Team Control Number

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Problem Chosen

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Summary

With the rapid development of China's economy and society and the intensification of the aging trend, the demand for hospital health services continues to grow, and the overall improvement of hospitals faces a series of new challenges.In response to this practical problem, this paper collects relevant data, establishes a targeted mathematical model, and gives corresponding suggestions based on the results of the model calculation.

For question 1, firstly, the index data of residents' income, population age, total health cost and gross domestic product are collected through reference data, and the GM(1.1) model is used to predict the ratio of the 65-year-old population aged 2019-2030. Trend graph; Secondly, using MTLAB software to analyze the collected total health expenditure, number of patients and other indicators, predicting the medical needs of residents, and based on the total cost of health, the trend of medical institutions, the trend of aging and residents in China The medical demand is increasing year by year. Finally, in order to ensure the accuracy of the model, the gray prediction model is used to compare the simulated data of 2017 and 2018 with the actual value, and the average relative error is <5%, which is the accuracy of the model fitting. More than 95%, the prediction effect is significant.

For question 2, first of all, taking Beijing as an example, collect data on the types and prevalence of diseases in Beijing from 2012 to 2017, and standardize the data.Secondly, using the entropy weight method to analyze the weights and scores of common diseases in the future, and obtain the final scores of the top 6 diseases in various diseases, showing that malignant tumors, heart disease, cerebrovascular disease, respiratory diseases, injuries and poisoning are the Common diseases in the city.Finally, combined with the results of data analysis, it provides feasible suggestions for the structural adjustment of public hospitals in Beijing.

For problem 3, first of all, problem 3 is essentially a queuing problem. Using the relevant knowledge of queuing theory, the model is further optimized to find the optimal queuing scheme.Secondly, the problem 3 is that the multiple patients correspond to the queue queue of the project, and the M|M|n random service queuing model of the multi-queue multi-window with waiting system is established.Finally, full consideration of various factors, combined with multi-project queuing window services for analysis, to provide the best queuing strategy for hospitals.

For problem 4, firstly, the data envelopment method is combined with the game theory to comprehensively evaluate the hospital's operational efficiency. Secondly, the input and output data of 14 hospitals in Inner Mongolia are selected, and the data envelope based on game theory is used. The analysis model conducts an in-depth analysis of cooperation and competition among hospitals, and obtains the classification of partners in different competition forms. Finally, combined with the results of data analysis, the best cooperation and competition among multiple hospitals is proposed. Strategy.

According to the problem of question 5, based on the analysis results of questions 1-4, taking into account the increasingly serious population aging, the increasing medical needs of residents, the distribution of some common diseases, and the inefficiency of hospital management, The hospital's medical construction development put forward five suggestions to provide suggestions and references for the decision-making department to formulate the "14th Five-Year Plan".

***K**ey word: data envelopment DEA model; grey prediction model; entropy weight method; queuing model; game theory

Content

1. Introduction

1.1 Background

China, which has one-fifth of the world's population, has experienced rapid economic development for more than two decades since the reform and opening up. People's demand for medical and health services is growing, making the health care industry increasingly important in the domestic economy. increase.With the healthy development of China's social economy and the trend of population aging, and with the rapid industrialization and urbanization development process, ecological and food safety face different levels of challenges.These developments place higher demands on health care and the overall level of the hospital.

In the highly competitive medical market environment, the change in the concept of medical treatment for patients, the rapid growth of medical needs and the diversification of development 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, meeting the residents' medical needs and improving the residents' demand for hospitals is the main direction of their efforts.For private hospitals, their efforts are to meet the peak needs of public hospitals and the treatment needs of special diseases.

Task 1: According to the relevant statistics of the National Bureau of Statistics and other data, analyze the data of residents' income, population age structure and economic development level in the data, and combine these statistics to reasonably predict the future aging of China by establishing a model or other methods. Trends and medical needs of residents.

Task 2: Take a province in our country as an example, according to the relevant statistics of the National Bureau of Statistics and other data, analyze the disease composition of a certain province, and rank the top diseases.Using some method to analyze the most common diseases in the province in the future, and provide suggestions for the overall development of the health services of key public hospitals in the province, the health resources input of various departments, and human resources input.

Task 3: During the hospital queuing check, different types of patients may need to perform different tests in the hospital; different inspection items are distributed in different departments, and there may be a large gap in the number of people in the column.A general queuing theory and its related optimal queuing method are proposed for the hospital for this queuing problem.

Task 4: Faced with a fierce competitive environment in the medical market, the number of private hospitals continues to increase.Considering the complex cooperation and competition between private hospitals and public hospitals, please propose the best cooperation and competition strategy among many hospitals, so that private hospitals and public hospitals can realize the maximum benefits together.

Task 5: With the overall development and a series of new challenges, with regard to the overall improvement of the hospital, combined with the development of these situations and problems, the 1-2 pages of the “fourteen five-year plan” recommendations for the relevant medical management departments The book provides a reference.

1.2 Work

Combine relevant indicators to establish an ageing and resident medical demand forecasting model, and use MATLAB to predict the trend of aging and the medical needs of residents. Take a province as an example, collect relevant data, qualitatively describe the distribution characteristics of the disease, and secondly, in order to achieve The optimal configuration of queuing, establish a queuing model and further optimize the model. Further consider the cooperation and competition between private hospitals and public hospitals, and use game theory to fully realize the optimal cooperation and competition strategy.

2. Problem analysis

2.1 Data analysis

First, through the China Statistical Yearbook, data on the total population at the end of the year from 1999 to 2018 and the age of 65 years old were collected to find out the proportion of the elderly, and the proportion of the elderly was increasing year by year.Second, through the collected total health expenditure, medical and health institutions and other data, it is found that the number of patients in the treatment is fluctuating, and the health needs of residents are increasing year by year.Third, through the collection of data on various diseases in Beijing, it can be seen that several diseases account for a large proportion of all diseases in each year.Finally, through the input and output data of 14 hospitals in Inner Mongolia, there is a certain gap between major hospitals.

