Analysis and Forecasting Research on Supply and Demand Relationship of Smart Elderly Care Based on Random Forest and ARIMA Models

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Abstract. With the aging of the population, the demand for elderly care services is increasing, and the contradiction between supply and demand is becoming more and more prominent. Under the background of big data and artificial intelligence, intelligent aging has become a trend for future development. Taking the six urban areas in the centre of Tianjin as an example, this paper explores the influencing factors and future development trend of intelligent aging development, and explores effective countermeasures to cope with the aging problem. This paper adopts the relevant data of the whole country and Tianjin from 2015 to 2023, constructs the indicator system affecting the development of smart old-age care, and analyses the influencing factors by using the entropy value method evaluation model. It is found that the main factors restricting the development of smart old-age care focus on the two aspects of residents' life and old-age care services, especially the number of nursing home beds and per capita disposable income of residents. Based on this, this paper establishes a supply relationship model based on the Lorenz curve and the Gini coefficient to analyse the supply and demand relationship of senior care facilities in Tianjin, revealing problems such as the oversupply of facilities, unbalanced distribution, and insufficient matching demand for different levels of senior care institutions. Further, this paper identifies the key factors affecting the changes in the number of nursing home beds through the random forest method, and constructs an ARIMA prediction model to predict the future demand for beds in six urban areas of Tianjin to alleviate the contradiction between supply and demand. The model construction in this study provides theoretical support for promoting the development of intelligent elderly care.

Keywords: Smart Ageing; Random Forest Method, ARIMA Prediction Model; Lorenz Curve; Gini Coefficient.

1. Introduction

With the aging of the population, the demand for elderly care services is growing [1]. In order to meet this demand, the number of beds in elderly care institutions has become an important factor affecting the relationship between the supply and demand of elderly care services [2]. However, the contradiction between the demand and supply of senior care services has also become increasingly prominent. In such a context, smart elderly care, which is carried by intelligent service equipment and information technology, provides a new idea to solve this contradiction [3]. Currently, some leading senior care organisations have begun to adopt AI technology to predict future demand for senior care beds and provide support for the optimisation of senior care services. These predictions are based on analyses of various information about the elderly's living habits, health conditions, family background, etc., and the data are mined and processed through big data technology. Through these data, elderly care institutions can better understand the needs of the elderly, predict future changes in demand, and make timely adjustments to the layout of beds and the provision of personalised services. However, with the arrival of the intelligent era, senior care service is not only a question of the number of beds, but also a question involving many aspects, including health care, health management, safety and security, leisure and entertainment, etc. [4].

In the future, intelligent ageing will become a trend and a new way of life. In this trend, people are focusing more and more on digitalisation and intelligent and convenient life, so intelligent elderly care has become a hot topic that young and old people are following nowadays. Through artificial intelligence and big data technology, future senior care institutions will be able to better manage resources, improve efficiency, optimise services, and provide more comprehensive, personalised and humanised services for the elderly [5]. In addition, through the introduction of digital technology, senior care organisations will be able to improve service quality and satisfaction, as well as enhance the quality of life and sense of well-being of the elderly.

In this paper, the entropy weight method and the random forest method are used to construct the indicators of supply and demand of elderly beds and the indicators of predicted beds and to find out the weights of the indicators, to analyse the relationship between supply and demand of the elderly population and institutional resources, and to establish the prediction model of the beds of elderly institutions based on the judgement of the spatial fairness and reasonableness of the facilities and services of the existing elderly institutions. The aim is to provide references for governmental decision-making and planning of senior care institutions, actively responding to population aging as well as positively adapting to senior care intelligence by conducting a spatial and temporal analysis and research on the relationship between supply and demand of senior care services in Tianjin. The study mainly focuses on the following aspects: interpretation of hotspots of national elderly policy, analysis of the relationship between supply and demand of elderly organisations, the current situation and problems of elderly services, construction of the bed prediction model of elderly organisations, and suggestions on the direction of intelligent elderly care.

2. Research methodology

2.1. Data acquisition and preprocessing

(1) Study area and data sources

The ageing of the population in Tianjin started earlier, and it is one of the cities with the fastest growth rate of population ageing. Compared with the proportion of the national elderly population, the degree of aging is higher than the national average, much higher than the aging standard set by the United Nations, and has entered a deeply aging society. The research object of this paper is the relationship between the supply of facilities and resources for the elderly in the six urban districts in the centre of Tianjin (Heping, Hebei, Hedong, Hexi, Nankai and Hongqiao districts) as well as the contradiction between supply and demand in relation to the elderly population, the main factors affecting the change in the number of beds in nursing homes, the relationship between the beds for the elderly, and the number of beds in the future. The six districts, with a total of 63 streets, are characterised by high population density, rapid growth rate, high degree of aging and high land costs, which are important references for the study of the relationship between the supply and demand of social services for the elderly in large cities.

