problem analysis

According to the information given by the topic, consult the relevant materials and analyze the following issues separately.

2.1 Analysis of problem one

Dividing the income of residents in 2010-2017, the age structure of the population, the level of economic development, the aging and the medical needs of residents, and drawing a line chart to analyze the income of residents, the age structure of the population, the level of economic development, the aging, the income of the residents, and the age structure of the population. The characteristics of economic development and the medical needs of residents are used to find the connection between the data, thereby predicting the trend of aging and the medical needs of residents.

2.2 Analysis of problem two

To calculate the incidence of disease in Sichuan Province in 2017, and to use the incidence rate as an important basis for the disease, consider classifying the incidence of diseases in Sichuan Province, classify the disease, and find out the common conditions, thus the overall public hospitals in the province. Development provides advice.

2.3 Analysis of the problem three

According to the needs of the problem, consult the relevant data, for the queuing problem, the queuing model is used to analyze the practical application of the model.

2.4 Analysis of the problem four

Find out the main influencing factors between cooperation and competition between private hospitals and public hospitals, analyze the influencing factors of the two, and combine the statistical analysis data of the National Bureau of Statistics to conduct analysis.

2.5 Analysis of the problem five

Check the relevant materials, make a summary form for the relevant medical management department, and write a proposal.

3. Model hypothesis

In combination with the actual problem, in order to ensure the accuracy and rationality of the model, in order to eliminate some factors, this paper puts forward the following assumptions.

1 Assume that the data is accurate and valid;

2 Assume that the hospital's daily working hours are 8:00-12:00, 14:00-18:00;

3 Assume that the average patient time is 1 hour;

4 Assume that both public hospitals and private hospitals aim at their maximum profits;

5 Assuming that public hospitals compete with private hospitals, their unit variable costs are the same.

4. symbol definitions and descriptions

In order to facilitate the solution of the problem, the following symbolic description is given.

Symbol	Definition and description
RI	Resident income
PA	Population aging
EDL	Economic development level
AT	Aging trend
MN	Medical needs of residents
cov	covariance
Z	Total time
Num	Total number of doctors and patients per day
μ	Average service rate per unit time
p	Price

i	Public hospital or private hospital
m_i	Hospital profitability
v_i	Unit variable cost of hospital
Q_i	Drug production

5. model preparation

5.1 Data Processing

According to the relevant statistical analysis data of the National Bureau of Statistics, consult relevant information and rationally deal with the problem.

5.1.1 Problem 1 Data Processing

Quantify the income of residents, the age structure of the population, the level of economic development, the aging of the population, and the medical needs of the residents. The per capita disposable income is an important indicator of the income of the residents. The total population is an important indicator of the age structure of the population, and the gross domestic product is the level of economic development. The important indicator is that the proportion of the population over 65 years old is an important basis for aging, and the per capita health expenditure is an important basis for the medical needs of residents. Looking at the knowledge of aging, the proportion of the population over 60 years old is 10%, and the proportion of the population over 65 years old is 7%. This paper mainly takes 7% of the population over 65 years old as an important criterion.

5.1.2 Problem 2 Data Processing

The incidence of disease in Sichuan Province in 2017 was selected as an important reference. This article maintains data on the incidence of 0 in the disease.

5.1.3 Problem 3 Data Processing

From 2013 to 2017, the average number of doctors and doctors will be taken daily, and the average will be taken as the number of patients who come to the hospital doctor daily. Looking at the information, the hospital queues are divided into: the arrival process (input), service time, service window and queuing rules.
(1) The coming process (input) means that different types of patients come to the

hospital according to various rules.

The patient's population can be unlimited or limited; the patient can arrive in a single or batch manner: the interval between successive arrivals can be determined or random: the patient's arrival can be independent of each other. The correlation between the interval of arrival of the patient and the included parameters (such as expected value, variance, etc.) are all irrelevant or related to the time, that is, the incoming process may be stationary or non-stationary. After the study of the actual queuing problem, it is confirmed that the general random arrival law obeys the Poisson process. The process of the patient arriving at the hospital is also generally the Poisson process. The so-called Poisson input is the input that satisfies the following four conditions:

1 Stationarity: The probability of the number of patients arriving within a certain time interval is only related to the length of the period and the number of patients;

2 No aftereffects: the number of patients arriving within the time interval of disjoint is independent of each other;

3 Generality: At the same time, the visit or surgery can reach up to 1 patient, and there is no case where more than 2 patients are reached at the same time.

4 Limitedness: Only a limited number of patients can be reached in a limited time interval, and it is impossible to have an unlimited number of patients arriving.

(2) Service time refers to the time rule of patients receiving services.

The timing of patients receiving services is often also described by probability distribution. In general, the service time of a simple queuing system is often subject to a negative exponential distribution, that is, each patient receives services independently and equally distributed.

