

# Research on future demographic trends based on the Chinese population growth model

Yuxing Li\*

Hunan University, Changsha, China

\* Corresponding Author Email: 1056822810@qq.com

**Abstract.** Population development plays a vital role in the healthy and orderly operation of our country. To understand the new trends and characteristics of population change can effectively grasp the basic national condition of population and promote the high-quality development of China's economy. Based on the new characteristics and influencing factors of China's population, this paper establishes the mathematical model of China's population growth in the new era, and predicts the change trend of short-term and long-term population in China. First, we adopt the classical GM (1,1) model to predict the short-and medium-term demographic changes, and the fitting effect is very good. Then, in the long-term prediction, based on China's population policy and the future trend of population development, we choose the logistic population block growth model, which also got relatively good results. Next, we selected the representative five provinces of Guangdong, Zhejiang, Hubei, Heilongjiang and Inner Mongolia for comparative analysis according to the above model, and concluded that the correlation coefficient of people such as age structure, urbanization rate, birth and mortality were the main factors affecting population change. Finally, we put forward corresponding policy suggestions by changing the age structure, urbanization rate, sex ratio model correlation coefficient, combined with our country's recent population policy.

**Keywords:** Population forecast; Gray GM (1,1) model; logistic Block growth model.

## 1. Introduction

First analyze the characteristics of China's population in recent years, considering the natural growth of population, and the influence of factors such as economic development, when predicting short-term population, to predict the future population, as (considering) era and the change of ideas, population aging degree is increasing, combined with the transformation of industrial structure, China's population structure is slowly change.

## 2. Short-and medium-term national population growth trend forecast

We take the data of the six years from the full opening of the two-child policy in 2016 to 2021 as the reference value of our short-and medium-term forecast.

**Table 1.** Total national population data

| Year | Total population (ten thousand people) |
|------|----------------------------------------|
| 2016 | 139232                                 |
| 2017 | 140011                                 |
| 2018 | 140541                                 |
| 2019 | 141008                                 |
| 2020 | 141212                                 |
| 2021 | 141260                                 |

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(6)) = (139232, 140011, \dots, 141260) \quad (1)$$

$$\lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)} \quad (2)$$

$$\lambda = (\lambda(2), \lambda(3), \dots, \lambda(6)) = (0.9944, 0.9962, 0.9967, 0.9986, 0.9997) \quad (3)$$

$$\lambda(k) \in \left[ e^{-\frac{2}{6+1}}, e^{\frac{2}{6+1}} \right], k = 2, 3, \dots, 6 \quad (4)$$

Add to  $x^{(0)}$ :

$$x^{(1)}(k) = \sum_{i=1}^k x^{(0)}(i), k = 1, 2, \dots, 6 \quad (5)$$

$$x(1)x^{(1)} = (139232, 279243, 419784, 560792, 702004, 843264) \quad (6)$$

$z^{(1)}$  is the sequence immediately the adjacent mean of  $x^{(1)}$ :

$$z^{(1)} = (z^{(1)}(1), z^{(1)}(2), \dots, z^{(1)}(n)) \quad (7)$$

Here,  $z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1), k = 1, 2, \dots, 6$

Construct the data matrix B and the vector matrix Y:

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \dots & \dots \\ -z^{(1)}(6) & 1 \end{bmatrix}, Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \dots \\ x^{(0)}(6) \end{bmatrix} \quad (8)$$

$\hat{\mu} = [a, b]^T$  to determine the model parameters:

$$\hat{\mu} = [a, b]^T = (B^T B)^{-1} B^T Y = [-0.0000 * 10^5, 1.3970 * 10^5]^T \quad (9)$$

The white equation and time response series of gray differential equation:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \quad (10)$$

Then the time response series of the GM (1,1) grey differential equation is:

$$\hat{x}^{(1)}(k+1) = \left( \hat{x}^{(1)}(1) - \frac{\hat{b}}{\hat{a}} \right) e^{-\hat{a}k} + \frac{\hat{b}}{\hat{a}} \quad (11)$$

Finally, the prediction equation is obtained and the raw data are restored:

$$\hat{x}^{(1)}(t+1) = 6.2267 * 10^7 e^{0.00224864t} - 6.21278 * 10^7 \quad (12)$$

