### Prediction of Long-term Care Insurance Enrollment Trends Based on the GM (1,1) Model in the Context of Population Aging: A Case Study of Kunming

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Abstract: This study aims to forecast the long-term care trend of insurance enrollment in Kunming from 2024 to 2027, with the goal of supporting strategic planning and providing a scientific basis for decision-making to address the challenges of population aging. Using the GM (1, 1) grev model, predictions were made based on enrollment data from 2021 to 2023 for long-term care insurance and basic medical insurance for urban employees. The forecast results show a steady increase in insurance enrollees, long-term care expected to reach 2.21 million by 2027. while urban employee basic medical insurance enrollment is projected to rise to 2.73346 million. The GM (1, 1) grey model effectively predicts future trends in long-term care insurance enrollment, highlighting the system's role in mitigating the impact of an aging population. It is recommended that relevant departments emphasize the development of long-term care insurance in policy planning and enhance the related policies to ensure both effectiveness and sustainability.

Keywords: Long-term Care Insurance; GM (1, 1) Grey Model; Population Aging; Health Insurance Policy; Enrollment Forecast

### 1. Introduction

The Long-Term Care Insurance system (hereinafter referred to as "LTCI") is a significant policy initiative by the state to address aging through a social insurance mechanism. [1] As one of the core components of the national medical security system, LTCI has received substantial attention and support from the state since the initiation of pilot programs in 2016. [2] With the proactive implementation of LTCI pilot programs, Kunming, as one of the second batch of pilot cities, has adopted several measures. These include establishing a separation of regulatory and operational functions, creating а multi-source funding mechanism, providing service deliverv options. flexible and developing comprehensive service а management system. These measures offer robust support for addressing population aging and ensuring the successful implementation of the LTCI system in Kunning. [3-5]

### 2. Theoretical Foundation

### 2.1 Grey System Theory

Grey system theory, [6] proposed to address problems with limited data and incomplete information, emphasizes extracting value from partially known information. It enables the prediction and control of system behavior through modeling and analysis. The GM (1,1)grey prediction model has shown unique effectiveness in analyzing situations with limited data and incomplete information, making it applicable in various fields, including socio-economic system analysis and emerging areas such as the study of LTCI. [7] The predictive accuracy of the GM (1,1)model depends on factors such as data characteristics and parameter selection, requiring proper optimization and adjustment in practical applications.

In China, the GM (1,1) model has been used to predict developments in community health services, demonstrating its ability to effectively forecast future trends. [8] The application of this model continues to improve and expand, such as through the optimization of parameters using the least squares method to enhance prediction accuracy. [9] For the study of Kunming's LTCI system, improving the GM (1,1) model and optimizing its parameters can provide precise forecasts of future development trends, offering a scientific basis for the formulation of effective policies.

## **2.2** Construction of the GM (1,1) Grey Model

The following steps outline the construction of the GM(1,1) model:

2.2.1 Data processing

Let  $x^{(0)}$  represent the original data series.  $x^{(k)}$  is the accumulated series generated.", and the grey differential equation is established as:

$$x^{(0)} = [x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)] \quad (1)$$

$$x^{(k)} = \sum^{i} x^{(0)}(m)$$
,  $k = 1, 2, \dots, n$  (2)  
2.2.2 Model construction

The GM-type grey differential equation is constructed based on the accumulated series  $\chi^{(k)}$ .

$$\frac{\mathrm{d}x^{(k)}}{\mathrm{d}t} + ax^{(k)} = u \tag{3}$$

Where  $\frac{dx^{(k)}}{dt}$  is the first-order accumulated series, *a* is the grey action quantity, and *u* is the non-homogeneous term.

Based on the established grey differential equation, the parameters a and u are determined using the least squares method or other parameter estimation techniques. By substituting the obtained values of a and u into the equation and solving it, the GM(1,1) prediction model is derived as:

$$x^{(k+1)} = [x^{(0)} + \frac{u}{a}]e^{-ak} - \frac{u}{a}$$
(4)

2.2.3Model validation and optimization Residual analysis and ratio deviation tests are conducted to evaluate the model's accuracy, ensuring its reliability for prediction purposes. [10]

### **3. Model Application and Results**

### 3.1 Data Processing and Analysis

### 3.1.1 Data sources

The data for this study comes from official statistics, relevant research literature, policy documents, and research reports. The primary sources include the "Statistical Bulletin" and "Statistical Yearbook" published on the Kunming municipal government's official website. These documents cover key indicators of Kunming's long-term care insurance (LTCI) system, such as historical enrollment figures,

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population and GDP statistics, municipal financial subsidies, and service coverage. For unpublished data, legal access was obtained through the Kunming municipal government's "by-request disclosure" channel.