2.2 Analysis of question one

According to the relevant data of the National Bureau of Statistics, we can reasonably predict China's aging trend and the medical needs of residents. For Question 1, after accessing data and statistics, China's aging trend and the medical needs of residents are increasing. The problem is divided into two parts. To analyze: First, predict the proportion of 65-year-olds in 2019-2030 through the gray prediction model to predict the aging trend in China. Secondly, the total health expenditure and the number of patients collected will be substituted into the matalb gray prediction model. The forecast curve of residents' medical needs increased with time. In order to ensure the reliability of the data, the gray prediction model is used to predict the data in 2017 and 2018, and compare with the actual values.

2.3 Analysis of question two

Question 2 requires analysis of the most common diseases in a province in the future and recommendations for the overall development of key public hospitals across the province.For question 2, through discussion and analysis, we selected Beijing as an analysis city.By collecting the disease data of Beijing in recent years, we use the entropy weight method to analyze the weights and scores of common diseases in the future, and by standardizing the data and further calculating the weights, we can get the final scores of various diseases and analyze the city's The most common disease in the future.Based on this, through the province's disease composition, the relevant public hospitals in the province made relevant and reasonable recommendations.

2.4 Analysis of question three

Question 3 requires that different inspections of different types of patients in the hospital may require queues at different locations, and the number of people queued at different locations may vary widely.A common queuing theory and its related optimal queuing scheme are proposed for this problem.For question 3, it is essentially a queuing problem.We decided to use the relevant knowledge of queuing theory and further optimize the model to find the optimal queuing scheme.Through discussion and analysis, the problem belongs to multiple patient queuing queues corresponding to multiple projects, so the multi-project queuing window service constitutes a waiting multi-queue multi-window random service queuing system.Find the best queuing solution by building a model analysis.

2.5 Analysis of question four

Question 4 combines the complex cooperative competition between private hospitals and public hospitals, and proposes the best cooperation and competition strategy among many hospitals.For question 4, through discussion and analysis, we build a game model based on the data envelope to analyze. Many real game problems may have more than one subject with decision-making power, so we need to explore the decision-making under multi-player cooperative game conditions. The choice of unit partners and optimal strategies.Using this as a model, we will further explore the cooperation and competition between private hospitals and public hospitals and propose strategies.

3. Symbol and Assumptions

3. 1 Symbol Description

symbol	Description
$p(k)$	Level ratio of series
$X^{(0)}$	sequence
$\varepsilon(k)$	Residual
$\frac{1}{u}$	Average service rate
u	Average service rate per unit time
$p_n(t)$	n patients in the system at any time t
L_s	Average captain
L_p	Average queue length
λ	Average patient arrival rate
μ	Parameter is μ Negative exponential distribution
ρ	Service intensity
t_i	Patient arrival time interval
$t_{i,m+1}$	The return time of the m+1th patient queuing channel system prompt
T_i	Time to accept queuing service
T_w	Hospital opening hours
$c_{1(t)}, c_{2(t)}$	Weight function for time
L_k	Average number of patients in the kth department
r_k	Waiting ratio of the kth department
$L_{k,i}$	Average waiting number of the kth department
$t_{1,i}$	The i-th patient arrives at the hospital with a reminder return time

3.2 Fundamental assumptions

3.2.1 Assume that the collected data is accurate and can effectively reflect the problem

3.2.2 Assume that the change in total health expenditure meets the law of index change

3.2.3 Suppose the actual situation is the same as the model

3.2.4 Assume that each patient's service time on each service platform must be

3.2.5 Assume that the influencing factors are independent of each other

4. Model

With the rapid development of the economy and society, the continuous improvement of the medical level, the phenomenon of aging is becoming more and more serious. By collecting and analyzing the data of residents' income, population age structure and economic development level, a grey prediction model is established to reasonably predict China's aging and Medical needs of residents.

Step 1: Check and process the data, and set the original data as

$$X^{(0)}=\left(X^{0}(1), X^{0}(2),\dots, X^{0}(\mathrm{n})\right)$$

Calculate the rank ratio of the series

$$p(k)=\frac{x^{(0)}(k-1)}{x^{(0)}(k)}, k=2,3,\dots,n$$

If the ratio falls within the allowable range

$$X=\left(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}}\right)$$

Then the sequence x(0) can establish the GM (1.1) model for gray prediction, otherwise the translation exchange is performed, and the constant C is obtained.

$$y^{(0)}(k)=x^{(0)}(k)+C, k=1,2,\dots n$$

The grade ratios are all within the tolerance range.

Step 2: Establish a GM(1.1) model. If the original data column meets the requirements, build a GM(1.1) model based on the data.

$$x^{(0)}(k)+az^{(1)}(k)=b$$

The regression analysis is used to obtain the estimated values of a and b, and the corresponding whitening model is obtained.

$$\frac{dx^{(1)}t}{dt}+ax^{(1)}(t)=b$$

Solution

$$x^{(1)}(t)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(t-1)}+\frac{b}{a}$$

Then get the predicted value

$$\hat{x}^{(1)}(k+1)=(x^{(0)}(1)-\frac{b}{a})e^{-ak}+\frac{b}{a},k=1,2,...,n-1$$

Obtaining the predicted value accordingly

$$\hat{x}^{(0)}(k+1)=(x^{(1)}(k+1)-x^{(1)}(k)),k=1,2,...,n-1.$$

Step 3: Test the predicted value and calculate the corresponding residual

$$\varepsilon(k)=\frac{x^{(0)}(k)-\hat{x}^{(0)}(k)}{x^{(0)}(k)},k=1,2,...,n$$

If for all

$$|\varepsilon(k)|\le 0.1$$

It is considered that a higher requirement is met;
If for all

$$|\varepsilon(k)|\le 0.2$$

Think that the general requirements are met
The ageing trend was analyzed through the statistical yearbook to collect population, population mortality, and total health costs for people aged 65 and over from 1999 to 2017.

Table 4.1 Analysis of the influencing factors of ageing trends

	B	Standard error	Beta	T	P
constant	1947.448	3.399		572.889	0.000
Population aged 65 and over (10,000 people)	0.004	0	1.722	9.22	0.000
Mortal mortality	2.286	0.718	0.132	3.182	0.006
Total health expenditure	0	0	-0.859	-5.22	0.000

From Table 4.1, it can be seen that the population aged 65 and over and the total health expenditure significantly affected aging ($p<0.05$), so the population over 65 years old was selected for research.