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \quad (13)$$

Calculate residuals

$$\varepsilon(k) = x^{(0)}(k) - \hat{x}^{(0)}(k) \quad (14)$$

At the same time, the relative error of the forecast value and the actual data

$$\Delta_k = \left| \frac{\varepsilon(k)}{x^{(0)}(k)} \right| \quad (15)$$

And according to the level ratio deviation formula

$$p(k) = 1 - \frac{1-0.5a}{1+0.5a} \cdot \lambda^{(0)}(k) \quad (16)$$

The following results are obtained:

**Table 2.** Numerical summary diagram

| Year | Actual value<br>(million) | Predicted value<br>(million) | Residuals | Relative error<br>(%) | Grade<br>deviation |
|------|---------------------------|------------------------------|-----------|-----------------------|--------------------|
| 2016 | 139232                    | 139230                       | 2         | 0                     |                    |
| 2017 | 140011                    | 140170                       | -162.8080 | 0.0012                | 0.0033             |
| 2018 | 140541                    | 140490                       | 51.6364   | 0.0004                | 0.0015             |
| 2019 | 141008                    | 140810                       | 202.3704  | 0.0014                | 0.0011             |
| 2020 | 141212                    | 141120                       | 89.3924   | 0.0006                | -0.0008            |
| 2021 | 141260                    | 141440                       | -180.2991 | 0.0013                | -0.0019            |

As can be seen from the above table, the relative error of the model is small, very close to the actual value, the simultaneous deviation value is much less than 10%, and the accuracy is high. The prediction model can be used to achieve the predetermined effect. The population numbers for 2022 – 2030 is predicted as given in Table 3.

**Table 3.** Population number forecast for 2022-2030

| Year | Predicted value |
|------|-----------------|
| 2022 | 142077.62       |
| 2023 | 142397.46       |
| 2024 | 142718.02       |
| 2025 | 143039.31       |
| 2026 | 143361.31       |
| 2027 | 143684.04       |
| 2028 | 144007.50       |
| 2029 | 144331.69       |
| 2030 | 144656.60       |

### 3. Long-term national population growth trend forecast

The logistic block growth model was used to predict the long-term population number. The principle of this model is that with the growth of population, due to the total limitation of natural environment and natural resources, it will block the growth of population, and with the increase of population, the blocking effect will be stronger. The block is reflected in the effect on the population growth rate  $r$ , expressing  $r$  as a function  $r(x)$  (about  $x$  is a minus function), assuming  $r(x) = r - sx$ , and build the model:

$$\begin{cases} \frac{dx}{dt} = r(1 - \alpha x) \\ x(0) = x_0 \end{cases} \quad (17)$$

The solution equation is obtained by:

$$x(t) = \frac{x_0}{\alpha x + (1 - \alpha x)e^{-rt}} \quad (18)$$

The maximum population of natural resources and environmental conditions is  $x_m$ , so when  $x = x_m$ , the growth rate should be 0, so  $\alpha = \frac{1}{x_m}$ , which is the population arrest growth model:

$$x(t) = \frac{x_m}{1 + (\frac{x_m}{x_0} - 1)e^{-rt}} \quad (19)$$

Upon examination, we found that the best fit was obtained when  $r=0.04284586673065913$ . Long-term population growth projections are shown in Table 4.

**Table 4.** Long-term population size forecast

| Year | Predicted value | Year | Predicted value | Year | Predicted value |
|------|-----------------|------|-----------------|------|-----------------|
| 2030 | 145377.7        | 2040 | 148592.4        | 2050 | 150764.3        |
| 2031 | 145757.2        | 2041 | 148850.4        | 2051 | 150937.3        |
| 2032 | 146122.7        | 2042 | 149098.5        | 2052 | 151103.4        |
| 2033 | 146474.5        | 2043 | 149337.0        | 2053 | 151262.9        |
| 2034 | 146813.2        | 2044 | 149566.2        | 2054 | 151416.0        |
| 2035 | 147139.2        | 2045 | 149786.4        | 2055 | 151563.0        |
| 2036 | 147452.8        | 2046 | 149998.0        | 2056 | 151704.1        |
| 2037 | 147754.5        | 2047 | 150201.3        | 2057 | 151839.5        |
| 2038 | 148044.8        | 2048 | 150396.6        | 2058 | 151969.5        |
| 2039 | 148323.9        | 2049 | 150584.2        | 2059 | 152094.2        |