(3) The service window indicates how many service windows can be opened to accommodate patients.

The main attribute of the service window is the number of service desks. The types are: single service desk, multi-service desk. The multi-service desks are divided into parallel, series and hybrid. The most basic type is multi-service desk parallel.

(4) The queuing rule determines that the arriving patient receives the service in a certain order.

When the patient arrives, if all the desks are not available, they are waiting in line. The queuing rule is the order rule for waiting for customers to wait in line:

1.first-come-first-served services, such as visits, queuing for drugs, etc.;

2. post-first-served services, such as hospitals for emergency patients;

3. random services, services When the station is idle, randomly select patients waiting for service;

4. priority services, such as hospitals give priority treatment to patients with serious illness. In addition, there are specific queuing (such as in the waiting room) and abstract queuing (such as booking queues). The number of columns queued is also divided into single columns and multiple columns.

5.1.4 Problem 4 Data Processing

The bed work days, bed utilization rates, and average hospitalization days of discharged hospitals in public hospitals and private hospitals in 2012-2017 were counted. The main factors influencing the cooperation and competition between public hospitals are drugs, prices and costs.

5.2 Keyword explanation

5.2.1 Aging

The aging of the population refers to the dynamic increase in the proportion of the elderly population caused by the decrease in the population fertility rate and the increase in the life expectancy of the elderly as a result of the decrease in the number of young people and the increase in the number of elderly people.

Two meanings: one refers to the relatively increasing number of elderly people, and the proportion of the total population is rising; the second is that the social demographic structure is old and enters an aging society. The international view is that when a country or region accounts for 10% of the total population of the population over 60 years old, or 7% of the total population of the population over 65 years old, it means that the population of this country or region is in an aging society.

5.2.2 Resident medical needs

Medical service demand refers to the amount of medical service that patients are willing and able to pay at different medical service prices. In this concept, three points need to be emphasized: first, the patient should have a subjective desire to receive medical services; second, the patient has a certain ability to pay for the economy; and third, the actual consumption of medical services occurs. This is the three major components that make up the demand for medical services.

6. Model establishment and solution

After the above analysis and preparation, this paper will gradually establish the following mathematical model to further elaborate the actual establishment process of the model.

6.1 The establishment and solution of the problem-model

6.1.1 Model establishment

Analyze the income of residents, the age structure of the population, the level of economic development and the aging, and establish a matrix of correlation coefficients.

Let (X_1, X_2, X_3, X_4) be a 4-dimensional random variable. If any correlation coefficient $\rho_{ij}(i, j = 1,2,3,4)$ between X_i and X_j exists, then the fourth-order matrix of the element is called the correlation matrix of the dimensional random vector. It is denoted as R, namely:

$$R = \begin{bmatrix} \rho_{11} & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{21} & \rho_{22} & \rho_{23} & \rho_{24} \\ \rho_{31} & \rho_{32} & \rho_{33} & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & \rho_{44} \end{bmatrix}$$

Where, the calculation formula of ρ_{ij} is:

$$\rho_{ij} = \frac{\text{cov}(X_i, X_j)}{\sqrt{DX_i \sqrt{DX_j}}}$$

Where, cov is covariance, and the calculation formula is:

$$\text{cov}(X_i, X_j) = E((X_i - E(X_i)) \cdot (X_j - E(X_j)))$$

Establish a multiple regression model of household income, population age structure, economic development level and aging:

$$y_{AT} = \alpha_0 + \alpha_1 x_{RI} + \alpha_2 x_{PA} + \alpha_3 x_{EDL}$$

Among them, AT, RI, PA, EDL are aging, resident income, population age structure, and economic development level; $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ is the parameter of the model.

Similarly, establish a multiple regression model of household income, population age structure, economic development level and residents' medical needs:

$$y_{MN} = \beta_0 + \beta_1 x_{RI} + \beta_2 x_{PA} + \beta_3 x_{EDL}$$

Among them, MN, RI, PA, EDL are the medical needs of residents, the income of residents, the age structure of the population, and the level of economic development; $\beta_0, \beta_1, \beta_2, \beta_3$ is the parameter of the model.