Table 4.2 Grey forecast of the proportion of 65-year-olds aged 2019-2030

years	Predicting the proportion of 65-year-olds (%)
2019	0.1199
2020	0.1239
2021	0.128
2022	0.1323
2023	0.1366
2024	0.1412
2025	0.1458
2026	0.1507

2027	0.1557
2028	0.1608
2029	0.1661
2030	0.1716

Table 4.2 The proportion of 65-year-olds aged 2019-2030 predicted by the gray prediction model shows that the proportion of elderly people in China is increasing year by year and will reach a peak of 17.16% in 2030, further indicating that China's aging trend is becoming more obvious. .

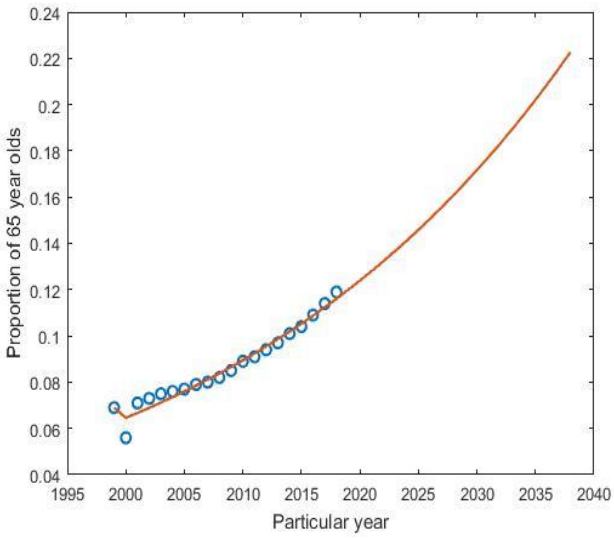

Figure 4.1 Grey forecast of the development trend of 65-year-olds aged 2019-2030

The total health expenditure and the number of medical treatments collected in the matalb gray prediction model are obtained as shown in Figure 4-1 and Figure 4-2.

Table 4.3 Gray forecasted number of hospitals in 2018-2027

years	Hospital treatment
2018	88.3
2019	92.58
2020	97.07
2021	101.77
2022	106.71
2023	111.88
2024	117.31
2025	123
2026	128.96
2027	135.22

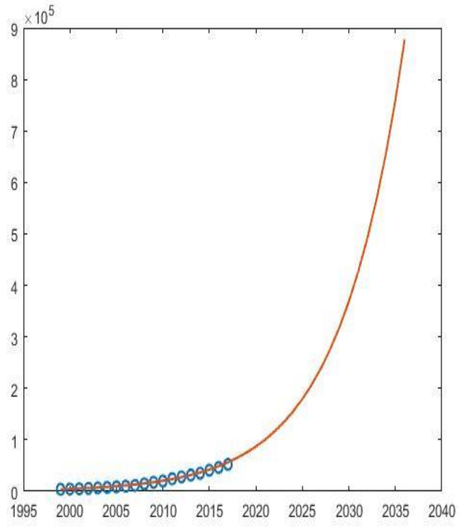

Figure 4.2 Gray prediction curve of total health expenditure

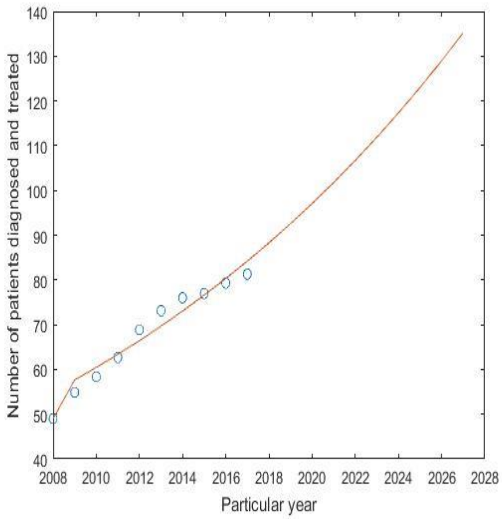

Figure 4.3 Gray curve of the number of patients

From the above two figures, it can be seen that the total health expenditure and the number of medical treatments are increasing year by year. These two indicators further illustrate the strong willingness of residents to have medical needs.The main reason for the increasing demand for health services is that various common diseases are becoming more and more serious. Taking Beijing as an example, we collect data on the disease in Beijing in recent years, and use the entropy method to analyze the weights and scores of common diseases in the future. Diseases such as malignant tumors, heart disease, cerebrovascular disease, respiratory diseases, injuries and poisoning are common diseases in the city.

Entropy weight method assignment step

Standardize the data of each indicator. Assume that k indicators are given.$x_1, x_2, \dots x_k$,among them $x_i = \{x_{1,} x_2 \dots x_n\}$.

Assume that the value of each indicator data is normalized

$$y_1, y_2 \dots, y_k,$$

Then

$$y_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)}.$$

Find the information entropy of each indicator

Information entropy of a set of data according to the definition of information entropy in information theory

$$E_j = -\ln(n)^{-1} \sum_{i=1}^{n} p_{ij} \ln p_{ij}$$

among them

$$P_{ij}=\frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}}$$

,

in case

$$P_{ij}=0$$

,

Then define

$$\lim_{p_{\pi}=0} P_{ij} \ln P_{ij}=0$$

Determine the weight of each indicator

According to the calculation formula of information entropy, the information entropy of each index is calculated as

$$E_1, E_2, \ldots. E_k$$

Calculate the weight of each indicator by the above formula:

$$W_t=\frac{1-E_i}{k-\sum E_i}(i=1,2,\ldots.,k)$$

Score by weight

$$Z_i=\sum_{i=1}^{n} X_{E_i} W_i$$

Table 4.4 Entropy weight method to get the final score of various diseases

Type of disease	Score
Malignant tumor	63.86724541
heart disease	60.66815384
Cerebrovascular disease	47.90446546
Respiratory diseases	23.33637489
Injury and poisoning	8.848695286
Endocrine, nutrition, metabolism	7.182211322
Digestive diseases	6.092155224
Nervous system disease	2.928658257
Genitourinary system disease	1.968845871
infectious disease	1.696598663

By standardizing the data and further calculating the weights, the final scores of various diseases can be obtained. From the scores, it can be seen that malignant tumors, heart disease, cerebrovascular diseases, respiratory diseases, etc. are common diseases in Beijing, and public hospitals are structured. The adjustment should focus on the construction of departments and disciplines in this area, and appropriately expand the scale to meet the medical needs of residents.

