Forecast of supply and demand of elderly care institutions in Guangzhou from 2021 to 2030 – Based on the ARIMA Model

Yongqiang Shi
South China University of Technology

Fangfang Fan (1398078911@qq.com)
South China University of Technology

Zhiyong Zhang
South China University of Technology

Research Article

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Abstract

Background: With the continuous growth of the elderly population, the pension burden in Guangzhou has increased in recent years, and the aging problem cannot be ignored. This study predicts the relationship between the number of elderly people over 60 years old in Guangzhou and the supply and demand of beds and nursing workers in elderly care institutions in the next ten years and provides a reference for decision-makers to regulate the supply of elderly care resources and formulate policies.

Method: Based on the data of the elderly population in Guangzhou from 1990 to 2014, this paper establishes an ARIMA prediction model, uses the data from 2015 to 2020 to verify the validity of the model, and further predicts the number of elderly people, the demand for elderly care facilities and nursing workers from 2021 to 2030 based on specific calculation formulas.

Result: In the future, Guangzhou's aging degree will continue to deepen. It is estimated that by 2030, Guangzhou's elderly population will be over 2.9 million. The increase in the number of elderly people puts forward higher requirements for the facilities and human resource supply of elderly care institutions. The prediction results of this study show that the demand for elderly care beds and nursing workers in Guangzhou will exceed 130,000 and 30,000 respectively by 2030.

Conclusion: The difficulties in the construction of institutional facilities and the loss of human resources coexist. In the future, the gap between the supply and demand of elderly care facilities and nursing workers will be further expanded. Guangzhou urgently needs to find more effective ways to deal with the increasingly serious aging problem.

Background

Guangzhou entered an aging society in 1992, eight years earlier than the overall aging process in China. Referring to the internationally accepted criteria for judging population aging, the age structure of the population in Guangzhou, Guangdong Province in 2020 belongs to the "old age" development period, whether in terms of the population coefficient of the elderly, the youth, or the ratio of the elderly to the young, as shown in Table 1. The old age dependency ratio indicator confirms that Guangzhou's net population inflow in the past few decades is very prominent. The young and middle-aged labor force accounts for a relatively large proportion. In the future, as this generation of labor gradually enters old age, the aging situation in Guangzhou will not be optimistic, and its pension pressure may even be much higher than the national average.

Table 1
Changes in the Comprehensive Population Aging Index of Guangdong Province in 2010 and 2020 Unit:%

Category	Commonly used international standards for determining population aging	2010		2020	
		Guangdong Province	Guangzhou City	Guangdong Province	Guangzhou City
Elderly population coefficient	> 7	6.75	6.67	8.58	7.82
Juvenile population coefficient	< 30	16.89	11.47	18.85	13.87
Old-young ratio	> 30	39.95	57.74	45.53	56.38
Median age	Over 30 years old	30.86	-	34.37	-
Old age dependency ratio	> 12.5	8.89	8.15	11.82	9.98
Source: Guangdong Province 2010 and 2020 census data					

The population of Guangzhou is aging fast, and the rigid demand for nursing care and medical services for the elderly is prominent [1]. From an overall perspective, the nursing market of elderly care institutions may ignore the potential mismatch of supply and demand [2], and institutional beds are always saturated. The state and the shortage of elderly care personnel have become a prominent manifestation of the imbalance between the supply and demand of elderly resources[3], [4], [5]. Li pointed out that understanding the current supply and demand gap in the elderly care industry is an important prerequisite for the good development of elderly care institutions[6]. Predicting the required number of nursing services and facilities by estimating the size of the elderly population will be the most straightforward response for governments to balance supply and demand in elderly care institutions and improve the public health care system[7]. Therefore, clarifying the degree of aging in Guangzhou in the future is of great significance for optimizing the facilities and service supply of elderly care institutions.