The error analysis of the model is carried out, and the total square sum SST is:

$$SST = \sum_{i=1}^{n} (y_i - \overline{y})^2$$

among them, $\overline{y} = \frac{1}{n} \sum_i y_i$

equally:

$$SST = \sum_{i=1}^{n} y_i^2 - \frac{1}{n} (\sum_i y_i)^2$$

The sum of squares is:

$$SSReg = \sum (\overline{y} - \hat{y})^2 = \hat{\beta}^T X^T y - \frac{1}{n} (y^T u u^T y)$$

The sum of squared residuals is:

$$SSE = \sum_i (y_i - \hat{y}_i)^2 = y^T y - \hat{\beta}^T X^T y$$

The sum of squares and SST can be written as:

$$SST = \sum_i (y_i - \overline{y})^2 = y^T y - \frac{1}{n}(y^T u u^T y) = SSReg + SSE$$

The regression coefficient R^2 is:

$$R^2 = \frac{SSReg}{SST} = 1 - \frac{SSE}{SST}$$

6.1.2 Model solution

Using SPSS software to draw the line of income of residents, population age structure, economic development level, aging and income, population age structure, economic development level, and medical needs of residents.

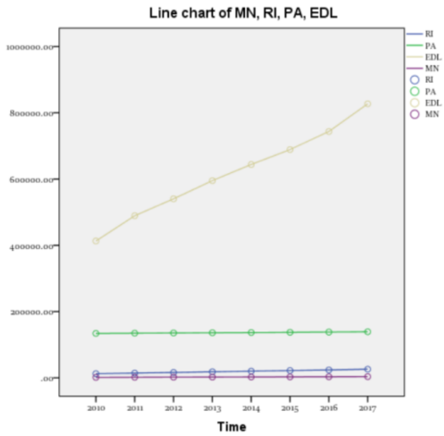

Figure 1 Line chart ofMN,RI,PA,EDL

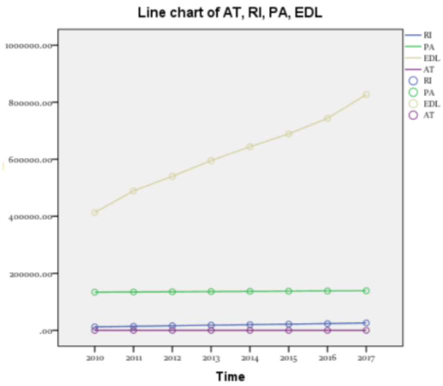

Figure 2 Line chart of AT,RI,PA,EDL

From the above figure, we can see that the income of residents, the age structure of the population, the level of economic development and aging, as well as the income of the residents, the age structure of the population, the level of economic development and the trend of the medical needs of residents may have a linear relationship. .

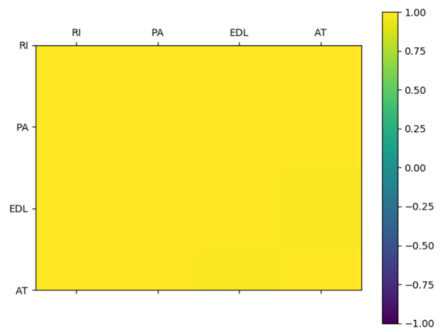

Figure 3 AT, RI, PA, EDL correlation coefficient matrix

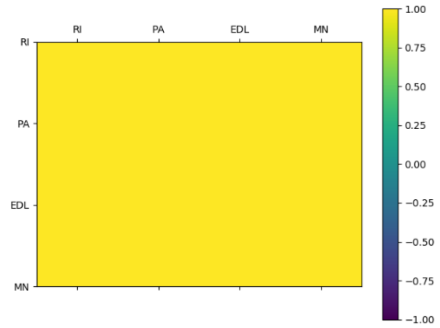

Figure 4 MN, RI, PA, EDL correlation coefficient matrix

Find the value of $\rho_{ij}(i, j = 1, 2, 3, 4)$ in the correlation coefficient matrix:

$$R = \begin{bmatrix} 1 & 1 & 1 & 0.99 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0.99 \\ 0.99 & 1 & 0.99 & 1 \end{bmatrix}$$

Similarly, the values of $\rho_{ij}(i, j = 1, 2, 3, 4)$ in the matrix of residents' income, population age structure, economic development level, and resident medical demand correlation coefficient are obtained:

$$R = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0.99 \\ 1 & 1 & 0.99 & 1 \end{bmatrix}$$

From the correlation coefficient matrix map and the value of $\rho_{ij}(i, j = 1, 2, 3, 4)$, it can be seen that the income of residents, the age structure of the population, and the correlation between economic development level and aging are strong.

The multiple regression model was solved by SPSS software and the regression expression was obtained as follows:

Table 1 Expression table of aging and residents' medical needs

	Regression expression

AT,RI,PA,EDL	$y_{AT} = \text{-}124.935169\text{-}0.000222 x_{RI} + 0.001014 x_{PA} + 0.000001 x_{EDL}$
MN,RI,PA,EDL	$y_{MN} = \text{-}142499.535\text{-}0.336156 x_{RI} + 1.094392 x_{PA} + 0.003455 x_{EDL}$

At the same time, the multiple regression models R^2 of AT, RI, PA, EDL and MN, RI, PA and EDL were 0.992 and 0.998, respectively.