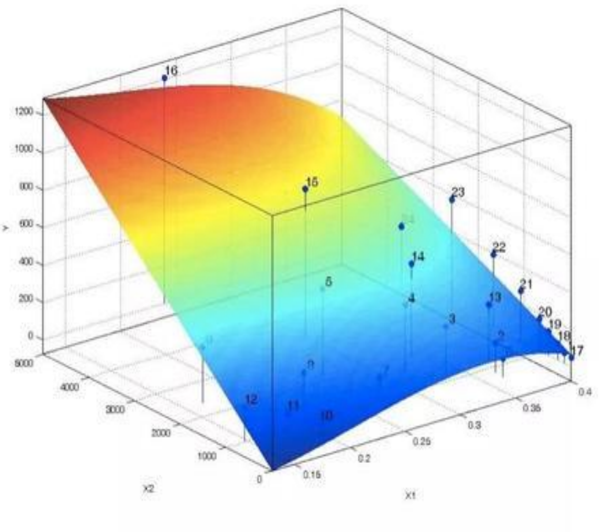

Figure 4.4 Thermal imaging map of major diseases

When the hospital needs to diagnose and treat these common diseases, it will face the problem in Task 3. Different patients need different tests. Different tests are distributed in different locations, and the number of people in different queues is different. Fully consider various factors to establish a general queuing model and further explore the optimal queuing method.This study is essentially a queuing problem, and the design iDEAs can be expressed in the following mathematical models:

Since multiple names correspond to multiple item queuing queues, the multi-item queuing window service constitutes a waiting multi-queue multi-window M/M/n random service queuing system.Average queue waiting time:

$$E_w = \rho / (\mu - \lambda)$$

Average waiting time:

$$W_q = \frac{L_q}{\lambda} = \frac{\rho}{\mu(1-\rho)} = \frac{\lambda}{\mu(\mu-\lambda)}$$

Average waiting for the captain:

$$E_{qw} = \rho^2 / (1-\rho)$$

Waiting time distribution at time t:

$$W(x) = \begin{cases} 1-\rho * \exp(-(\mu-\lambda)x), (x \geq 0) \\ 0, (x < 0) \end{cases}$$

Average length of stay:

$$d_q = \frac{L}{\lambda} = \frac{\rho}{\lambda(1-\rho)} = \frac{1}{\mu-\lambda}$$

The first optimization objective function:

$$Z = \min\{c_1(t)t_1 + c_2(t)t_{2,i}\}$$

The second objective function:

$$\min\{\sum_{i\neq j}\sum_{j=1}\left|r_i - r_j\right|^2\}$$

Target constraints:

$$t_{1,i} \geq \sum_{j=1}^{i-n_0} t_j + t_{2.,i-n_0} + \overline{t} + t_{0,i}$$

The number of visitors that can be accommodated at t:

$$N_{(t)} = N_{(0)} - X_{1(t)} - X_{2(t)} + X'_{1(t)} + X'_{2(t)}$$

There is always a complex cooperation and competition between private hospitals and public hospitals. We build a game model based on the data envelope, assuming n Dmu, each dmu has m Input and s Kind of output, DMU_i Input and output vector is $(\boldsymbol{X}_i, \boldsymbol{Y}_i)$, among them $\boldsymbol{X}_i = (x_{1i}, x_{2i}, \cdots, x_{mi})^{\mathrm{T}}, \boldsymbol{Y}_i = (y_{1i}, y_{2i}, \cdots, y_{si})^{\mathrm{T}}$, the output indicator weight is $\boldsymbol{\mu} = (\mu_1, \mu_2, \cdots, \mu_s)^{\mathrm{T}}$, input indicator weight is $\boldsymbol{\omega} = (\omega_1, \omega_2, \cdots, \omega_m)^{\mathrm{T}}$.

There may be more than one subject with decision-making power in many realistic game problems. The following is a further discussion of the decision-making unit partners and the optimal strategy selection under multi-player cooperative game conditions. The structural relationship of cooperation, competitors, and neutral dmu is shown in Figure 4.5. Shown.

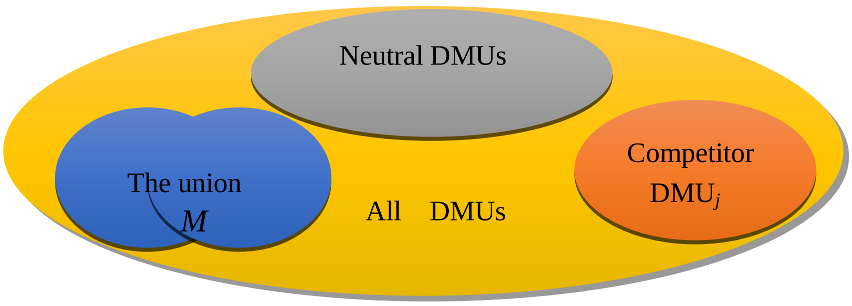

Figure 4.5 Structure of cooperation, competitors, and neutral dmu
Figure 4.5 The structure chart of the union, competitor, and neutral DMUs

The following main considerations are when multiple decision-making units form a cooperation with decision-making power, and in the case of the most efficient cooperation, the collaborators select the appropriate weights to make the competitor's efficiency value as low as possible.

Let m be the subscript set that forms the cooperative decision unit, $M \subseteq I$, then have the following model.

$$P^{I}_{GAME\text{-}CD6}\begin{cases} E_M = \max \boldsymbol{\mu}^{T}(\sum_{i\in M}\boldsymbol{Y}_i), \\ \text{s.t. } \boldsymbol{\omega}^{T}\boldsymbol{X}_s - \boldsymbol{\mu}^{T}\boldsymbol{Y}_s \geqq 0,\ s\in I\setminus M, \\ \quad \boldsymbol{\omega}^{T}(\sum_{i\in M}\boldsymbol{X}_i) - \boldsymbol{\mu}^{T}(\sum_{i\in M}\boldsymbol{Y}_i) \geqq 0, \\ \quad \boldsymbol{\omega}^{T}(\sum_{i\in M}\boldsymbol{X}_i) = 1, \\ \quad \boldsymbol{\omega}\geqq\boldsymbol{0}, \boldsymbol{\mu}\geqq\boldsymbol{0}. \end{cases}$$

among them, E_M Is the efficiency of cooperation m.