In 1789, the British political scientist and demographer Malthus proposed the famous exponential model in his masterpiece "On Population", which showed that under unlimited conditions, the population will show an exponential growth [8]; then the Netherlands Biologist Fair Haas proposed the Logistics population growth model, which shows the relationship between population size, population growth rate and environmental carrying capacity [9]. In contrast, ARIMA (autoregressive integrated moving average considering the trend of change) can focus on the changing law of the variable itself, and combine the extrapolation mechanism to describe the change of the time series, without considering the explanation of the variable based on economic theory. The ARIMA model is a short-term prediction method with high accuracy. The prediction results can reach the optimal level in the sense of the smallest variance, and it is favored in the research of population forecasting. Tu XL estimated the population of China from 2010 to 2015[10], and Sun SY used the ARIMA model to fit the trend of the land-lost population and predicted the number of land-lost population in Jilin Province in the future [11]. Han ST combined multiple linear regression and time series models based on the ARIMA algorithm to predict the population of China, proving that the Chinese population will continue to grow in the short term [12]. Chen P conducted a case analysis of Q city and made a scientific regional

population forecast [13]. Sun L predicted the number of the elderly population and its proportion in the future [14]. Rao CJ analyzed the influencing factors of aging in Wuhan and predicted its development trend [15]. Chang DF took Taiwan as an example and used the ARIMA model to further explain the problem of population aging [16]. It can be seen that the ARIMA model can accurately reflect the population change trend of a certain area, and it also has a high application value in the short-term prediction of the population of a certain age.

To sum up, this article uses Guangzhou's elderly population data from 1990 to 2020 as the basis to establish an ARIMA model to predict the number of elderly people from 2021 to 2030 and further explores the future supply and demand relationship of elderly care institutions in conjunction with the relevant policy documents of the Guangzhou development plan, in order to provide countermeasures for Guangzhou to actively respond to population aging.

Method

Data source and analysis

This study selects the number of elderly people aged 60 and over in Guangzhou from 1990 to 2020. The data comes from the population data officially released by the Guangzhou Civil Affairs Bureau and obtained from a web-based public database. The data analysis tool used in the study is SPSS26.0.

ARIMA model

The ARIMA model is also called the BOX-Jenkins Model, and the model structure is as follows:

$$\begin{cases} \nabla^{d} X_t = \mu + \frac{\Theta(B)}{\Phi(B)} \varepsilon_t & (1) \\ E(\varepsilon_t) = 0,\ VAR(\varepsilon_t) = \sigma^2, E(\varepsilon_s \varepsilon_t) = 0, s \neq t & (2) \\ E(\varepsilon_s \varepsilon_t) = 0,\ \forall s < t & (3) \end{cases}$$

Where μ is the mean value of the sequence $\{x_t\}$, B is the delay operator, $\Phi(\mathrm{B}) = 1 - \Phi_1 B - \cdots - \Phi_n B^p$ is the P-order autoregressive coefficient polynomial, $\Theta(\mathrm{B}) = 1 - \Theta_1 B - \cdots - \Theta_n B^p$ is the q-order moving average coefficient polynomial, $\{\epsilon_t\}$ is a sequence whose mean is white noise [17]. The construction of the ARIMA model mainly includes four steps: stationarity identification and difference processing of the original data, model identification and parameter estimation, model testing, and prediction using the ARIMA (p, d, q) model. The step diagram is shown in Fig. 1.

Result

Time series smoothing processing

The first step of ARIMA modeling is to stabilize the time series. The number of elderly people in Guangzhou showed a clear upward trend from 1990 to 2018. The data is a non-stationary series, and differential processing is required. The condition for judging that the data is stable is that the residual is a sequence of white noise. The white noise test P values of the original data, the first-order difference, and the second-order difference are shown in Table 2(significance level is 0.01). It can be seen that the data after the second-order difference passes the white

noise test, that is, after the second-order difference, the trend of the original series has been eliminated, so the parameter d = 2 in the ARIMA (p, d, q) model.

Table 2
White noise inspection results

Difference order	P value	White noise test result
Raw data	1.58326215e-06	Non-stationary
First order difference	0.00037672	Non-stationary
Second order difference	0.05285948	stationary

Model establishment and validation

According to the autocorrelation graph and partial autocorrelation graph after the second-order difference, the values of p and q are determined to be 1 and 0, respectively. The final model is ARIMA (1,2,0), and the residuals pass the white noise test, indicating that the model structure is reasonable. The actual and predicted values of the number of elderly people in Guangzhou from 2015 to 2020 are shown in Table 3. The average relative error of the model is 0.903%, indicating that the model is highly reliable.