Elderly institutions, refers to the institutions that provide comprehensive services for the elderly such as diet and living, cleanliness and hygiene, life care, health management and cultural, sports and recreational activities, including the types of institutions such as homes for the elderly, nursing homes, and senior citizen flats. From the State Council Policy Document Library and the State Council Policy Document Library, we obtained the policies related to the elderly and analysed the policy tendency and the future development direction of the elderly [6], from the National Bureau of Statistics, we obtained the number of institutions for the elderly, the per capita disposable income of Tianjin residents, the per capita consumption expenditure of Tianjin residents, the government's investment, and the total number of the population; from the Ministry of Civil Affairs of the State and the Ministry of Civil Affairs of Tianjin, we obtained the number of the elderly population aged 60 years old or above, the Tianjin's total number of beds, and the number of elderly institutions in Tianjin; and from the Senior Care Network to obtain the building area of elderly institutions, the number of beds in elderly institutions, the grade of elderly institutions, and the minimum fee of elderly institutions.

(2) Indicator system establishment

This paper systematically analyzes all the factors that affect the development of smart aging services in the Beijing-Tianjin-Hebei region by conducting a literature review and searching for relevant indicators. A three-level index system is established. This paper establishes three levels of indicators, the first level is the influencing factors of smart elderly care, which is divided into demand indicators, supply indicators and forecast indicators, the second level indicators include the elderly population, healthcare resources, building area, number of beds, institutional grade, fee standards, residents' life, elderly care services and government investment. Tertiary indicators include the number of elderly people over 60 years old, the number of hospitals within 1km, the floor space of elderly institutions, the number of beds in elderly institutions, the grade of elderly institutions, the minimum fee for elderly institutions, the per capita disposable income, the per capital consumer spending, the total population, the number of beds per 1,000 people in Tianjin, the total number of beds in Tianjin, the number of elderly institutions in Tianjin, and the government's investment. The supply, demand and forecast indicators are shown in Table 1:

Table.1. Indicators of supply, demand, needs, projections

norm		Calculation of indicators
Demand indicators	Elderly population	Number of persons over 60 years of age
	medical resources	Number of hospitals within 1km
	building area	Floor area of elderly care institutions
	Number of beds	Number of beds in elderly care institutions
Indicators of supply	Institutional level	Classes of elderly care institutions
	tariff	Minimum fees for nursing homes
		Per capital disposable income
	people's lives	Consumption expenditure per inhabitant
		Total population
		Beds per 1,000 population in Tianjin
Predictive indicators	Elderly services	Total beds in Tianjin
		Number of elderly care institutions in Tianjin
	government input	government input

(3) Indicator weights

1) Supply and Demand Indicator Weights As shown in Table 2

Table.2. Supply and demand indicator weights

Summary of the results of the entropy method of calculating weights			
term (in a mathematical formula)	The information entropy value e	Information utility value d	Weighting factor w
hierarchy	0.768	0.232	21.694 %
building area	0.624	0.376	35.205 %
Number of hospitals within 1km	0.94	0.06	5.632 %
minimum fee	0.892	0.108	10.068 %
Population over 60 years of age	0.911	0.089	8.338 %
bed (in hospital, hotel, train etc)	0.796	0.204	19.064 %

2) Weights of indicators for forecasting elderly beds as shown in Table 3

Table.3. Indicator weights for forecasting elderly beds

feature weight value			
norm	weighting	Tertiary indicators	weighting
people's lives	0.449	Disposable income per capital:Tianjin:Cumulative:Quarterly	0.195
		Consumer spending per capital:Tianjin:Cumulative:Quarterly	0.170
		Total population	0.084
government input	0.148	government input	0.148
Elderly services	0.404	Total beds in Tianjin	0.266
		Number of elderly care institutions in Tianjin	0.138

2.2. Description of the methodology (advantages, rationale)

(1) Entropy weight method: Entropy weight method is an objective assignment method for determining the weight of each indicator in a multi-indicator decision-making problem. The method is based on the concept of information entropy, which measures the variability of each indicator by calculating its information entropy, and then determines the weights. The smaller the entropy value of an indicator, the more information the indicator provides and the higher its weight.

(2) Lorenz Curve: The Lorenz curve is a graphical tool used to show the distribution of resources (e.g., wealth or income), and is now widely used in studies of equity in the distribution of public resources. In this paper, the Lorenz curve consists of a combination of the cumulative number of elderly population by age and the cumulative number of beds, floor space and other resources of the elderly institutions according to the streets of the districts, which can be used to compare the differences of the same indicator in different urban areas, and the demand and supply of resources of the population and the institutions in an urban area. The Lorenz curve is closely related to the Gini coefficient, and the more the curve deviates from the 45-degree equality line, the higher the degree of inequality [7].

(3) Gini coefficient: The Gini coefficient is a quantitative measure of the degree of disparity proposed by the statistician Corrado Gini on the basis of the Lorenz curve, which measures the deviation of the Lorenz curve from the absolute mean. The value of Gini coefficient is between 0 and 1, the closer the value is to 0, the more equal the income distribution is; the closer the value is to 1, the higher the degree of inequality in income distribution is.The value of G ranges from <0.3, which indicates special fairness: ⩾0.3, <0.4 is normal, indicating relative fairness: ⩾0.4, <0.5 is a cause for concern, indicating unfairness; ⩾0.5 is a dangerous condition, indicating very unfair [8].