After forming cooperation m, application $P^{I}_{GAME\text{-}CD6}$ The model can calculate the efficiency of other non-cooperative members DMUj $\tilde{E}_j$, $j\in I\setminus M$ The cooperation with decision-making power m is the most unfavorable weight model for dmu$_j$ under the condition that the cooperation efficiency is unchanged.

$$P^{I}_{GAME\text{-}CD7}\begin{cases} E_{j(M)} = \min \boldsymbol{\mu}^{T}\boldsymbol{Y}_j, \\ \text{s.t. } \boldsymbol{\omega}^{T}\boldsymbol{X}_s - \boldsymbol{\mu}^{T}\boldsymbol{Y}_s \geqq 0,\ s\in I\setminus M, \\ \quad \boldsymbol{\omega}^{T}\boldsymbol{X}_j = 1, \\ \quad \boldsymbol{\mu}^{T}(\sum_{i\in M}\boldsymbol{Y}_i)_i - E_i\boldsymbol{\omega}^{T}(\sum_{i\in M}\boldsymbol{X}_i) \geqq 0, \\ \quad \boldsymbol{\omega}\geqq\boldsymbol{0}, \boldsymbol{\mu}\geqq\boldsymbol{0}. \end{cases}$$

If $E_{j(M)}$ Yes $P^{I}_{GAME\text{-}CD7}$ The optimal solution of the model,

$$hit_{j(M)} = \tilde{E}_j - E_{j(M)}$$

For cooperation M Competition against competitor dmu$_j$.

In cooperation M Under the condition of having decision-making power, non-cooperative member dmu$_j$, $j\in I\setminus M$ Finding the best partner among non-cooperative members can be determined by the following model.

$$P^{I}_{GAME\text{-}CD8}\begin{cases} E^{M}_{j\bar{k}} = \max_{k\in I\setminus(M\cup\{j\})} \min_{\omega,\mu} \boldsymbol{\mu}^{T}(\boldsymbol{Y}_j+\boldsymbol{Y}_k), \\ \text{s.t. } \boldsymbol{\omega}^{T}\boldsymbol{X}_s - \boldsymbol{\mu}^{T}\boldsymbol{Y}_s \geqq 0,\ s\in I\setminus(M\cup\{j,k\}), \\ \quad \boldsymbol{\omega}^{T}(\boldsymbol{X}_j+\boldsymbol{X}_k) - \boldsymbol{\mu}^{T}(\boldsymbol{Y}_j+\boldsymbol{Y}_k) \geqq 0, \\ \quad \boldsymbol{\omega}^{T}(\boldsymbol{X}_j+\boldsymbol{X}_k) = 1, \\ \quad \boldsymbol{\mu}^{T}(\sum_{i\in M}\boldsymbol{Y}_i)_i - E_M\boldsymbol{\omega}^{T}(\sum_{i\in M}\boldsymbol{X}_i) \geqq 0, \\ \quad \boldsymbol{\omega}\geqq\boldsymbol{0}, \boldsymbol{\mu}\geqq\boldsymbol{0}. \end{cases}$$

Assume $E^{M}_{j\bar{k}}$ for $P^{I}_{GAME\text{-}CD8}$ The optimal solution of the model, called dmu $_{\bar{k}}$ The best anti-stress partner for dmu$_j$.

In cooperation M With the right to make decisions, dmu$_j$ can find the best partner, but the other party may not be willing to cooperate with it. M Under the condition of having decision-making power, the willingness of other non-cooperative units to cooperate with dmu$_j$ can be given by the following model.

$$
P^{I}_{GAME\text{-}CD9}\begin{cases} E_{jk}^{M} = \min \boldsymbol{\mu}^{T}(\boldsymbol{Y}_j + \boldsymbol{Y}_k), \\ s.t.\ \boldsymbol{\omega}^{T}\boldsymbol{X}_s - \boldsymbol{\mu}^{T}\boldsymbol{Y}_s \geqq 0,\ s \in I \setminus (M \cup \{j,k\}), \\ \boldsymbol{\omega}^{T}(\boldsymbol{X}_j + \boldsymbol{X}_k) - \boldsymbol{\mu}^{T}(\boldsymbol{Y}_j + \boldsymbol{Y}_k) \geqq 0, \\ \boldsymbol{\omega}^{T}(\boldsymbol{X}_j + \boldsymbol{X}_k) = 1, \\ \boldsymbol{\mu}^{T}(\sum_{i\in M} \boldsymbol{Y}_i)_i - E_M \boldsymbol{\omega}^{T}(\sum_{i\in M} \boldsymbol{X}_i) \geqq 0, \\ \boldsymbol{\omega} \geqq \boldsymbol{0}, \boldsymbol{\mu} \geqq \boldsymbol{0}. \end{cases}
$$

(1) If $E_{jk}^{M} \geqq E_{j(M)}, E_{jk}^{M} \geqq E_{k(M)}, 2E_{jk}^{M} > E_{j(M)} + E_{k(M)}$, called dmu$_k$ as a priority partner of dmu$_j$.

(2) If $\max\{E_{j(M)}, E_{k(M)}\} \geqq E_{jk}^{M} \geqq (E_{j(M)} + E_{k(M)})/2$, called dmu$_k$ as a potential partner of dmu$_j$.

(3) If $E_{jk}^{M} < (E_{j(M)} + E_{k(M)})/2$, called dmu$_k$ and dmu$_j$ have a competitive relationship.

With the continuous development of the economy, the people's living standards and health levels are constantly improving, and the population structure and the health needs of disease structures are constantly changing, which puts higher requirements on hospital development and hospital construction.Therefore we have made the following recommendations:

The future development of the hospital should pay attention to the health problems of the elderly, and more inclined to develop the elderly service industry.China should combine the trend of aging and pay attention to the impact of the elderly population on health care consumption expenditure.Through the gray forecast, it is obvious that China's aging trend and the medical needs of residents are increasing year by year.Therefore, we need to pay attention to the health problems of the elderly. In the future, we will tend to develop the elderly service industry. We will accelerate the training of professionals in the medical care service and promote the healthy development of the market for medical care.