Table 3
2015–2020 actual and predicted values of the elderly population in Guangzhou

Year	Actual value	Predictive value	Relative error
2015	147.53	148.37	0.00569
2016	154.61	155.21	0.00388
2017	161.85	162.15	0.00185
2018	169.27	169.59	0.00189
2019	175.51	176.64	0.00969
2020	179.94	181.85	0.03118*

* Note: The severe natural disasters in China in 1960 caused the birth rate of Guangzhou to reach the lowest value in history. Therefore, the number of newly-increased elderly people in Guangzhou in 2020 is relatively small, which has a certain error with the predicted value.

Forecast of the number of elderly people in Guangzhou from 2021 to 2030

Using the ARIMA (1,2,0) model to predict the number of elderly people in Guangzhou from 2021 to 2030, as shown in Fig. 2, the results show that the number of elderly people in Guangzhou will continue to grow in the next decade.

The predicted values of the elderly population are shown in Table 4. From 2021 to 2030, the growth rate of the elderly population in Guangzhou is relatively stable. The growth rate is between 4.7% and 4.9%, showing a slight increase first and then a decline. It is expected that the elderly population in Guangzhou will exceed 2.9 million by 2030, a

huge increase. The increase in the number of elderly people is accompanied by a decline in the birth rate and an increase in life expectancy. Judging from Guangzhou's existing population policy, nearly a quarter of the population in Guangzhou will be elderly in the future, and the government's pension pressure will further increase.

Table 4
The predicted number and growth rate of the elderly population in Guangzhou from 2021 to 2030

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Number of elderly (ten thousand people)	194.36	203.65	213.43	223.72	234.52	245.87	257.78	270.26	283.32	297.00
growth rate (%)	4.75	4.78	4.80	4.82	4.83	4.84	4.84	4.84	4.83	4.83

Forecast of bed demand in elderly care institutions

Combined with the construction plan of Guangzhou "9064" and the requirements of the "Revision of the Layout Planning of Elderly Service Institutions (2019–2025)" [18] issued by Guangzhou in 2020: The standard for the construction of elderly care service beds in the newly built community is 4.5 beds per thousand people. It is assumed that the demand for elderly care beds in Guangzhou should be 44.5 per thousand people, and the number of beds in elderly care institutions required by Guangzhou in the future can be calculated, as shown in Fig. 3. From 2021 to 2030, the demand for beds in elderly care institutions in Guangzhou has been increasing steadily year by year. By 2030, the demand for elderly care beds in institutions has reached 132,165, an increase of more than 45,000, indicating that the construction of facilities for the elderly in Guangzhou will be under great pressure in the future.

Demand forecast for elderly care staff

Liu YY conducted a survey of 20,221 elderly people in 179 elderly care institutions in Guangzhou and found that among the elderly living in elderly care institutions, self-care elderly accounted for 30.6%, semi-disabled elderly accounted for 19.9%, and disabled elderly accounted for 49.5%[19]. In 2014, Guangdong Province issued the "Detailed Implementation Rules for the Establishment License of Elderly Care Institutions by the Civil Affairs Department of Guangdong Province", which stipulates that: the ratio of workers directly serving the elderly in elderly care institutions to the elderly who take care of their own lives shall not be less than 1:10; the ratio to the semi-disabled elderly is no less than 1:6; the ratio to the disabled elderly is no less than 1:3. According to this standard, the minimum number of nursing workers required under each category is calculated, as shown in Fig. 4.. The calculation formula is:

$$\text{Number of nursing workers required for category I} = f * i * p * t \quad (4)$$

Among them:

I = self-care elderly, semi-disabled elderly, disabled elderly;

f = Forecast number of elderly people;

i = Percentage choosing institutional care;

p = Proportion of seniors in category I in institutions;

t = The required minimum ratio of workers to Category I elderly.

Figure 4 shows that the demand for nursing workers will increase year by year from 2021 to 2030. Among them, the demand for nursing workers for self-care elderly will increase the most. By 2030, the demand for nursing workers in Guangzhou will exceed 30,000. By comparing the gap between the forecast results and the current status of the number of nursing workers in Guangzhou, it is not difficult to find that the gap between the supply and demand of nursing workers will increase year by year, and solving the problem of human resources for elderly care has become the primary task of Guangzhou in dealing with the aging population.