And the error test of the model, as shown in the following table:

Table 2 Error test form

AT	t	Saliency	MN	t	Saliency
RI	-0.760519	0.489306	RI	-2.709100	0.053587
PA	1.514807	0.204393	PA	3.835752	0.018527
EDL	0.272745	0.798551	EDL	1.903984	0.129642

It can be seen from the above table that the two multivariate regression models with t value are only slightly smaller than 0, and the smaller the significance is, the smaller the model error is. In summary, the model is reasonable within the error tolerance.

According to the income of residents, the age structure of the population, and the growth of economic development level, the trend of AT and MN is further predicted:

Table 3 Forecast of aging and medical needs of residents

AT(%)	MN (unit: yuan)
11.49	4127.67
11.85	4499.18
12.20	4870.69
12.56	5242.20

As can be seen from the above table, the aging index is much larger than 7%, and it shows an upward trend; medical demand shows an upward trend; therefore, with the income of residents, the age structure of the population and the level of economic development, the proportion of aging of residents is greater. Medical needs are greater.

6.2 The establishment and solution of the problem two model

6.2.1 Model establishment

Firstly, Sichuan Province was selected as the reference basis for this paper. The incidence of diseases in Sichuan Province was statistically analyzed. The clustering rate of Sichuan Province was analyzed. The steps of establishing K-Means algorithm model are as follows:

Step 1: Select the number of clusters K and select K center points;

Step 2: For each sample point, find the nearest center point (find the organization), and the point closest to the same center point is a class, thus completing a cluster.

Step 3: It is judged whether the category of the sample points before and after the cluster is the same. If they are the same, the algorithm terminates, otherwise, the process proceeds to step 4.

Step 4: Calculate the center point of the sample points for each sample point in each category. As the new center point of the class, proceed to step 4.

Set to the incidence data set $X=\{X_1,X_2,\cdots,X_n\}$, $X_1,X_2,\cdots,X_n$ in X is n data objects and each data object is $X=\{X_{11},X_{12},\cdots,X_{1n}\}$ dimensional, ie .

A collection of K cluster centers:

$$C=\{C_1,C_2,\cdots,C_k\}=\{\{c_{11},c_{12},\cdots,c_{1n}\},\cdots,\{c_{k1},c_{k2},\cdots,c_{kn}\}\}$$

Objective function:

$$J(X,C)=\min(\sum_{i=1}^{k}\sum_{j=1}^{n}d(C_i,X_j))$$

Where $d(C_i,X_j)$ represents the Euclidean distance between the cluster center C_i and the data object X_j:

$$d(C_i,X_j)=\sqrt{(c_{i1}-x_{j1})^2+(c_{i2}-x_{j2})^2+(c_{in}-x_{jn})^2}$$

6.2.2 Model solution

The SPSS software is used to solve the model and the initial cluster center is obtained:

Table 4 Initial cluster center table

	clustering				
	1	2	3	4	5
Morbidity	0	47.79	75.52	15.05	33.09

Iterate using SPSS, as shown in the following table:

Table 5 Iteration history[a]

iteration	Change of cluster center				
	1	2	3	4	5
1	0.674	2.353	7.671	0.683	0
2	0	0	0	0	0

As can be seen from the above table, the convergence is achieved because there is no change or only minor changes in the cluster center. The maximum absolute coordinate of any center is changed to 0. The current iteration is 2. The minimum distance between the initial centers is 14.709.

And get, the final cluster center, see the following table:

Table 6 Final cluster center table

	clustering				
	1	2	3	4	5
Morbidity	0.67	45.44	67.85	14.37	33.09

To classify the incidence of diseases in Sichuan Province, see the following table:

Table 7 Classification of disease incidence in Sichuan Province

Name of disease	Grade of incidence
Viral hepatitis	Extremely high
Pulmonary tuberculosis	Extremely high
Hand foot mouth disease	Extremely high
hepatitis B	higher
Other infectious diarrhea	higher
Syphilis	secondary
AIDS	less
HIV	less
hepatitis C	less
Influenza	less
Mumps epidemic	less
The Plague	Very seldom
Cholera	Very seldom
SARS	Very seldom
hepatitis A	Very seldom
hepatitis D	Very seldom
hepatitis E	Very seldom
Hepatitis (non component)	Very seldom
Poliomyelitis	Very seldom
Human infection with highly pathogenic avian influenza	Very seldom
measles	Very seldom
epidemic hemorrhagic fever	Very seldom
rabies	Very seldom
Epidemic encephalitis B	Very seldom
Dengue fever	Very seldom
anthrax	Very seldom
Bacillary and amebic dysentery	Very seldom
Typhoid and paratyphoid	Very seldom
Epidemic cerebrospinal meningitis	Very seldom
Pertussis	Very seldom
diphtheria	Very seldom
Tetanus neonatorum	Very seldom
Scarlet fever	Very seldom
Brucellosis	Very seldom
gonorrhea	Very seldom
Leptospirosis of fishing end	Very seldom

schistosomiasis	Very seldom
malaria	Very seldom
Human infection with h7n9 avian influenza	Very seldom
Rubella	Very seldom
Acute hemorrhagic conjunctivitis	Very seldom
Leprosy	Very seldom
Epidemic and endemic typhus	Very seldom
Kala Azar	Very seldom
Echinococcosis	Very seldom
filariasis	Very seldom