#### 4. Major factors affecting demographic change

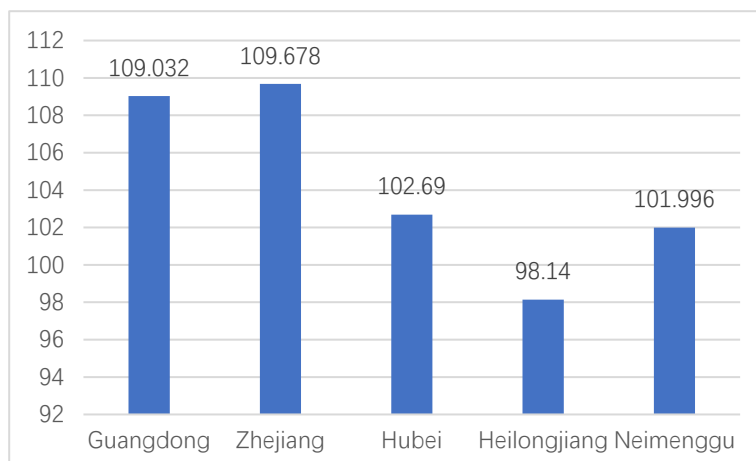
According to the division of China's geographical regions and the economic conditions of each region, we selected five representative provinces: Guangdong, Zhejiang, Hubei, Heilongjiang and Inner Mongolia Autonomous Region, and drew images from the following angles and made specific analysis.

**Table 5.** Basic information of the five provinces

| Province                         | Birth rate (%) | Per capita disposable income | Mortality rate (%) | Sex ratio (%) | Percentage under 15 years of age (%) | 16-59 years old (%) | Percentage over 60 years old (%) | Urbanization rate is (%) |
|----------------------------------|----------------|------------------------------|--------------------|---------------|--------------------------------------|---------------------|----------------------------------|--------------------------|
| Guangdong Province               | 12.54          | 41023.6                      | 4.46               | 109.032       | 25.97                                | 62.21               | 11.82                            | 74.15                    |
| Zhejiang Province                | 10.51          | 52397.4                      | 5.52               | 109.678       | 18.35                                | 63.55               | 18.1                             | 72.17                    |
| Hubei Province                   | 11.50          | 27880.6                      | 7.08               | 102.69        | 23.61                                | 55.28               | 21.11                            | 62.89                    |
| Heilongjiang Province            | 5.23           | 24902.0                      | 6.74               | 98.14         | 13.97                                | 64.49               | 21.08                            | 65.61                    |
| Inner Mongolia Autonomous Region | 8.23           | 31497.3                      | 5.66               | 101.996       | 19.27                                | 62.83               | 17.9                             | 67.48                    |

##### 4.1. Sex ratio factors

We can see from the chart we draw that although the sex ratio of the five provinces is high or low, the overall sex ratio is close to 1:1, and the difference is not obvious, while in recent years, the population growth rate of each province is positive or negative. In Guangdong, where Zhejiang has positive population growth, the opposite sex ratio is relatively high, which indicates that the sex ratio may not constitute the main influencing factor for the population growth of these two provinces, that is, the main factor may not be a moderate sex ratio, or a large proportion of women of appropriate age.