Hospitals should plan the technical input and development of hospitals from the disease composition of the region.This requires hospital decision-makers to be based on medical needs and to strengthen the technical expertise of specialized departments to treat these diseases.According to the needs, the bed and staffing should be adjusted reasonably to meet the needs of people's health care.In order to continuously develop in the social competition, hospitals must plan the technology investment and development of hospitals from the changes in medical needs. In the case of maintaining the original specialty advantages, the scope of services will be broadened, and the hospitals will be transformed from traditional medical services to prevention. Community-based service hospitals for health care, rehabilitation, and medical care.

The hospital should optimize the entire treatment process to create a comfortable waiting environment.This will greatly save patient time and maximize efficiency.Patients can be provided with a comfortable waiting environment by providing some free magazines or brochures on health knowledge in the area the patient is waiting for.This will not only avoid a great impact on hospital operating expenses, but also reduce patient dissatisfaction to some extent.When people are idle, they will feel that the waiting time becomes extraordinarily long. Due to the uncertainty of this waiting, the length of people's perception of waiting time is prolonged.Therefore, the hospital staff needs to make a statistical estimate of the length of the queue waiting time, and let the patient know if necessary, which can shorten the length of time the patient perceives unknown time.

Competition and coordinated development of private hospitals and public hospitals should be promoted.Since the management level of private hospitals and public hospitals is directly proportional to their distribution coefficient of interest in the medical service market, and is proportional to the contribution coefficient of the medical service market, we can form an effective coordination mechanism by setting up an information collaboration platform; To establish collaborative performance evaluation; improve medical innovation capabilities, promote sustainable and coordinated development, and promote cooperation between private hospitals and public hospitals.With the continuous development of the society and the demand of the market, the scale of the private hospitals has grown steadily, and the proportion of private hospitals in China's medical service system has also increased, which has brought great challenges to public hospitals.In the face of challenges, public hospitals should focus on their weaknesses in the process of reform, accelerate the recruitment of shortcomings, and improve their sustained and good development capabilities.

In short, under the "Fourth Five-Year Plan" plan, we will continue to improve the overall level of hospitals and meet the growing demand for health services.

5.Test the Models

In the model processing of task 1, the gray prediction model is used to predict the data in 2017 and 2018, and the actual value is compared, and the average relative error is <5%, that is, the accuracy of the model fitting is greater than 95%, and the prediction effect is significant.

Table 5.1Comparison of predicted and actual values

years	Actual value	Predictive value	Difference	Average relative error (%)
2017	0.1139	0.1124	0.0015	1.32
2018	0.1194	0.1161	0.0033	2.76

The names and corresponding numbers of 14 hospitals in Inner Mongolia are given in Table 4.6.

Numbering	hospital name
H1	Inner Mongolia Medical University Affiliated Hospital
H2	Inner Mongolia Autonomous Region Hospital
H3	The Second Affiliated Hospital of Inner Mongolia Medical University

H4	Inner Mongolia International Mongolian Medical Hospital
H5	Inner Mongolia Autonomous Region Chinese Medicine Hospital
H6	Inner Mongolia Autonomous Region Maternal and Child Health Hospital
H7	Baotou Central Hospital
H8	Inner Mongolia Baogang Hospital
H9	Baotou Hospital First Affiliated Hospital
H10	Baotou City Mongolian Medicine Chinese Medicine Hospital
H11	Chifeng City Hospital
H12	Inner Mongolia University for Nationalities
H13	Ordos City Center Hospital
H14	Inner Mongolia Forestry General Hospital

The input and output data of 14 hospitals in Inner Mongolia are given in Table 5.2. The data envelopment analysis method based on game theory established in Task 4 provides cooperation and competition between hospitals.

Table5.2Input-output data of 14 hospitals in Inner Mongolia

Hospital number	Total number of employees (person)	Total number of beds (张)	Fixed assets (hundred yuan)	Total expenditure (thousand yuan)	Annual emergency volume (thousands)	Number of discharged patients (100 people)	Total revenue (thousand yuan)
H_1	2806	2561	8500	1910	1474	800	1939
H_2	4258	2639	9380	1657	1520	770	1670
H_3	423	400	900	365	90	100	390
H_4	570	1174	5570	406	557	200	420
H_5	561	511	590	285	286	110	246
H_6	852	370	600	267	459	160	270
H_7	1821	1416	5590	789	510	390	846
H_8	1930	1500	5650	670	910	360	600
H_9	2322	1455	4640	850	552	470	908
H_{10}	835	649	960	228	165	110	228
H_{11}	1914	1962	8740	1124	890	600	1204
H_{12}	1475	770	1580	463	428	270	515
H_{13}	1859	1200	5500	763	954	380	790
H_{14}	1599	1077	1800	466	299	240	448

The following is a further discussion of decision-making unit cooperation and competition based on efficiency game.

First, the data analysis results of 14 hospitals based on game theory are given in Table 5.3.

Table 5.3Data analysis results of 14 hospitals

Hospital number	Efficiency value	Average competition	Anti-competitive ability	Sort	Strongest competitor
H_1	1.0000	0.2269	0.7731	2	6
H_2	0.9357	0.2425	0.6931	10	6
H_3	1.0000	0.3132	0.6868	11	6
H_4	1.0000	0.2802	0.7198	6	6
H_5	1.0000	0.2993	0.7007	8	6
H_6	1.0000	0.1607	0.8393	1	3
H_7	0.9832	0.2843	0.6989	9	6
H_8	0.9175	0.2658	0.6517	12	6
H_9	0.9729	0.2538	0.7192	7	6
H_{10}	0.8990	0.2914	0.6076	14	4
H_{11}	1.0000	0.2282	0.7718	3	6
H_{12}	1.0000	0.2288	0.7712	4	4
H_{13}	0.9949	0.2636	0.7314	5	6
H_{14}	0.8788	0.2567	0.6220	13	4

Secondly, the results of the classification of partners in different competitions are further analyzed. Table 4.6 shows the results of partner classification under the joint competition of h1 and h1 and h13.