As can be seen from the above table, the incidence of Viral hepatitis, Pulmonary tuberculosis, and Hand foot mouth disease is relatively higher than that of other diseases; therefore, for diseases with extremely high incidence, important public hospitals in Sichuan Province can introduce Viral hepatitis, Pulmonary tuberculosis, Hand. The professional doctor of foot mouth disease strengthens the corresponding clinical specialist capacity building; for the disease with moderately high incidence rate, Sichuan public hospitals should introduce relevant professional doctors appropriately; for public diseases with less or little incidence, Sichuan public hospitals can Introduce a small number of relevant professional doctors to ensure that residents are ill. The hospital can be equipped with relevant professional medical staff, medical equipment and drugs according to the proportion of each disease, and use resources reasonably and to meet the medical needs of patients with maximum validity.

6.3 The establishment and solution of the problem three model

6.3.1 Model establishment

According to the problem, referring to the relevant data, combined with the actual factors of this question, this paper uses the $M|M|C$ waiting system queuing model.

First, calculate the average number of times a doctor is responsible for the number of visits per day:

$$Ave = \frac{Num}{Z}$$

Where Z is the total time, Num is the average number of doctors and doctors who are responsible for the daily treatment.

Because the patient's queuing process in the hospital is very complicated, the patient is queued to the hospital: the process (input), service time, service window and queuing rules (for the detailed description of these four steps, see problem three data processing) .

Check the relevant data, generally the random arrival law obeys the Poisson process, the service time is often subject to the negative exponential distribution, and the most basic service window is parallel.

Establish a Poisson distribution for this:

$$P_k(t)=\frac{(\lambda t)^k}{k!}e^{-\lambda t}$$

Where $P_k(t)$ represents the probability of occurrence of k events in a time period of length t.

Establish a negative exponential distribution function:

$$B(t)=1-e^{-\mu t}(t\geq 0)$$

Where μ is a constant and greater than 0, representing the average service rate per unit time.

Then, combine the problem three data processing with the above representation method. Establish a $M|M|C$ waiting system queuing model.

Assuming that C service stations are arranged in parallel and each service station works independently, the average service efficiency is the same, that is $\mu=\mu_1=\mu_2=\ldots=\mu_C$. Therefore, the average service rate is $C\mu$.

In the statistical equilibrium state, the service intensity:

$$\rho=\frac{\lambda}{C\mu}<1$$

At this point, the steady state probability of the system is:

$$P_0=\left[\sum_{k=0}^{C-1}\frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k+\frac{1}{C!}\left(\frac{\lambda}{\mu}\right)^C\frac{C\mu}{C\mu-\lambda}\right]^{-1}$$

$$P_n=\begin{cases}\frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n P_0 & n\leq C\\ \frac{1}{C!C^{n-C}}\left(\frac{\lambda}{\mu}\right)^n P_0 & n\geq C\end{cases}$$

The main indicators for the $M|M|C$ model and their calculation formulas are as follows:

Average queue length(L_q):

$$L_q=\sum_{n=C+1}^{\infty}(n-C)P_n=\frac{(C\rho)^C}{C!(1-\rho)^2}\rho P_0$$

Average queue length(L_s):

$$L_s=L_q+C\rho$$

Average patient stay in the system:

$$W_s=\frac{L_s}{\lambda}$$

The average waiting time for patients in the queue:

$$W_q = \frac{L_q}{\lambda}$$

6.3.2 Model solution

Use Origin software to draw a line chart of the average number of medical treatments for doctors in 2013-2017:

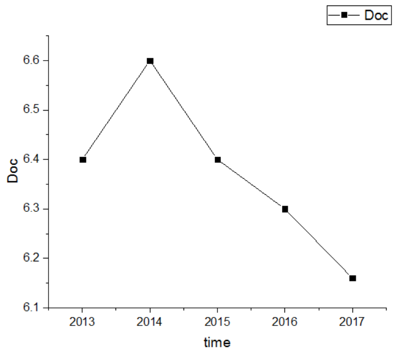

Figure 5 Line chart of patients

Among them, the Doc on behalf of the doctor is responsible for the daily treatment of doctors.