3.1.2 Data preprocessing

Using Excel software, the basic data on Kunming's LTCI from 2021 to 2023 was comprehensively compiled and organized, resulting in a table (Table 1) summarizing the key information on LTCI in Kunming during this period. This includes critical indicators such as coverage numbers, fiscal budget allocations, and pilot program expenditures, providing a clear overview of the LTCI trial system's performance over the past three years. As shown in Table 1, from 2021 to 2023, Kunming's LTCI program received steadily increasing municipal financial subsidies ranging from 16 million to 19.6 million yuan annually. These funds primarily supported the implementation of LTCI projects, ensuring improvements in both coverage and service quality. The target participants of the program are urban employees enrolled in basic medical insurance, who must also be enrolled in LTCI. The Kunming Medical Insurance Bureau, following national policies, has gradually expanded the LTCI coverage to meet the increasing demand for long-term care. The program's funding is fully allocated, and it has increased with the rising number of enrollees, reflecting the government's continued investment and policy support in the LTCI sector. This ensures an important guarantee for improving coverage and service levels, while also providing sustainable financial support for the future development of LTCI.

Table 1. Basic Overview of Kunming's Long-Term Care Insurance (LTCI), 2021-2023

2021 2020					
	Coverage	Fiscal Budget	Pilot Program		
Year	(10,000	Allocation	Expenditure		
	people)	(million yuan)	(million yuan)		
2021	189.03	1600	9.06		
2022	196.58	1760	1.89		
2023	201.24	1960			

Data Source: Kunming Medical Insurance Bureau Response [2024] No. 1.

3.1.3 Data analysis

The long-term care insurance (LTCI) enrollment numbers in Kunming from 2021 to 2023 were extracted (see Figure 1), showing a steady upward trend in coverage. This indicates significant progress in the promotion and expansion of the LTCI system in Kunming. The increase in the number of people covered reflects the important role that the LTCI system plays in improving social welfare and service quality.

According to Kunming's pilot scheme, urban employees enrolled in basic medical insurance must also participate in LTCI. Therefore, changes in the enrollment figures of Kunming's urban employee basic medical insurance have a significant impact on LTCI enrollment numbers. To better predict future LTCI enrollment trends, the number of urban employee basic medical insurance enrollees in Kunming (see Table 2) is also used to establish the GM (1,1) model for predictive analysis. This compensates for the relatively short implementation period of LTCI in Kunming and the limited amount of available data, providing a more comprehensive and accurate forecast of LTCI trends.



Figure 1. Annual Coverage of Kunming's Long-Term Care Insurance (LTCI), 2021-2023

Table 2. Annual Enrollment Numbers for Kunming's Urban Employee Basic Medical Insurance, 2019-2022

Year	Coverage (10,000 people)	Growth ratio
2019	198.63	
2020	208.57	5.00%
2021	218.93	4.95%
2022	225.22	2.89%

Data Source: Kunming Municipal Bureau of Statistics.

### **3.2 Model Validation**

3.2.1 Likelihood ratio test

The likelihood ratio test was employed to assess the accuracy of the model by comparing the differences between the observed data values and the model's predictions to determine the precision of the forecasting model. As indicated by Figures 2 and 3, the model was constructed using data on long-term care insurance enrollment in Kunming and urban employee basic medical insurance enrollment in Kunming. The likelihood ratio values for the long-term care insurance enrollment predictions were 0.95 and 0.97, while the values for the urban employee basic medical insurance predictions were 0.95, 0.95, and 0.97. Both sets of likelihood ratio values fall within the standard range of [0.751, 1.331], suggesting that the data are suitable for model construction.





1.5			
1.1			
0.9			
0.7	2020	2021	2022
		Likelihood Ratio	

### Figure 3. Likelihood Ratio Deviation Test for Predicted Enrollment Numbers of Kunming's Urban Employee Basic Medical Insurance

3.2.2 Posterior residual ratio test

After constructing GM (1,1) models for the enrollment numbers of Kunming's Long-Term Care Insurance and Urban Employee Basic Medical the development Insurance, coefficient a, grey action quantity b, posterior residual ratio C, and small error probability Pwere obtained. The posterior residual ratio Cis used to assess the model's accuracy level, where a smaller C value indicates better model accuracy. A C value less than 0.35 signifies excellent model accuracy. [11] Additionally, a small error probability P value greater than 0.95 indicates high model accuracy. The specific standards for the P and C values are detailed in Table 3.

<b>Fable 3. Accuracy</b>	Classification	Standards for	r Gre	y Prediction Models
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Prediction Accuracy	Excellent	Acceptable	Marginal	Unacceptable
С	C<=0.35	0.35 <c<=0.5< td=""><td>0.5<c<=0.65< td=""><td>C&gt;0.65</td></c<=0.65<></td></c<=0.5<>	0.5 <c<=0.65< td=""><td>C&gt;0.65</td></c<=0.65<>	C>0.65
Р	P>0.95	0.8 <p<=0.95< td=""><td>0.7&lt;=P&lt;0.8</td><td>P&lt;0.7</td></p<=0.95<>	0.7<=P<0.8	P<0.7

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According to Tables 4 and 5, the C values for prediction models of Kunming's the Long-Term Care Insurance and Urban Employee Basic Medical Insurance are 0.0000 and 0.0076, respectively, both of which are below 0.35. The PPP values are 1.000 and 1.000, respectively, both exceeding 0.95. This indicates that both models exhibit high accuracy, with their predictions closely aligning with the actual observed data, demonstrating high precision and reliability. The constructed GM(1,1) models accurately reflect the future trends in enrollment numbers for Kunming's Long-Term Care Insurance.