(4) Random Forest (RF): Random Forest is an integrated learning algorithm that performs classification or regression analysis by constructing multiple decision trees. In classification problems, the output of Random Forest is the pattern predicted by all the decision trees that make up the forest (i.e., the majority voting principle); in regression problems, it is the average of the predictions of these trees. The core idea of Random Forest is to combine the predictive power of multiple decision trees to improve the accuracy and stability of the overall model, while avoiding the problem of easy overfitting of individual decision trees.

(5) Autoregressive Integral Sliding Average Model: ARIMA is a time series forecasting model that combines the three methods of autoregression (AR), differencing (I) and sliding average (MA). The ARIMA model is able to simulate and forecast trends and seasonal variations in the data. It is suitable for forecasting linear time series data and requires the data to be stable or become stable after differencing [9].

3. Equity Study of Institutionalised Elderly Facilities

As public service facilities are an important part of residents' daily lives, their fair allocation and equalised provision are the basis for promoting social justice and common prosperity. The rational layout of public service facilities is an important manifestation of the spatial implementation of social equity, and in the case of institutional care for the elderly, the resources of the facilities and the services provided in different urban areas should be matched to the supply and demand of the distribution of the elderly population within a reasonable range.

A Lorenz curve combining the resources and services of elderly institutions in the six urban centres with the cumulative number of elderly people according to the categories of the elderly (over 80 years old), the middle-aged (71-80 years old), and the young (55-70 years old) was plotted and the Gini coefficients of the different criteria were obtained by using R.

3.1. Analysis of the relationship between the needs of older people within different urban areas

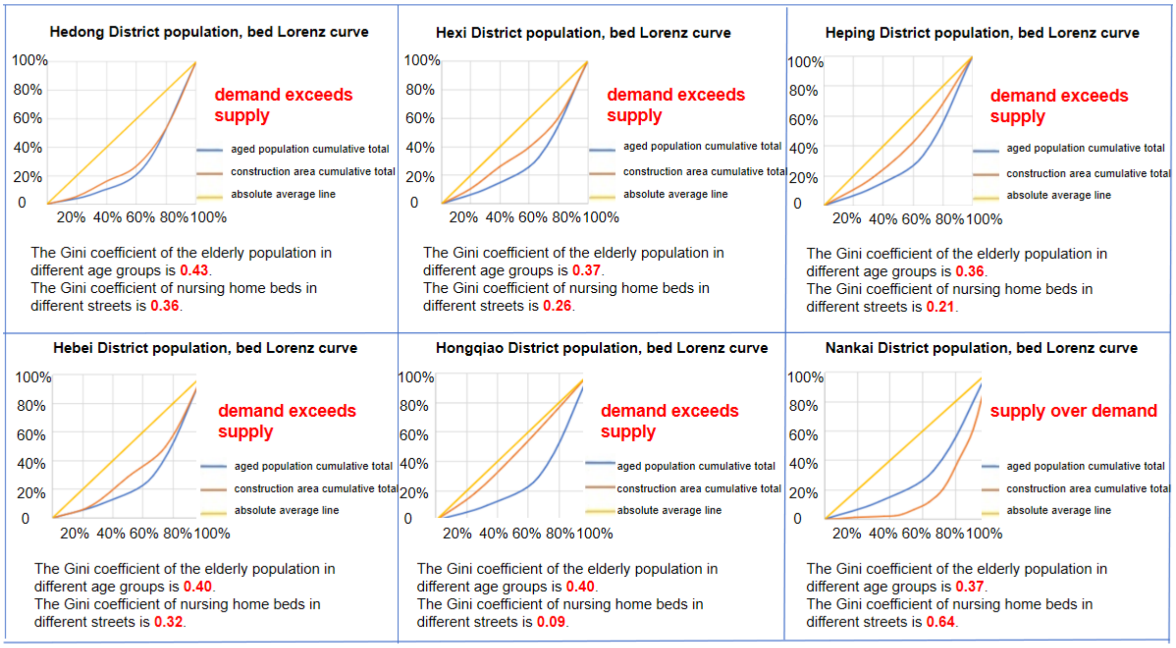

Figure 1. Lorenz Curve of Population and Beds in the Six Districts of Tianjin

As can be seen from Figure 1, the Gini coefficients of the elderly population in each urban area, divided by age group, are, in descending order, Hedong District > Hebei District = Hongqiao District > Hexi District = Nankai District = Heping District. Except for Hedong District (0.43), the rest of the urban areas are between 0.3 and 0.4, which generally indicates that the number of elderly people of all ages in the central urban area is reasonable and that there is no great difference in the number of elderly people's needs in each area. Analysed from the perspective of differences in the demand of the elderly population in specific urban areas, Hedong District has the highest Gini coefficient, and compared with other urban areas, the distribution of the number of elderly people of all ages differs greatly, among which, the number of young elderly people is larger, accounting for a larger proportion, and the aging process in the district is more rapid, and at the same time, the young elderly in the district have a higher demand for the reasonableness of the number of resources of the institutional facilities for the elderly and the fairness in the distribution of the resources, while large-scale. At the same time, there is a higher demand for the rationality of the number of institutional aged care facilities and the fairness of resource distribution among the young elderly in the region, and at the same time, it is also more urgent for large-scale, high-efficiency, and multi-subject modern information technology to empower aged care services to further satisfy the requirements of young elderly in the region.