It is also concluded that the average number of times a doctor is responsible for the number of visits per person (number of visits) is 6 (the results are rounded off).

Using Excel software, the two queuing windows are empty, only one queuing window is empty, the patient does not have to wait and the probability that the patient must wait, see the following table:

Table 8 Queuing probability table

Probability of two queuing windows being empty	0.51
The probability that only one queue window is empty	0.38
Probability of patients not having to wait	0.89
The probability that the patient has to wait	0.11

From the above table, it is concluded that the two queuing windows are empty, and only one queuing window is empty, the probability that the patient does not have to wait and the patient must wait is 0.51, 0.38, 0.89, 0.11.

According to Table 8, the average queue length (L_q), the average length of the team (L_s), the average length of stay of the patient in the system, and the average waiting time of the patient in the queue are as follows:

Table 9 Patient queue attribute table

Average queue length (L_q)	0.14 person
Average queue length (L_s)	0.89 person
Average stay time of patients in the system	0.19 hours

Average waiting time of patients in the queue	1.19 hours

As can be seen from the above table, the average cohort length (L_q) is 0.14, the average captain (L_s) is 0.89, the average duration of stay in the system is 0.19 hours, and the average waiting time of the patient in the cohort is 1.19 hours. In the case where the number of queued windows is 2, it is reasonable to wait for the queuing model.

6.4 The establishment and solution of the problem four model

6.4.1 Model establishment

Access to relevant information, in the process of competition and cooperation between public hospitals and private hospitals, the main factors affecting the two profits: drugs, prices and costs. Under normal circumstances, the price changes inversely with the number of patients, establishing the relationship between price and drug supply:

$$p = a - bQ$$

Where p is the price and a,b is the constant

The quantity affects the hospital's profits by affecting the market price. The relationship between establishing hospital profits and costs, and drug sales is:

$$m_i = (p - v_i)\mathrm{Q}_i - F_i$$

Among them, m_i is the profit of i hospital, v_i is the unit variable cost of hospital, Q_i is the drug output of i enterprise, and F_i is the fixed cost of i hospital.

Combined with the assumptions of the model, a multi-objective programming model is established for the income function between hospitals:

$$\max\ m_i = (p - v_i)\mathrm{Q}_i - F_i$$

$$s.t.\begin{cases} p = p(Q) = a - bQ \\ Q = \sum Q_i \\ Q_i \le L \end{cases}$$

Due to the particularity of the multi-objective programming model, this paper solves the solution of the derivative equations and makes the derivative of each hospital's profit to drug yield 0, and calculates and sorts out:

$$\sum bQ_i + bQ_i = a - v_i \qquad (1)$$

$$b\sum Qi = (na - \sum v_i) / (n+1) \qquad (2)$$

$$p = \frac{a + \sum v_i}{n+1} \quad (3)$$

Substituting (3) into (2)-(1) yields:

$$Q_i = \frac{p - v_i}{b} \quad (4)$$

(3), (4) is the production and sales volume and price of the drug under the condition that each hospital is the most profitable, that is, the optimal production and sales volume and the best price.

Since the optimal production and sales volume and the optimal price have nothing to do with the fixed cost of the hospital, the marginal profit is established:

$$m_i = \frac{(\frac{a + \sum v_i}{n+1} - v_i)^2}{b}$$

Because public hospitals and private hospitals belong to the same industry, they conform to the above model. When public hospitals compete with private hospitals, they assume that their unit variable cost v is the same, and the best competitive point is obtained:

$$p_0 = \frac{a + 2v}{3}$$

The best return is:

$$m_1 = m_2 = \frac{(a-v)^2}{9b}$$

When public hospitals cooperate with private hospitals, they pursue their own profits. Therefore, the multi-objective planning is turned into a single-objective planning, and the calculation process of increasing profits is established:

$$\max\,(2m_i) = (p - v)2Q_i$$

$$s.t. \begin{cases} p = a - 2bQ_i \\ Q_i \le L_i \end{cases}$$

For the above single-objective nonlinear programming model, the optimal solution is at the point where the derivative of the objective function is 0, resulting in:

$$P_0 = \frac{a+v}{2}$$

This solution is the best point for cooperation strategies between public hospitals and private hospitals. At this time, the maximum benefits of public hospitals and private hospitals are:

$$m_{1i} = \frac{(a-v)^2}{8b}$$

Compare with competitive hospital revenues:

$$\frac{(a-v)^2}{8b} > \frac{(a-v)^2}{9b}$$

Assume that A (public hospital) implements a cooperative strategy, B (private hospital) to take optimization measures:

$$\max m_B = (p-v)Q_B$$

$$s.t.\begin{cases} p = a - b\dfrac{a-v}{4b-Q_B} \\ Q_B \le L_i \end{cases}$$

At this time, the maximum benefit of B (private hospital) is:

$$m_{22} = \frac{9(a-v)^2}{64b} > \frac{(a-v)^2}{8b}$$

B (private hospital) income is greater than the cooperative strategy income, and the income for A (public hospital) is:

$$m_{21} = \frac{3(a-v)^2}{32b} < \frac{(a-v)^2}{9b}$$

The income of A (public hospital) is not only less than the cooperation strategy, but also less than the competition strategy. In the same way, when B (private hospitals) adopt cooperative decision-making, the benefits of the two of them are exactly the opposite.