Discussion

At the end of 2012, Guangzhou had only 34,000 beds. By 2021, 240 elderly care institutions in Guangzhou had 72,700 beds. There is still a gap between the demand for 86,490 beds calculated in Table 4. The General Office of the Guangzhou Municipal Government issued the "Fourteenth Five-Year Plan for the Construction of the Guangzhou Elderly Care Service System" and proposed that the total number of elderly care beds in the city should reach 101,200 by 2025. This goal can basically meet the demand for elderly care beds in Guangzhou in 2025 calculated in this paper. At the same time, it should be considered that the demand for elderly care beds in 2030 will exceed 130,000. The increase in beds will inevitably require scientific planning of the layout of elderly care facilities. At present, the urban construction land in Guangzhou is very tight, and it is difficult to open up new land for the construction of elderly care facilities [20], It is not possible to only rely on increasing the number of institutional beds to meet the growing demand for elderly care. It is necessary to explore new ways to make up for the gap in supply and demand for elderly care beds.

In 2015 and 2016, the number of nursing workers in elderly care institutions in Guangzhou was 4,028 and 4,672, respectively, and the growth rate was slow. By the end of 2016, the city's shortage of nursing workers exceeded 12,000. Nursing workers in elderly care institutions have high work intensity, low salaries, and low social recognition, which makes it difficult to recruit professional talents [21]. Some scholars conducted a survey of 600 nursing students in colleges and secondary schools, and the results showed that the proportion of students who intend to work in elderly care institutions is only 15.56%[22]. At the same time, nursing workers who have been engaged in nursing care for the elderly also have a strong willingness to resign[23, 24]. Studies have proved that elderly care workers with high intensity of work involvement also have a certain degree of job burnout and a higher tendency to quit[25], all of which have caused a serious brain drain problem.

This paper has several limitations. First of all, due to the availability of population data, this study only collected the number of the elderly population in Guangzhou since 1990, and the floating population was not included in the government statistics. Therefore, the prediction of the elderly population in 2021 and later is based on the data published by the existing government. Flows in and out of the population may skew ARIMA's predictions to a small extent, but they do not matter much. Secondly, the prediction ability of ARIMA model is limited, and the prediction error increases with the extension of the prediction time. Therefore, this paper only uses ARIMA model to predict the number of elderly people in Guangzhou in the next ten years, without a longer-term prediction. Finally, the advantage of the ARIMA model is to pay attention to the data itself and don't need to explain variables, but further study the effect of still should consider more variables, such as the end of 2019, an outbreak of the COVID-19. Although China has been able to effectively control the new crown epidemic and reduce the impact of the epidemic on the mortality rate of the elderly population, it can be foreseen that the new crown epidemic will greatly affect the lifestyle of the

elderly for a long time in the future, and the proportion of the elderly choosing home-based care in the community may increase, which may cause some errors in the demand for beds and nursing workers in elderly care institutions calculated in this paper.

Conclusion

Based on the historical data of the elderly population aged 60 and over in Guangzhou, this paper uses the ARIMA model to predict the number of elderly people in Guangzhou from 2021 to 2030. The results of effective verification show that the ARIMA model has a good performance in aging prediction. Through the analysis of the forecast results, it can be seen that the population aging of Guangzhou will further deepen in the future, and the supply and demand of elderly care institutions will still be out of balance for a long time.

From 2021 to 2030, the growth rate of the elderly population in Guangzhou is relatively stable, but the number of the new elderly population is relatively large. The results of the calculation of the demand for beds and nursing workers in elderly care institutions show that, On the one hand, the government’s target number of elderly care beds in 2025 can basically meet the demand. However, due to the limitation of land resources, it is difficult to build new elderly care facilities. It is still necessary to open up new ways to cope with the growing demand for elderly care beds, such as accelerating the construction of family elderly care beds; on the other hand, there is a huge gap in the supply and demand of nursing workers, and the construction of the talent team is difficult. We should focus on solving the treatment problems faced by nursing workers. The government should play an active role in policy guidance, effectively improve the welfare benefits and social identity of nursing workers, reduce the brain drain rate, and speed up the construction of a perfect nursing workers service talent system. The forecast based on the ARIMA model and the analysis of the future supply and demand of elderly care in Guangzhou will help decision-makers to clarify the direction of policy formulation and construction priorities.