The Gini coefficients of the remaining four districts are all distributed between 0.36-0.40, and the distribution of the elderly in these districts is more even than that in Hedong District, but there is still a situation in which the young elderly account for a larger proportion, so the urban areas should also strengthen the rationality of the distribution of resources for institutional aged-care facilities for the young elderly. At the same time, in combination with the characteristics of young elderly people's stronger self-care ability and more convenient mobility, it can be concluded that community pension and home pension can strengthen the resource supply capacity and personalized service capacity of young elderly people through the promotion of intelligent pension and the use of AI technology, so that the needs of elderly people of all ages can be better met.

3.2. Analysis of the relationship between the supply of institutional care facilities in different urban areas

(1) Analysis of the supply of institutional care bed resources within different urban areas

As can be seen from Figure 1, after the elderly institutions in various urban areas are divided by street, the Gini coefficient as a whole shows a large difference in different urban areas, from large to small Nankai District > Hedong District > Hebei District > Hexi District > Heping District > Hongqiao District, of which the Nankai District is 0.64 indicating that the beds of its elderly institutions in the spatial distribution of a reasonable degree of low, by analysing the possibility of the existence of old elderly facilities, uneven distribution of facilities and other reasons. Older facilities may have various hidden dangers such as lack of functional space, fire evacuation, etc. due to the lack of specifications when they are built, which makes them unable to meet the demands of modern elderly services, thus affecting the reasonable distribution and utilisation of their beds; in terms of the uneven distribution of facilities, the elderly institutions in Nankai District may be densely distributed in some small areas, while in other areas, they are vacant. In terms of uneven distribution of facilities, Nankai District may have a dense distribution of elderly care facilities in some small areas, while in some other areas they are vacant. For example, there may be a relative gap in the distribution of elderly care facilities in the area around the Water Park in the southern part of Nankai District and the area around Tianjin University in the centre of Nankai District. The Gini coefficient of Hongqiao District is the smallest, only 0.09, which shows that the distribution of institutional beds in the district is very reasonable, and the government of the district carries out effective planning and guidance, based on the actual situation of a large elderly population, and constantly strengthens departmental linkage to create a "fifteen-minute" senior care circle, which has strongly promoted the even distribution of the district's senior care bed resources. Uniform distribution of elderly bed resources in the district.

(2) Analysis of the relationship between the supply of institutional floor space in different urban areas

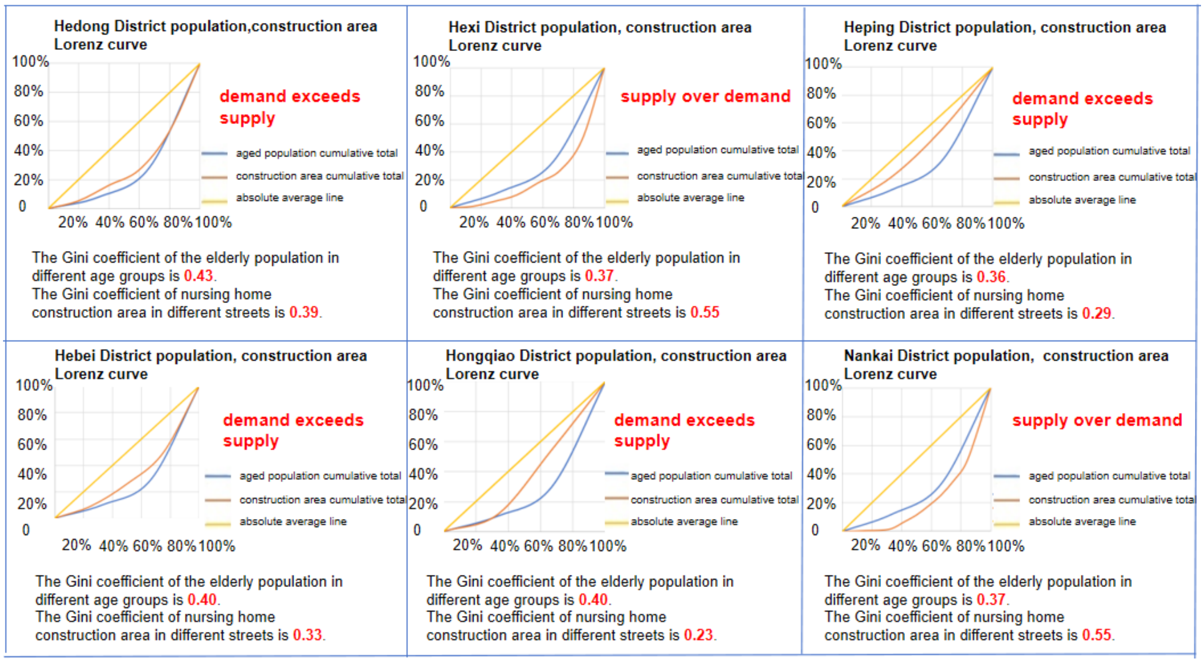

Figure 2. Lorenz Curve of Population and Floor Area in the Six Districts of Tianjin