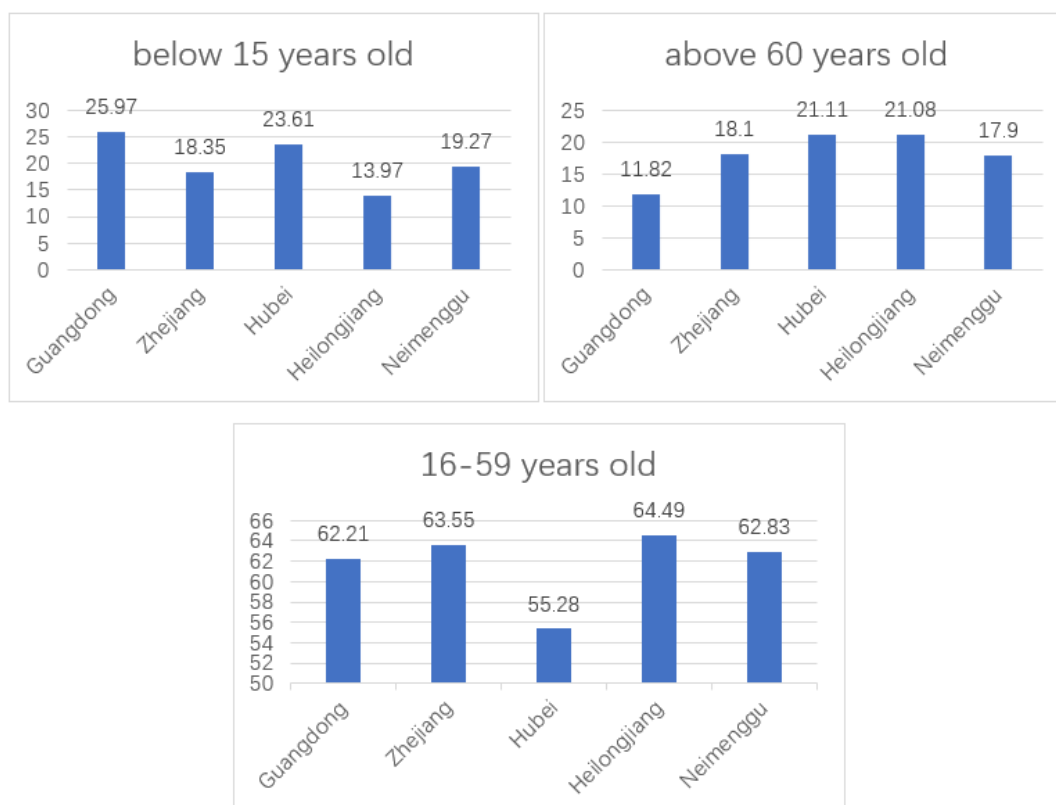


**Fig. 1** Sex ratio per province in 2020

## 4.2. Age structure factors

The age structure of the population is also called the age composition of the population, that is, the percentage of the population of each age composition in the total population. It not only has a significant impact on the type, speed and trend of the future population development, but also plays a corresponding role in the future economic development of the future society. Generally speaking, according to some indicators of the reaction population age structure, the population can be divided into three different population age structure types, namely young, adult and elderly. According to the proportion of the total population of the three types, the overall age structure was divided into expansion, stationary and systolic.

According to this analysis method, we divided the ages of the population of the five provinces into three stages, and counted the population of different provinces at different ages, and drew the following figure.



**Fig. 2** The ratio of people of all ages in China in 2020

Through observation, we can see that the age structure is relatively reasonable, 16-59 young adults labor population more, the population of 15 than the remaining five provinces, and the aging population over 60 is less, far lower than the aging ratio (19.74%), the characteristics of the overall age structure, the population expansion, so its population is relatively growth, at the same time can further show that the cause of population growth in Guangdong province may be mainly due to the population structure is reasonable, population aging degree is small.

At the same time, among the five provinces, the population under the age of 15 is the least, and Heilongjiang, with the largest population over the age of 60, has the lowest population growth rate and negative growth, showing an obvious trend of aging.

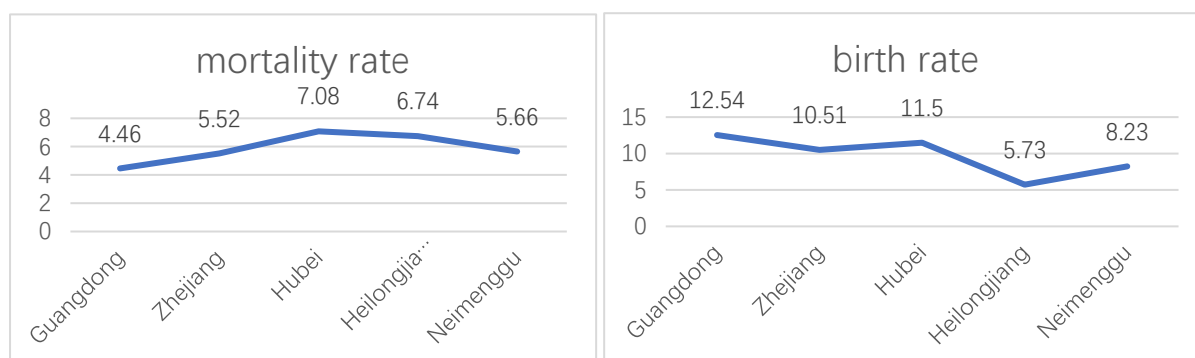
In Hubei province, which also has negative growth, the proportion of elderly population is still relatively high, while the number of young and middle-aged people is lower than that of the other four provinces, but the population under 15 years of age is relatively high. We can predict that in the future, the population growth rate of Hubei Province will increase to a certain extent.