Declarations

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Authors' contributions

Y.S. designed the study, Y.S., F.F., and Z.Z. performed data analysis, Y.S. produced all tables, F.F. produced all figures, and all authors participated in the writing, revision, and final review of the manuscript, who read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable. This study does not require ethical approval or participant consent

Competing interests

I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Consent for publication

Not applicable.

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Figures

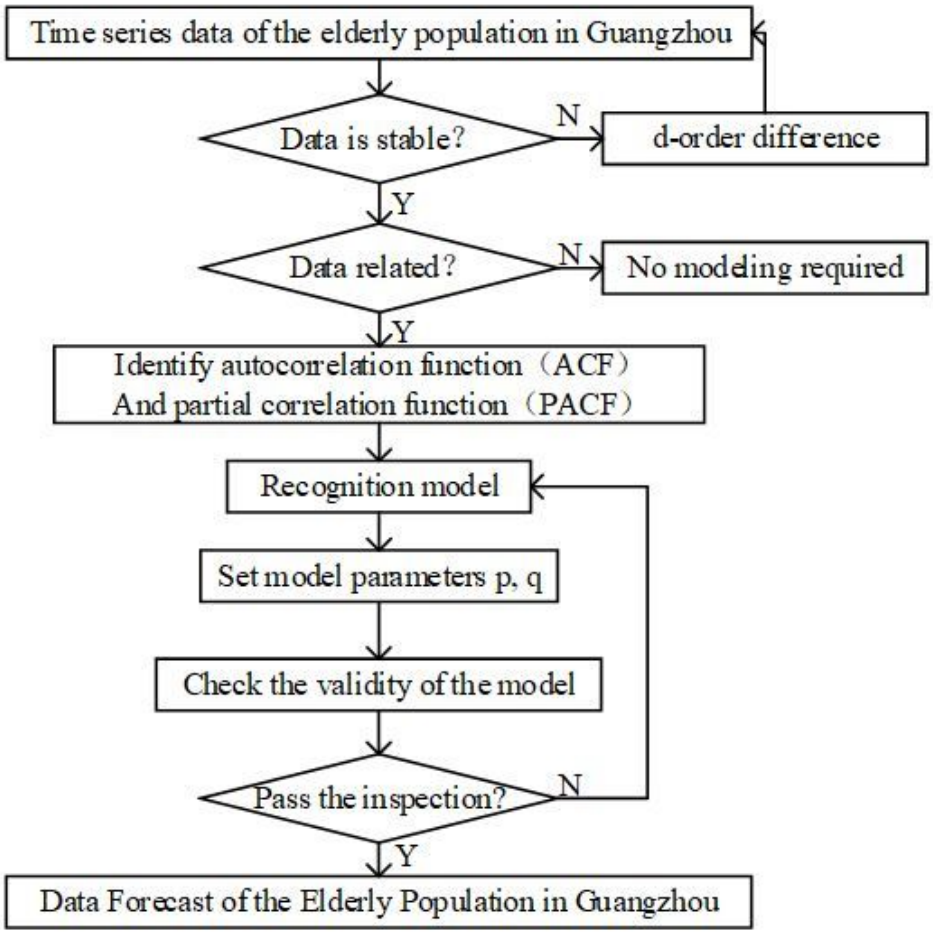

Figure 1

Application steps of the ARIMA model

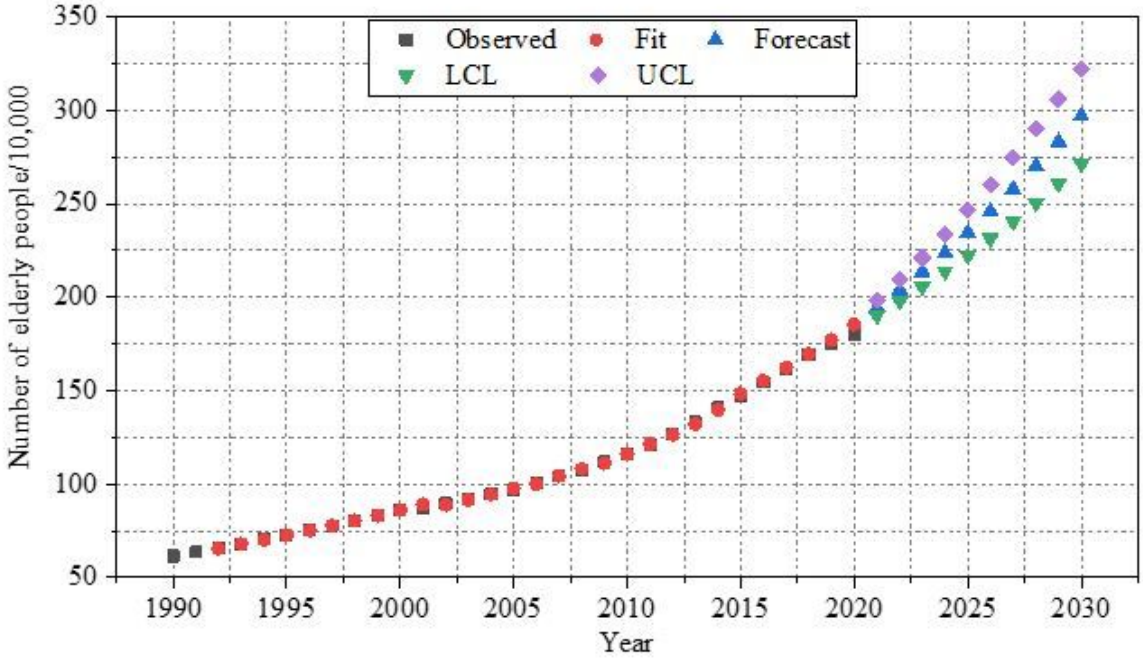