Table 5.4 Optimal partner and partner classification of decision-making units under h1, h1 and h13 joint competition

Table 5.5 Best partners and partner classification under the strike of H_1, and the union of H_1 and H_{13}

	h_1 under competition		h_1 and h_{13} under the joint competition	
Hospital number	Optimal partner	Partner classification	Optimal partner	Partner classification
H_1	---	---	---	---
H_2	11	(3, 4, 7, 12), (8, 9, 10, 11, 14), (2, 5, 6, 13)	11	(-), (5, 7, 8, 9, 10, 14)(2, 3, 4, 6, 11, 12)
H_3	11	(4, 5, 6, 11, 12, 13), (7), (2, 3, 8, 9, 10, 14)	6	(11), (5, 6, 1), (2, 3, 4, 7, 8, 9, 12, 14)
H_4	11	(2, 3, 6, 7, 8, 9, 11, 12, 14), (10, 13), (4, 5)	11	(-), (3, 5, 6, 7, 10, 11, 12), (2, 4, 8, 9, 14)
H_5	11	(3, 7, 11, 13), (6, 9, 10, 12), (2, 4, 5, 8, 14)	11	(-), (2, 3, 4, 6, 7, 9, 10, 11, 12), (5, 8, 14)
H_6	11	(3, 4, 7, 11), (5, 9, 10, 12, 13, 14), (2, 6, 8)	5	(-), (5), (2, 3, 4, 6, 7, 8, 9, 1, 11, 12, 14)
H_7	11	(2, 4, 5, 6, 8, 12, 13), (3, 10, 11, 14), (7, 9)	11	(-), (2, 4, 5, 8, 10, 11, 14), (3, 6, 7, 9, 12)
H_8	11	(3, 4, 7, 12), (2, 9, 10, 11, 14), (5, 6, 8, 13)	11	(-), (2, 7, 9, 10, 11, 14), (3, 4, 5, 6, 8, 12)
H_9	11	(4), (2, 5, 6, 8, 10, 11, 12, 13, 14), (3, 7, 9)	11	(-), (2, 5, 8, 10, 11, 14), (3, 4, 6, 7, 9, 12)
H_{10}	11	(-), (2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14), (3, 10)	11	(-), (2, 3 , 4 , 5, 6, 7, 8, 9, 11, 12, 14), (10)
H_{11}	6	(3, 4, 5, 6, 13), (2, 7, 8, 9, 10, 12, 14), (11)	6	(-), (4, 5, 7, 8, 9, 1, 12, 14), (2, 6, 11)
H_{12}	11	(2, 3, 4, 7, 8), (5, 6, 9, 10, 11, 13), (12, 14)	11	(-), (4, 5, 10, 11), (2, 3, 6, 7, 8, 9, 12, 14)
H_{13}	11	(3, 5, 7, 11), (4, 6, 9, 10, 12, 14), (2, 8, 13)	---	---
H_{14}	11	(4), (2, 6, 7, 8, 9, 10, 11, 13), (3, 5, 12, 14)	11	(3), (2, 7, 8 , 9, 10, 11), (3, 4, 5, 6, 12, 14)

In Table 5.1, "(3, 4, 7, 12), (8, 9, 10, 11, 14), (2, 5, 6, 13)" means: Under the competition of the Affiliated Hospital of Inner Mongolia Medical University, The best partner of Inner Mongolia Autonomous Region Hospital is the second affiliated element of Inner Mongolia Medical University, Inner Mongolia International Mongolian Hospital, Baotou Central Hospital, Inner Mongolia University for Nationalities Affiliated Hospital;; potential partners are Inner Mongolia Baotou Steel Hospital, Baotou City Mongolian Traditional Chinese Medicine Hospital, Baotou City Mongolian Traditional Chinese Medicine Hospital, Chifeng City Hospital, Inner Mongolia Forestry General Hospital; Infeasible partners are Inner Mongolia Autonomous Region Hospital, Inner Mongolia Autonomous Region Chinese Medicine Hospital, Inner Mongolia Autonomous Region Maternal and Child Health Hospital, Ordos Central Hospital.The interpretation of other data is similar.

6. Sensitivity Analysis

Question 1 Sensitivity analysis: the impact of the proportion of the elderly population on the prediction of aging

According to the prediction of the gray population of the elderly population and the establishment of the gray prediction model, it can be seen that the proportion of the elderly population is also rising in the past years and in the future.We increase the proportion of the elderly population from 10 to 2018 by 10%. The predicted value is predicted by the gray prediction model. Compared with the original value, it is worth 6.1, indicating that the predicted value is also close to 10%, indicating that the elderly population accounts for Sensitive to the value of the prediction model

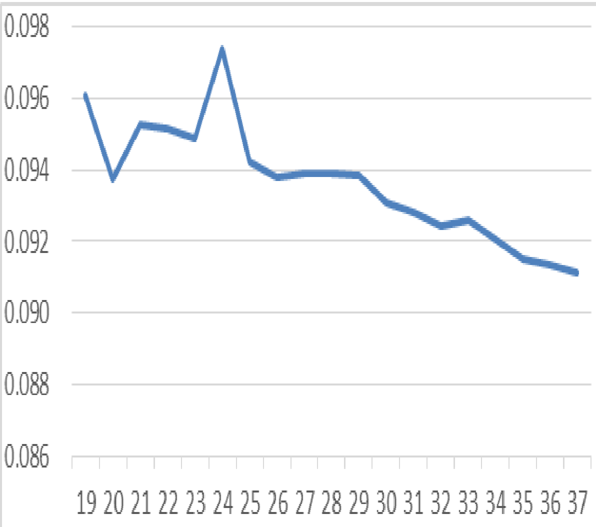

Figure 6.1 Ratio of predicted values to original values after changing parameter values

Question 2 Sensitivity analysis: The weight analysis of various diseases affects the most common diseases

For the weight analysis of various diseases, the calculation formula of the information entropy to be used can calculate the weight score of each indicator,

$$W_t = \frac{1-E_i}{k-\sum E_i}\left(i=1,2,...,k\right)$$

It can be used to derive the scores of the most common types of diseases in the future. The weight analysis of each level is sensitive to the most common diseases.