### 4.3. Birth rate and mortality factors

Birth rate and death rate are the direct factors affecting the natural growth rate of the population: the birth rate is also known as the crude birth rate, which reflects the birth level of the population in a certain period of time, and has an important impact on the local economic development and population structure. In areas with high birth rate, the economic situation is not bad and there is a good development status. The birth rate is calculated as follows:  $\text{birth rate} = \text{annual number of births} / \text{annual average number} \times 1000 \%$ .

Mortality rate refers to the ratio of the number of deaths in a certain period of time to the average total number of deaths in the period, which is calculated as  $\text{mortality rate} = \text{number of deaths per year} / \text{annual average number} \times 1000 \%$ . Population mortality rate can be used to measure the population size of a region, and to some extent, it also reflects the local medical care level and the health status of the population.

Birth rate and mortality were used as a criterion for whether the population was normal. If the birth rate is far greater than the population mortality rate, it means the need to implement family planning, otherwise, it means that the population structure appears "pathological", the society will enter the aging, and the country needs to increase the birth encouragement policy. In general, the higher the birth rate, the dynamic the society is, making the age structure concentrated on the young adults. However, if the mortality rate is higher than the birth rate, it indicates that the overall age of the social population is older and will enter an aging society. At the same time, the aging of the population is more affected by the mortality rate, because the mortality rate can reflect the proportion of deaths in each age group in the total population of the age group, the higher the mortality rate, the serious aging of the society.



**Fig. 3** Line chart of the mortality and birth rate in the five provinces in 2020

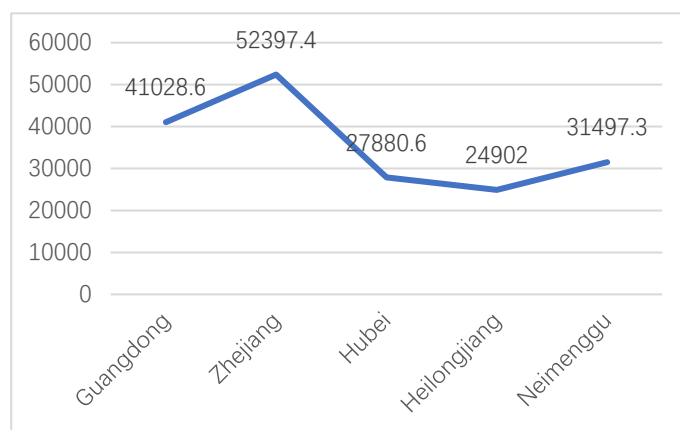
Through the curve, we can intuitively see that the population growth rate between birth rate and mortality, such as Guangdong and Zhejiang, in the negative, the negative population growth rate is negative, and this is consistent with the age structure affecting birth rate and mortality. At the same time, we find that the birth rate and mortality rate greatly affect the natural growth rate of the

population, and the changing trend of the population growth rate is very consistent with the natural growth rate of the population, so we are reasonable to speculate that the natural growth rate of the population has a great impact on the population growth rate.

#### 4.4. Urbanization rate

Economic factors can affect the natural growth rate of the population. The urbanization rate is an important indicator of economic development; other economic factors include education level, health status, urbanization, probability of survival, women's employment, material living standard, productivity and per capita disposable income.

Since per capita disposable income can reflect the urbanization rate, below we will draw and analyze the image of per capita disposable income.