As can be seen from Figure 2, the Gini coefficient of the floor area of the elderly institutions according to the street division from large to small for Hexi District = Nankai District > Hedong District > Hebei District > Heping District > Hongqiao District, the overall view of the fairness can be divided into three categories, i.e., need to pay attention to, normal, better. In the first category of Nankai District, the need to pay attention to the Gini coefficient is larger than its distribution of beds with poor rationality of resources are inextricably linked to the reasons, so the district can promote home care, community care and other diversified elderly care model, on the one hand, to alleviate the current problems, on the other hand, the existing old elderly facilities to assess and determine which need to be rebuilt or expanded in order to meet the needs of the modern elderly care for the development of the future elderly care institutions. Provide feasible directions for the future development of elderly organisations. In the second and third categories, Hebei District and other urban areas have a reasonable distribution of floor space resources, which helps to improve the quality and efficiency of elderly care services and at the same time helps the region to attract more investment and consumption, promote the development and growth of related industries, and further promote economic development.

(3) Supply relationship analysis of institutional tariffs in different inner-city areas

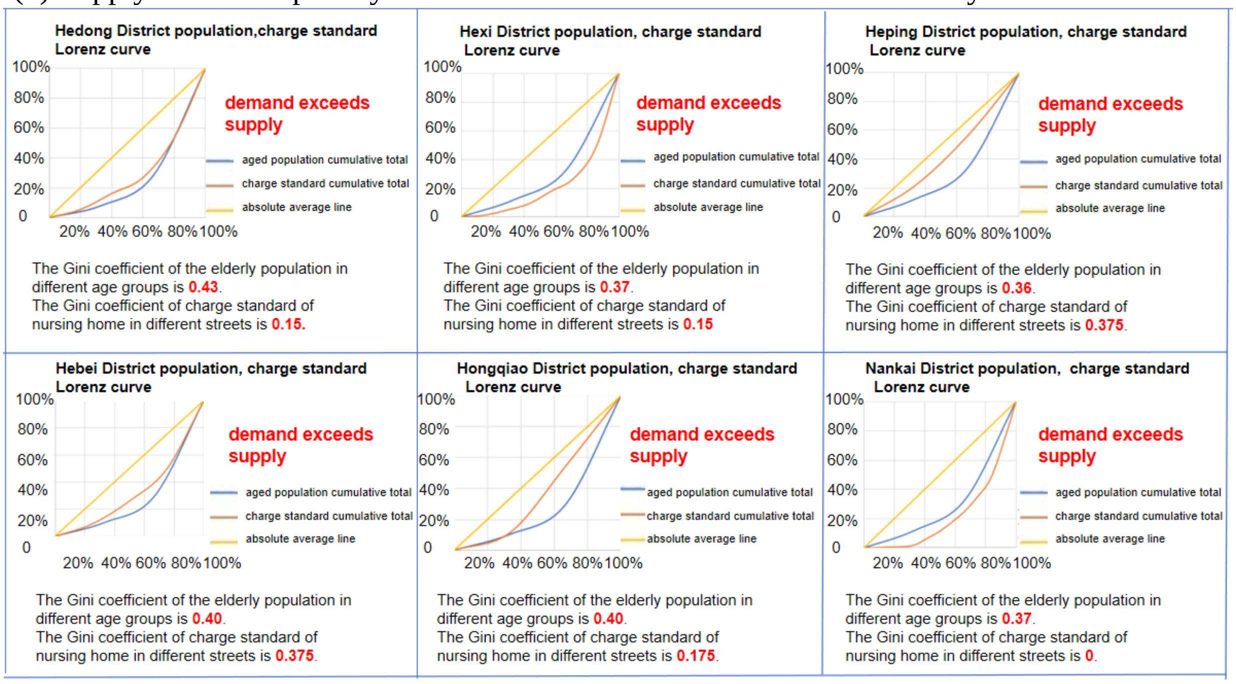

Figure 3. Lorenz Curve of Population and Charges in the Six Districts of Tianjin

As shown in Fig. 3, the number of institutions under each standard is accumulated by sorting the institutions according to different charges from low to high, and the Gini coefficients of the institutions from small to large are as follows: Heibei District > Heping District > Hedong District > Hesi District > Nankai District, and the Gini coefficients of the charges in each urban area are all under 0.4, which is a very reasonable distribution, among which the Gini coefficient of the Nankai District is nearly 0, indicating that the number of institutions of different standards in this district is reasonably distributed in terms of charges. The Gini coefficient of Nankai District is approximately 0, which means that the number of elderly institutions of different standards in this district is reasonably distributed from the analysis of charging standards, which can effectively meet the needs of families with different consumption levels and elderly people with different financial situations. However, this balance may not be ideal in reality because different institutions may differ in terms of facilities, services, geographical location, etc., and all these factors will affect the charging standards. Therefore, while taking into account realistic factors, more fine-tuning and comprehensive consideration of various aspects are necessary in setting fees and charges.