Problem 3 Sensitivity analysis: the impact of queuing locations on random service queuing systems with multiple windows and multiple queues

In the multi-queue multi-window queuing service system, the queuing waiting time and the average waiting queue length are calculated. The derivation of the average stay time is also very strict, and in the subsequent optimization objective function.

$$Z = \min\{c_1(t)t_1 + c_2(t)t_{2,i}\}$$

There is also no relevant influence of the distribution of queuing locations on queuing optimization, indicating that queuing locations are not sensitive to random service queuing systems with multiple queues in the window.

Problem 4 Sensitivity Analysis: The Impact of Competitor DMUj's Competition on Decision Models

For the optimal solution of the decision model, we need to make appropriate adjustments to the competition value of the competitor DMUj, and adjust it to the original 1/2. The position of the formula DMUj in our decision model should also be adjusted by 18/2. So the competition of competitor DMUj is sensitive to the decision model.

7.Strengths and Weakness

7.1 Advantages of the model

The simple model is combined with the actual problem, and the MATLAB software is used to simulate and predict the analysis, and the proposed problem is analyzed according to the actual situation, so that the model is more practical and popular.

Through the analysis of the survey data, not only can the problem be solved to a certain extent, but also the characteristics of the survey data can be quickly grasped, and the reference experience can be provided for more suitable model establishment.

The reliability of the model is high, and the research method used is consistent, but the possible satisfaction value may be deviated, and the model verification method is more complicated.

7.2 shortcomings of the model

There are some random factors in the process of model formulation. The analysis of the model and the analysis of the algorithm lack the participation of large-scale data, so that the model can not accurately reflect it, and the results are one-sided.

8.Conclusion

In summary, with the advancement of China's medical and health system reform process, advances in telemedicine technology, and changes in patient care concepts, in the face of public hospital reforms and the highly competitive medical market environment.Through the forecast, it is predicted that the demand for health services and aging of residents in China will continue to rise, and the best value of cooperation and competition between public hospitals and private hospitals will be realized. The hospital queuing model will be continuously optimized, and China will be upgraded in many aspects. The overall level of the hospital has spurred the hospital to move steadily on the track of mobilizing and enhancing patient satisfaction.

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Appendix

```
syms a b;
c=[a b]';
A= [0.069, 0.056, 0.071,0.073,0.075,0.076 ,0.077,0.079,0.080,0.082,0.085,0.089,0.091,0.094,0.097,0.101,0.104,0.109,0.114,0.119];
B=cumsum(A); % raw data is accumulated
n=length(A);
for i=1:(n-1)
    C(i)=(B(i)+B(i+1))/2; % generates an accumulation matrix
end
% calculates the value of the pending parameter
D=A;D(1)=[];
D=D';
E=[-C;ones(1,n-1)];
c=inv(E*E')*E*D;
c=c';
a=c(1);b=c(2);
% forecast follow-up data
F=[];F(1)=A(1);
For i=2:(n+20) % only speculates the last 20 data, which can be modified from here
    F(i)=(A(1)-b/a)/exp(a*(i-1))+b/a;
end
G=[];G(1)=A(1);
For i=2:(n+20) % only speculates the last 20 data, which can be modified from here
    G(i)=F(i)-F(i-1); % get predicted data
end
t1=1999:2018;
T2=1999:2038; % more than 20 sets of data
G
h=plot(t1,A,'o',t2,G,'-'); % comparison of raw data with predicted data
set(h,'LineWidth',1.5);xlabel('Particular year')

    ylabel('Proportion of 65 year olds')
```

Appendix 2 diagnosis and treatment needs prediction MATLAB program

```
syms a b;
    c=[a b]';
    A=[49.01 54.88 58.38 62.71 68.88 73.14 76.02 76.99 79.32 81.32];
    B=cumsum(A); % raw data is accumulated
    n=length(A);
    for i=1:(n-1)
    C(i)=(B(i)+B(i+1))/2; % generates an accumulation matrix
    end
    % Calculate the value of the pending parameter
    D=A;D(1)=[];
    D=D';
    E=[-C;ones(1,n-1)];
    c=inv(E*E')*E*D;
    c=c';
    a=c(1);b=c(2);
    % predict subsequent data
    F=[];F(1)=A(1);
    for i=2:(n+10)
        F(i)=(A(1)-b/a)/exp(a*(i-1))+b/a ;
    end
    G=[];G(1)=A(1);
    for i=2:(n+10)
        G(i)=F(i)-F(i-1); % get predicted data
    end
    t1=2008:2017;

    t2=2008:2027;

    G, a, b % output predicted value, development coefficient and gray action

    Plot(t1,A,'o',t2,G) % comparison of raw data with predicted data

    xlabel('Particular year')

    ylabel('Number of patients diagnosed and treated')
```

Appendix 2 Health total cost trend forecast MATLAB program

```
syms a b;
c=[a b]';
A=                    [4047.50,                    4586.63,
5025.93,5790.03,6584.10,7590.29  ,8659.91,9843.34,11573.97,14535.40,17541.92,19980.39,243
45.91,28119.00,31668.95,35312.40,40974.64,46344.88,52598.28];
B=cumsum(A); % raw data is accumulated
```

```
n=length(A);
for i=1:(n-1)
        C(i)=(B(i)+B(i+1))/2; % generates an accumulation matrix
end
% calculates the value of the pending parameter
D=A;D(1)=[];
D=D';
E=[-C;ones(1,n-1)];
c=inv(E*E')*E*D;
c=c';
a=c(1);b=c(2);
% forecast follow-up data
F=[];F(1)=A(1);
For i=2:(n+19) % only guesses the last 19 data, which can be modified from here
        F(i)=(A(1)-b/a)/exp(a*(i-1))+b/a;
end
G=[];G(1)=A(1);
For i=2:(n+19) % only guesses the last 19 data, which can be modified from here
        G(i)=F(i)-F(i-1); % get predicted data
end
t1=1999:2017;
T2=1999:2036; % more 19 sets of data
G
h=plot(t1,A,'o',t2,G,'-'); % comparison of raw data with predicted data
set(h,'LineWidth',1.5);
```