6.4.2 Model establishment

According to the above model, the strategy for cooperation and competition between public hospitals and private hospitals is as follows.

If public hospitals and private hospitals cooperate, they can cooperate at the best time (ie, the best cooperation point).

When public hospitals implement cooperation, private hospitals adopt optimized countermeasures, which can make private hospitals outweigh the benefits of cooperation; when private hospitals implement cooperation, public hospitals take optimal measures, which can make public hospitals' income more than cooperative income.

If public hospitals and private hospitals compete, they can compete in the best time (ie, the best competitive point).

This paper combines the establishment of theoretical support, according to the relevant statistical analysis data of the National Bureau of Statistics, to find out the bed workdays, bed occupancy rate, and average hospitalization days of hospital discharges in public hospitals and private hospitals in 2012-2017, and draw a line chart as follows :

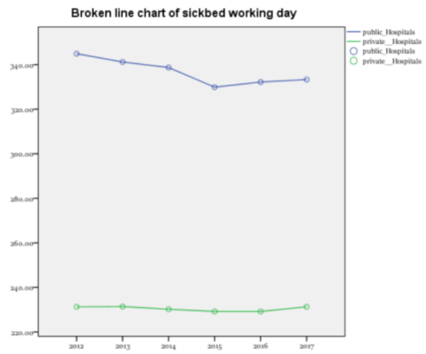

Figure 6 Broken line chart of sickbed working day

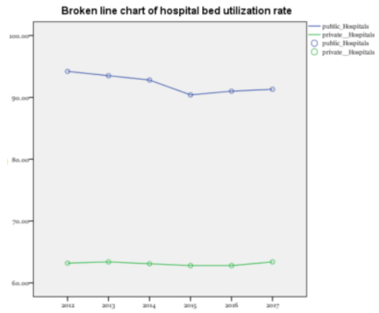

Figure 7 Broken line chart of hospital bed utilization rate

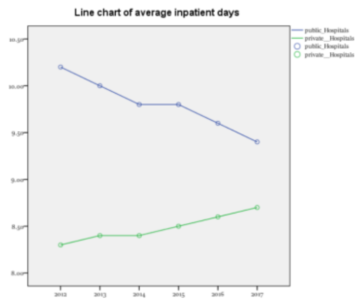

Figure 8 Line chart of average inpatient days

As can be seen from the above figure, the hospital bed days, bed occupancy rates, and average hospitalization days of hospital discharges are generally higher than those of private hospitals, but the hospital bed days, bed use rates, and average hospitalization days of hospital discharges are decreasing year by year in public hospitals. The scale is too small; in general, public hospitals and private hospitals compete with each other, and cooperation is more desirable. In the process of cooperation, not only can the financial burden be reduced, the resources of public hospitals, equipment, scientific research projects and other resource advantages can be used to support the development of private hospitals, but also to provide medical services to people at different levels of demand and increase the effective supply of medical services. The cooperation methods worthy of promotion include: public. The hospital and private hospitals share software and hardware resources, establish internal meetings and two-way referral systems, personnel training, and private hospitals and public hospitals.

6.5.1 Summary Table

Table 10 Summary table

Summary table		
time	2014	2015
Disposable income (unit: yuan)	20167.1	21966.2
Total population (unit: 10000)	136782	137462
Population aged 0-14	22558	22715
Proportion between 0-14 years old	16.5	16.5
Population aged 15-64	100469	100361
15-64 proportion (%)	73.4	73
Population over 65	13755	14386
Proportion over 65 (%)	10.1	10.5
GDP (unit: 100 million yuan)	643974	689052.1
Per capita health expenses (unit: yuan)	2581.66	2980.8
time	2016	2017
Disposable income (unit: yuan)	23821	25973.8
Total population (unit: 10000)	138271	139008
Population aged 0-14	23008	23348
Proportion between 0-14 years old	16.7	16.8
Population aged 15-64	100260	99829
15-64 proportion (%)	72.5	71.8
Population over 65	15003	15831
Proportion over 65 (%)	10.8	11.4
GDP (unit: 100 million yuan)	743585.5	827121.7
Per capita health expenses (unit: yuan)	3351.74	3783.83

6.5.2 proposal

Dear relevant medical department:

With the development of China's economic society and the aging trend, the following suggestions are proposed.