**Fig. 4** Per capita disposable income in 2020

In the analysis of age structure, we found that Zhejiang and Inner Mongolia each age structure of population proportion is similar, but the population of Zhejiang province growth rate is significantly higher than the population growth rate of Inner Mongolia, so we can speculate that due to Zhejiang per capita disposable income is higher than Inner Mongolia of Guangdong Zhejiang provinces per capita disposable income is much higher than other provinces, economic strength is sufficient, fertility desire is sufficient, the fertility rate is higher, medical and health condition at the same time is better, the probability of newborn survival is higher.

At the same time, economic factors will also affect the mechanical growth rate of population migration and migration. It is reasonable to ignore the migration and migration of the population change of the country, which is allowed. However, in the comparative analysis of each province, the migration and migration of population has a great impact on a province, so we cannot ignore the impact of migration and migration at this time. According to the seventh census report, Guangdong, Zhejiang and Jiangsu are the top population growth rates, which are the two core economic growth poles of the Yangtze River Delta and the Pearl River Delta. These economically developed cities in the eastern coastal areas with complete urban facilities are very attractive to the young and middle-aged labor force and enjoy great demographic dividend, that is, the working-age population accounts for a large proportion of the total population and the dependency rate is relatively low, creating favorable population conditions for economic development.

In contrast, China's northeast, northwest, central China and other places are facing their own development difficulties: deep inland, remote location. Lack of ports and key roads prevents economic development; secondly, the northeast has cold climate, unfavorable traffic; high latitude and cold climate, once the road is frozen, the railway transportation is difficult in the northeast; and the lack of ports is difficult to facilitate the single industrial structure and severe brain drain. Today, it still retains its traditional industrial model, dominated by public enterprises but lacks private enterprises, which greatly reduces the momentum and vitality of the market. So the population of these places will move out, thus affecting the overall total number of people.

## 5. policy suggestion

In view of the current population problems facing China, namely, the unbalanced sex ratio, the aging population of the age structure, and the unbalanced regional development affecting the economy, we hereby put forward the following policy suggestions:

**Planning:** To prevent and comprehensively respond to the potential security problems within the population system and the security challenges between the systems in advance, so as to effectively ensure the population security.

**Measures:** Adhere to the current family planning policy, but the appropriate relaxation of the family planning policy will improve the birth rate, balance the sex ratio, and optimize the age structure. Improve the level of medical care, allow the newborn to get good care and rescue, so as to reduce the mortality rate and increase the birth rate, and strengthen relevant education to eliminate a series of backward ideas to promote gender balance. Strengthen the positive regulation, make the steady growth of the population. We will respect the law of population, meet the requirements of economic and social development and the fundamental interests of the people, improve policies to guarantee services, regulate fertility levels and maintain them within an appropriate range, optimize the population structure, improve the quality of the population, make the population flow more orderly, and continue to increase the population and resource endowment.

**Concept aspect:** highlight the people-oriented. We will adhere to the people-centered development philosophy and ensure the safety of people's lives and property.

**Layout aspect:** adhere to the comprehensive decision-making. We will effectively integrate population into economic and social policies, take full consideration into account in major decision-making such as strategic planning for economic and social development, strategic adjustment of the economic structure, distribution of investment projects and productive forces, coordination between urban and rural areas and sustainable development, and constantly improve the comprehensive decision-making mechanism for population and development. Vigorously develop the economy, promote the increase of individual disposable income, and then promote the overall fertility rate.

## 6. Advantages and weakness

### 6.1. Advantages

The established model has good fitting effect and high fitting coefficient. Based on the different characteristics of different factors in different periods, different models are established to seek truth from facts and well reflect the characteristics of population change.

Based on the population problems that we studied with a large number of complex samples, which need to be analyzed one by one to obtain more accurate results, we drew a large number of images and combined figures, so as to facilitate intuitive comparison.

In order to facilitate the in-depth study of the problem and obtain more accurate results, we have analyzed a variety of factors that may affect the population growth rate, and constantly improved our model in combination with the policy background and economic factors, so that it can have real practical significance and can play a role in the formulation of policies.

### 6.2. Weakness

The model was built without considering the impact of emergencies such as outbreaks.

The analysis of the total population of the country did not consider emigration.

There is no detailed explanation of the characteristics and differences of different urban and rural areas.



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