# Table 4. Prediction Model ConstructionResults for Enrollment Numbers ofKunming's Long-Term Care Insurance

Development	Grey	Posterior	Small Error
Coefficient	Action	Residual	Probability
а	Quantity b	Ratio C	Р
-0.0234	189.8488	0.0000	1.000

### Table 5. Prediction Model Construction Results for Enrollment Numbers of Kunming's Urban Employee Basic Medical Insurance

	1115 41 41100						
Development		Grey	Posterior	Small Error			
Coefficient		Action	Residual	Probability			
а		Quantity b	Ratio C	Р			
	-0.0381	197.7510	0.0076	1.000			

### **3.3 Forecast Results**

According to Table 6, the GM(1,1) model predicts that the enrollment numbers for Kunming's Long-Term Care Insurance will reach 2.06 million in 2024 and further increase to 2.21 million by 2027. The results indicate a continuous growth trend in the enrollment

numbers for Kunming's Long-Term Care Insurance, reflecting the initial success of the pilot system. The insurance coverage is gradually expanding, and the number of insured individuals is increasing. This trend also highlights the surge in demand for long-term care due to population aging and the growing emphasis on medical and long-term care insurance.

The forecast for the enrollment numbers in Kunming's Urban Employee Basic Medical Insurance from 2023 to 2027 indicates that by 2027, the number of insured individuals is expected to reach 2.7335 million, continuing to rise thereafter. This trend reflects a steady increase in enrollment numbers, driven by comprehensive medical insurance policies and the impact of the aging population.

### 4. Forecast Results and Recommendations

## 4.1 Actively and Steadily Expand the Coverage of Long-Term Care Insurance

Based on the forecast results, the enrollment numbers for Kunming's Urban Employee Basic Medical Insurance and Long-Term Care Insurance are expected to continue growing over the next four years. The Kunming Long-Term Care Insurance policy should be advanced in an active, steady, and orderly manner. It is anticipated that the coverage and scope of protection will gradually expand to include more individuals with long-term care needs. [12]Consideration should be given to incorporating participants of urban and rural resident medical insurance into the Long-Term Care Insurance policy.

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	Employee Medical	Employee Medical	Long-Term Care	Long-Term Care
Year	Insurance	Insurance	Insurance	Insurance
	Enrollment	Enrollment Forecast	Enrollment	Enrollment Forecast
2019	198.63	198.63		
2020	208.57	209.29		
2021	218.90	217.43	189.03	189.03
2022	225.22	225.88	196.58	196.57
2023		234.67	201.24	201.23
2024		243.79		206.00
2025		253.27		210.88
2026		263.12		215.88
2027		273.35		221.00

 

 Table 6. Forecast of Enrollment Numbers for Kunming's Urban Employee Basic Medical Insurance (2019-2027) and Long-Term Care Insurance (2021-2027)

Note: "--" indicates that the data is missing or not yet available.

4.2 Establish and Improve a Kunming-Unique Long-Term Care

### **Insurance System**

With the increasing enrollment in Kunming's Urban Employee Basic Medical Insurance and Long-Term Care Insurance, it is necessary to further optimize policies to meet the growing demand. The Kunming municipal government should establish a coordinated cooperation mechanism and develop detailed implementation measures and regulations for Long-Term Care Insurance. This should include clarifying the insured population, benefit standards. service scope, and qualification requirements for service providers to ensure standardized operation and service quality. [13]

### **4.3 Strengthen Service System Construction** to Meet Diverse Service Needs

The forecast results indicate that the increase in enrollment for Kunming's Long-Term Care Insurance will drive a rise in long-term care needs. Kunming should focus on developing the long-term care service system by increasing the number of service institutions and points of service. Additionally, projects that integrate medical and nursing care should be promoted to achieve the seamless integration of healthcare and eldercare services. Services should be diversified, exploring personalized service models and establishing more nursing homes, rehabilitation centers, and community medical institutions to improve service coverage and quality. This will provide more convenient and attentive long-term care services for individuals with disabilities. [14-16]

### 5. Conclusion

This study utilizes Matlab software to construct a GM(1,1) model, predicting that by 2027, the number of insured individuals under the long-term care insurance (LTCI) program in Kunming will reach 2.21 million. The forecast provides a reference for future policy formulation and resource planning regarding LTCI in Kunming. It is anticipated that the Kunming municipal government and relevant departments will implement proactive and prudent measures to gradually expand the LTCI and establish coverage of я comprehensive tailored system to the characteristics of Kunming. This involves strengthening the service system and enriching the content of long-term care services to meet

the growing and diverse service needs. It is hoped that Kunming's LTCI system will be further improved and enhanced to provide more comprehensive and high-quality long-term care services, effectively addressing the challenges posed by population aging.

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