(1) Reforming the performance management system

Although the medical reform has been implemented for many years, many public hospitals are still implementing the performance management system of the “big pot” stage. They have not really achieved distribution according to work, and have not customized detailed performance management systems and indicators according to the hospital's vision and goals. The competition in the medical service market is ultimately the competition of talents. Without a perfect performance management system, it is impossible to implement the indicators to individual employees, and it is impossible to encourage employees to work towards the overall goal of the hospital. By constructing a scientific and reasonable performance appraisal system, it is conducive to promoting employees to improve their enthusiasm and enthusiasm, increase the performance of individuals and hospitals, and thus improve the competitiveness of hospitals and promote sustainable development.

(2) Improve patient experience

According to Deloitte's 2011 China Medical Service Survey, many patients believe that public hospitals have much room for improvement in service quality. 47% of patients believe that public hospital services are not patient-oriented; 32% believe that current public hospital medical services can not meet their needs; 45% of patients believe that treatment waiting time is too long. In order to avoid a large number of patients being diverted, public hospitals must make up for their own shortcomings, truly build a patient-centered service concept, and improve the patient experience in all aspects to maintain their status as a market.

(3) Introduce marketing management and establish a solid and trusting relationship with patients

The medical needs of our people are developing in a multi-level and diversified direction. Marketing management helps public hospitals to break away from the rigid management model, based on the needs of the target population and their own technical strength to carry out market segmentation and market positioning, and provide differentiated services to enhance their competitive strength. In addition, brand promotion in public hospitals is also conducive to enhancing communication with the public, increasing patient retention, expanding public awareness and increasing market share.

(4) Establish standardized medical services and clinical procedures

Medical institutions should design patient-centered, scientifically and rationally designed procedures for streamlining medical services. Based on the patient's needs and using standardized processes, the hospital can coordinate the various services and human resources, promote the organic integration of the work team, reduce the inter-departmental push, improve the patient's treatment effect and maximize the use of medical resources.

(5) From the compensation mechanism should be treated equally

Whether it is a public hospital or a private hospital, the same set of medical quality management system and medical cost control system should be used for homogenization management, as long as it can provide lower cost, better efficacy and service, from medical insurance and other policies. Should be treated equally. The proportion of government procurement services should be increased. In particular, the introduction of hospital performance evaluation, reputation mechanism and purchase service compensation, allowing consumers to vote with their feet, the patient's recognition and satisfaction as an important support for compensation.

(6) Further loosening from market access

In recent years, favorable policies have simplified the optimization of examination and approval services and lowered the standards and thresholds for social medical treatment. However, it is still very difficult for some local governments to practice medical treatment. For example, in the practice of examination and approval of licenses, many places to apply for medical institutions to practice licenses need to obtain land use approval in advance, and the application for sanitary land needs to obtain a medical institution license. The time cost of self-built hospitals is less than half a year, and it takes five to six years to increase the burden and cost of running a doctor. In addition, in terms of procedures such as fire protection, environmental assessment, and civil air defense, there are problems such as opaque information.

7. Model evaluation and improvement

7.1 Advantages of the model

7.1.1 advantage

(1) The calculation of the model uses professional mathematical software with high credibility;

(2) Using the regression model, as long as the model and data used are the same, the only results can be calculated by standard statistical methods;

(3) Using cluster analysis, the principle is relatively simple, and the implementation is also very easy, and the convergence speed is fast.

7.1.2 Disadvantage

This paper analyzes the problem based on the model preparation, which may cause slight deviation of the model.

7.2 Model improvement

Finally, the model proposed in the paper is deeply studied and analyzed, and some improvement ideas are provided for the optimization of the model.

In the process of building the model, considering the state of too ideal, ignoring the characteristics of the model itself, due to the lack of theoretical knowledge, ignoring the impact of the error on the model, and the actual model is different, so that the result is not the most perfect. Now the model is improved. Considering the factors affecting the interests between public hospitals and private hospitals in the fourth model is drug, price and cost. Because of the less influential factors, the model error will be larger. Increasing the influencing factors makes the error smaller and more practical; for this, corresponding improvements should be made.

8. Model promotion

With the rapid development of China's economy and society and the aging trend, the demand for hospital health services is increasing. At the same time, with the acceleration of industrialization and urbanization, ecological security and food safety face different levels of challenges. These comprehensive developments have also brought a series of new challenges to health care. This paper mainly establishes multiple regression models, K-Means clustering algorithm model, M|M|C queuing model, multi-objective programming model, and its strategic plan. It has extremely high application ability and can be extended to the financial industry. Requirements, refer to the mathematical model established in this paper, and develop corresponding plans.

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