(4) Analysing the supply relationship between institutional classes in different urban areas

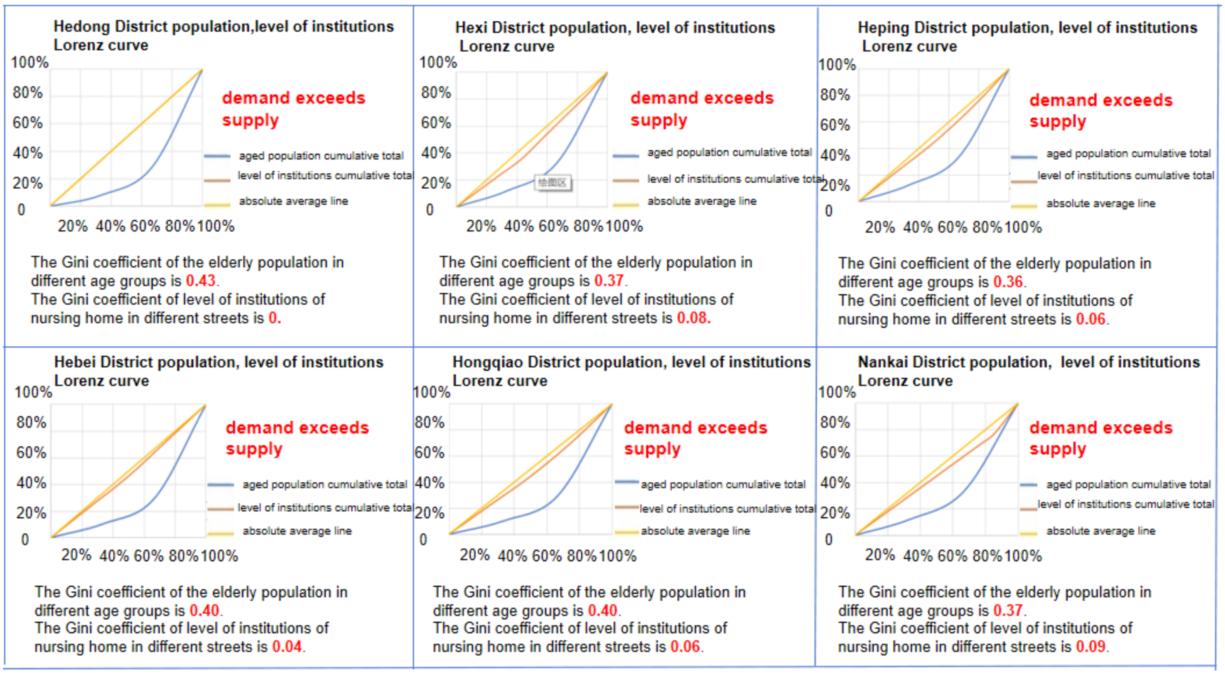

Figure 4. Lorenz Curve of Population and Institutional Levels in the Six Districts of Tianjin

As shown in Figure 4, the elderly care institutions are divided into the city's elderly care institutions according to the rating levels published by the Tianjin Civil Affairs Bureau.

The Gini coefficients of the various grades are as follows: Hedong District > Hebei District > Hongqiao District = Heping District > Hexi District > Nankai District, and the Gini coefficients of the various grades of the fees in the urban areas are below 0.1, which indicates that the distribution of the various grades of institutions in the urban areas is relatively balanced. The Gini coefficient of Hedong District is 0. Combined with the limited number of institutions searched in the region and the errors in the data, it can be concluded that the distribution of institutions of the same level of old-age care in the district is relatively even, but the number of institutions of different levels for the different needs of the elderly is insufficient, and analysed from the perspective of planning and management, the Hedong District pays attention to the planning and management of the old-age care institutions in a scientific and reasonable manner, and through the establishment of a joint meeting system of old-age care services, the construction of a new capacity-led base for old-age care services Through the establishment of a joint meeting system for elderly services, the construction of new elderly service capacity leading bases and other initiatives, policies and implementation have ensured that all elderly institutions can meet certain standards in terms of scale and service quality. In this regard, all urban areas should strengthen the construction of differentiated elderly care institutions, so that while there is a balanced spatial distribution of the same level of care, the coverage of different levels of care for elderly groups with different needs can be enhanced.

3.3. Analysis of the supply and demand relationship between the resources and population of institutional care facilities in different urban areas

Combined with Figure 1, Figure 2, Figure 3 and Figure 4, the overall view is that, whether it is facility beds, floor area, or fee rates, institutional grade, the resource supply of institutional aged-care facilities and the elderly population are in a state of oversupply, mainly due to the aggravation of the aging population, the imbalance in the distribution of resources of aged-care institutions, and the occupancy rate of private aged-care institutions, such as the reasons for the low occupancy rate. One of the oversupply situation exists in the Nankai District, the distribution of floor space resources, Nankai District, in addition to meeting the demand for institutional elderly care services, the elderly centre to play the radiation-driven function of the elderly service base, supporting the construction of geriatric and gerontological rehabilitation as the characteristics of the hospital for the elderly in the surrounding community to provide the elderly with Medicare network of basic medical care and rehabilitation diagnostic and treatment services[10]. In addition, through the refined planning and management, the building area resources have been efficiently utilised, which also provides experience for other urban areas to learn from when they face the problems of shortage of land area and high prices, which result in the oversupply of resources and the elderly population.