Figure 2

Forecast of the elderly population in Guangzhou from 2021 to 2030

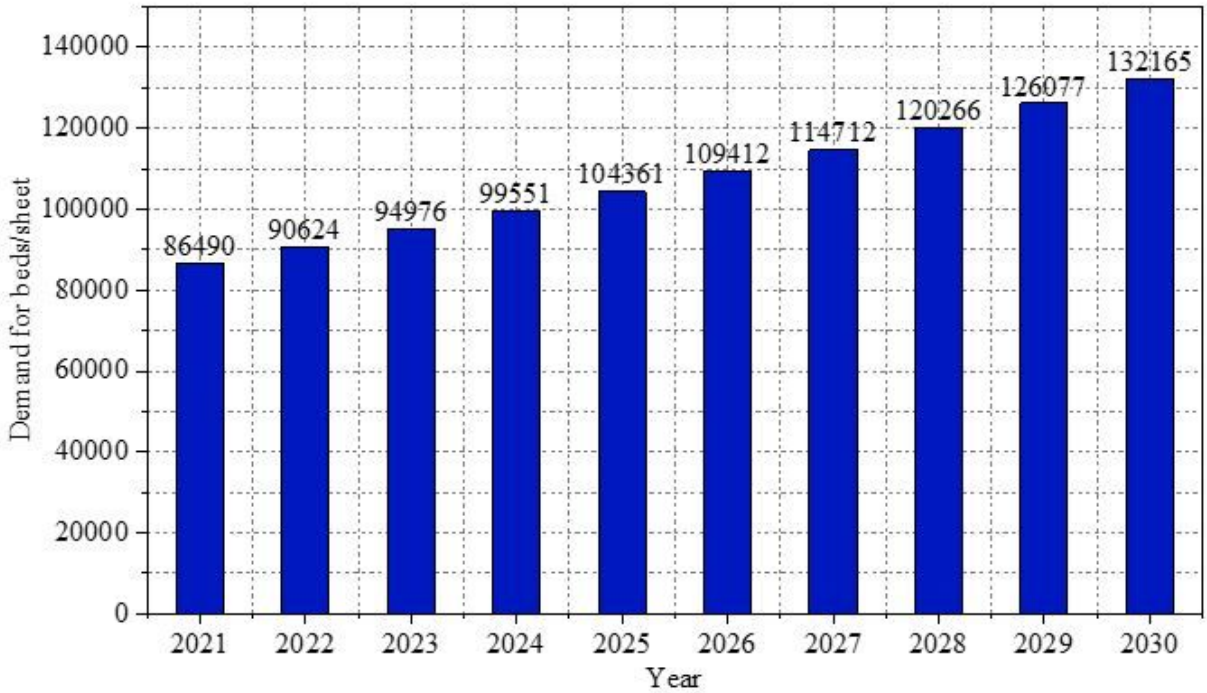

Figure 3

Forecast of demand for beds in elderly care institutions in Guangzhou from 2021 to 2030

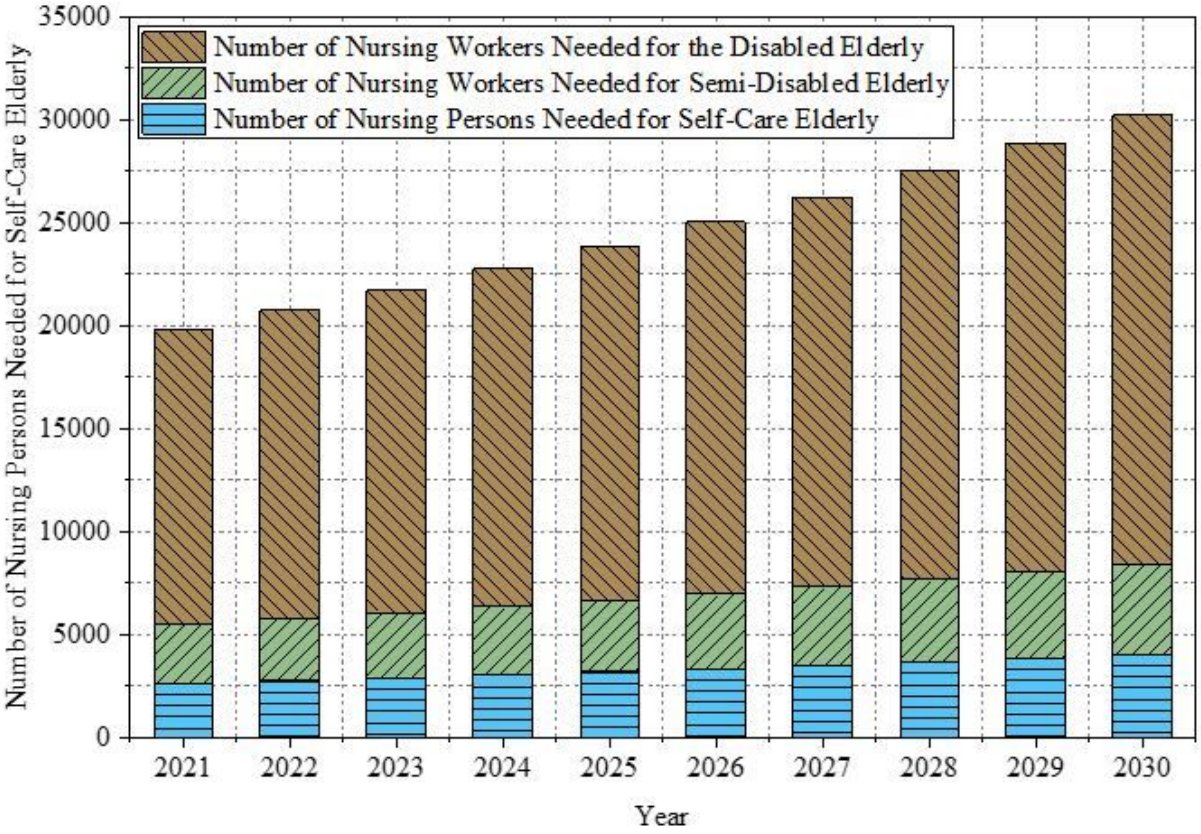

Figure 4

Forecast of demand for nursing workers in elderly care institutions from 2021 to 2030