Specifically analysing the relationship between supply and demand in the urban area, Hedong District, in terms of the number and type of nursing institutions, as a region in the city centre, has a relatively large number of nursing institutions, but through the information of the senior care network shows that it is mainly dominated by low-end and medium-end institutions, and there are fewer high-end institutions, which leads to the inability to meet the needs of some seniors for institutions of a higher grade; in terms of occupancy rate, some privately-run institutions charge lower fees, and there are problems such as improved hardware facilities and skilled nursing staff, and their occupancy rate may be relatively low. As for the occupancy rate, some private elderly care institutions charge lower fees, and there are problems such as inadequate hardware facilities and poor nursing staff skills, so their occupancy rate may be relatively low. On the other hand, some nursing institutions with complete facilities and good nursing conditions may have a tight bed situation, which also provides an explanation for the oversupply of beds and other demand in the region. In Hebei District, in terms of the characteristics of the elderly institutions, the services of the institutions such as medical and nursing care, rehabilitation and nursing care are more complete, which caters well to the demand of the elderly for the medical resources of the elderly institutions, and to a certain extent, effectively improves the occupancy rate of the elderly. In terms of geographical location, the distribution of beds and floor area of nursing institutions in Hebei District under different streets is balanced, and some of them are located in convenient locations, which is easy for the elderly to travel and for their families to visit, and it also provides an explanation for the situation that the demand exceeds the supply.

During the research process, we improve the accuracy and reliability of the model by continuously optimising the model parameters. At the same time, we will also continue to sum up our experience in practice and optimise the elderly service supply system to meet the diversified needs of the elderly.

4. Forecasting model for elderly beds

4.1. Random Forest Model Construction and Prediction

In this paper, Tianjin quarterly per capita disposable income, per capita consumer spending, government investment, total number of beds in Tianjin elderly care institutions, number of elderly care institutions in Tianjin, and total population are taken as independent variables, while the number of beds per 1,000 people in Tianjin is taken as the dependent variable for the Random Forest modelling. The weights of various independent variables are obtained, from the table, the weights of the characteristics show the importance of the contribution of each variable to the model, and the sum value is 1. From the table, it can be seen that: the proportion of the total number of beds in Tianjin is 26.56%, and the weight of this characteristic is the highest, which is crucial for the construction of the model; the proportion of the per capita disposable income of the residents in Tianjin: the cumulative value of the quarter is 19.51%; the proportion of the per capita consumption expenditure of the residents in Tianjin is 19.51%; and the per capita consumption expenditure of the residents in Tianjin is 19.51%, and the per capita consumption expenditure of the residents in Tianjin is 19.51%. The weight of per capita disposable income is 19.51%; the weight of per capita consumption expenditure is 16.99%; the weight of per capita consumption expenditure is 16.99%; the weight of per capita government investment is 14.81%; the weight of the above four characteristics accounts for 77.87%; the weights of the number of elderly care institutions in Tianjin and the total number of the population are 13.77% and 8.36%, respectively. We derived the weights of each indicator, as shown in Table 4.

Table.4. Indicator weights for elderly bed projections

feature weight value			
norm	weighting	norm	weighting
people's lives	0.449	Disposable income per capita: Tianjin: Cumulative: Quarterly	0.195
		Consumer spending per capita: Tianjin: Cumulative: Quarterly	0.170
		Total population	0.084
government input	0.148	government input	0.148
Elderly services	0.404	Total beds in Tianjin	0.266
		Number of elderly care institutions in Tianjin	0.138

4.2. ARIMA prediction model construction and forecasting

After determining the weights of the indicators, the ARIMA prediction model was used for the number of beds per 1,000 people in Tianjin, combined with the AIC information criterion (Akaike information criterion, the lower the value the better), to model and compare the selection of a number of potential alternative models, and ultimately to find out the optimal model is: ARMA (1,1), whose model formula is:

$$y(t) = 17.752 + 0.225 * y(t-1) - 0.993 * \varepsilon(t-1) \quad (1)$$

The reasons for the selection are shown in Table 5:

Table.5. Table of model Q statistics

Model Q statistic table		
term (in a mathematical formula)	statistic	p-value
Q1	0.294	0.587
Q2	1.353	0.508
Q3	1.691	0.639
Q4	2.479	0.648
Q5	2.685	0.748
Q6	5.405	0.493
Q7	10.208	0.177
Q8	10.697	0.219

The table shows the model Q statistic information (specifically Ljung-Box Q test statistic), including the statistic value and p-value; First: ARIMA model requires the model residuals for white noise, i.e., there is no autocorrelation of the residuals, can be carried out through the Q statistic test for white noise test (the original hypothesis: residuals are white noise); Second: For example, Q6 is used to test the residuals of the first six orders of autocorrelation coefficients to meet the white noise. Second: for example, Q6 is used to test whether the first 6 orders of autocorrelation coefficients of residuals meet the white noise, usually the corresponding p-value is greater than 0.1, which means that it meets the white noise test (or vice versa, which means that it is not white noise), and in common cases, it can be analysed by Q6 directly; Third: if the white noise assumption is rejected ($p<0.05$), which implies that the model is not well fitted, and vice versa, it usually implies that the model can be used normally.

From the result of Q statistic, the p-value of Q6 is greater than 0.1, then the original hypothesis cannot be rejected at the significance level of 0.1, the residuals of the model are white noise, and the model basically meets the requirements. The number of beds per 1,000 population is predicted to be 22.918 for the subsequent periods, as shown in Figure 5.

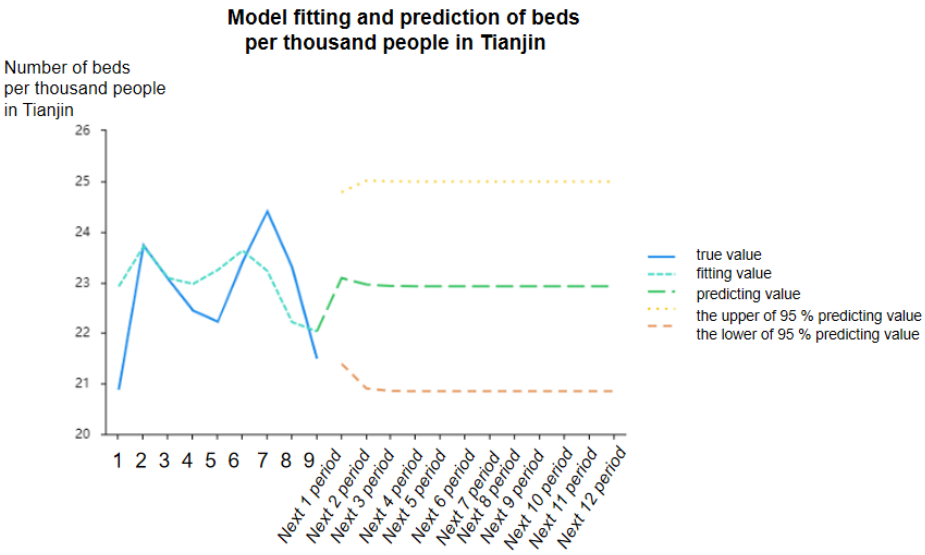

Figure 5. Tianjin beds per 1,000 population model fit and prediction

SPSS software was then used to establish a regression equation to predict the population numbers after the six central districts of Tianjin, and it was found that the best fit was a linear equation, where y is the number of permanent residents at the end of the year and x is the year. The curve fit for the number of permanent residents in the six districts is as follows.

The number of permanent residents at the end of 2024 in the above six districts are 483,700 in Heping District, 647,800 in Hebei District, 786,400 in Hedong District, 976,700 in Hexi District, 501,700 in Hongqiao District and 933,200 in Nankai District.

Then, based on the predicted number of beds per 1,000 people of 22.926, the calculation suggests that the number of beds to be put into elderly care in 2024 will be 11,089 in Heping District, 14,851 in Hebei District, 18,029 in Hedong District, 22,391 in Hexi District, 11,502 in Hongqiao District, and 21,395 in Nankai District.

5. Conclusions and recommendations

This paper obtains the following conclusions through an in-depth analysis of the supply and demand relationship of smart aging in Tianjin's central six cities:

(1) The aging situation is grim, smart aging is imperative

The increasingly serious problem of aging in China is particularly prominent in the six urban areas in the centre of Tianjin. Intelligent ageing, as an important measure to cope with aging, will effectively alleviate the contradiction between the supply and demand of elderly care services and improve the quality of elderly care services. The utilisation rate of bed resources will be enhanced through the use of intelligent technology, intelligent monitoring and assessment will be implemented for elderly care institutions, providing a scientific basis through big data and artificial intelligence; and in the case of ageing in place, intelligent equipment will be installed to monitor health in real time and provide timely assistance in case of emergencies.

(2) Highlighting the conflict between supply and demand, resource allocation needs to be optimised

The contradiction between supply and demand in the six urban areas in the centre of Tianjin is prominent, with the rest of the urban areas unable to meet the needs of the growing elderly population, despite the relative abundance of elderly beds in Nankai District. In addition, elderly care resources are unevenly distributed, with an excess of beds in some areas and a severe shortage in others, and different levels of elderly care facilities failing to adequately match the needs of elderly people in different states of health. Differentiated allocation of elderly care resources according to regional characteristics, increased construction of elderly care facilities in economically weaker regions, promotion of intelligent and home-based elderly care services in economically developed regions, installation of venues such as audio-visual rooms and activity rooms for the elderly, and assistance to the elderly with lower levels of social adaptation and higher levels of depression to improve their life satisfaction, to ensure the fair distribution and efficient use of resources, and establishment of integrated intelligent elderly care platforms with real-time updated bed information, and provide accurate resource matching services to help the elderly and their families choose suitable elderly care services more efficiently and optimise the allocation of resources.

(3) Diversification of influencing factors, policy support

The influencing factors for the development of smart elderly care in Tianjin are diversified, including the living standard of residents, the number of elderly care institutions, the number of beds and government investment. At present, the number of elderly care beds is still in short supply and the elderly population continues to grow, making it difficult to solve the aging problem in the short term. The government needs to further increase its investment in elderly care institutions, reduce the cost of elderly care services through tax incentives, financial subsidies and other measures, and encourage social capital and institutions to increase the construction of elderly care facilities, especially in regions where the contradiction between supply and demand is more prominent. At the same time, targeted policies should be formulated to promote the construction of a multi-level, wide-ranging system for the training of middle- and high-end senior-care personnel, so as to meet the demand for new types of senior-care personnel in diversified senior-care modes.

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