

## Rapid Estimation of Commercial Housing Price for Sale in Small-medium Cities Using GM (0, N) Model

Haitao Li\*, Feilong Zhang, Yilu Zhang and Rui Wang

School of Civil Engineering and Architecture, Anyang Normal University, Anyang, 455002, China

\*Corresponding Author: lht1585@aynu.edu.cn

### Abstract

The price of commercial housing in small-medium cities has a great influence on the development of real estate market, but the price is always difficult to be estimated accurately. The existing researches are both difficult to estimate the price of a single commercial building, and difficult to deal with the actual situation of many influencing factors and complex correlation of commercial housing price. Accordingly, this paper puts forward a rapid price estimation method of commercial housing price for sale in small-medium cities based on GM (0, N) model. Anyang city, a regional central city in northern Henan Province, is taken as an example, to verify the feasibility and effectiveness of the proposed method. This research has realized the accurate estimation of the sale price of a single commercial building under the static condition, and it has a reference value for the government, the real estate developers and the potential house buyers to estimate the price of commercial housing quickly and accurately.

### Keywords

Commercial housing; Price estimation; GM (0, N) model; Small-medium cities.

### 1. Introduction

The accuracy of commercial housing price estimation is related to the pricing rationality of its sales price and has an important impact on the long-term stability and prosperity of the real estate market. Therefore, the estimation of urban commercial housing price has become an important part of promoting the high-quality development of the real estate industry. The price of commercial housing is affected by many factors, and the relationship between these factors is complex, and many data are difficult to quantify. It is still a difficult problem to estimate the price of a single real estate quickly and accurately. There have been many related researches at present, Yan and Liu (2011) put forward the principal component analysis method to predict the price of commercial housing in Xi'an city [1]; Wu and Lan (2020) established multivariate regression model to analyze the influencing factors of commercial housing price in Yuncheng city [2], but the above two research results are difficult to estimate the price of a single commercial residential development project. Duan et al. (2019) used five kinds of regression models to predict the housing cost [3], but this research involves many factors and many samples, thus it is more complex. In conclusion, there is no fully applicable method to estimate the price of urban commercial housing. Although some quantitative or easily quantifiable factor data can be easily obtained, at the same time, a large number of factor data are difficult to obtain or quantify, which increases the difficulty of housing price estimation.

The Grey System Theory takes the small sample and poor information uncertain system with "some information is known and some information is unknown" as the research object, and it has been widely recognized in uncertainty research of less data and poor information [4]. GM (0, N) model is a very important prediction model in grey system theory, which has been

successfully applied in many fields, for instance, Zhang et al. (2019) used GM (0, N) model to predict the acquisition cost of intelligence radar [5]; Ge et al. (2016) used GM (0, N) model to predict the price of domestic large aircraft C919 [6]; Kang et al. (2021) used GM (0, N) model to predict gas emission [7], and Gao (2019) used GM (0, N) model to predict and quantitatively evaluate the structure of Luling minefield [8], and so on.

Anyang, a city in Henan Province of China, is located in the northernmost part of Henan Province and is positioned as a regional central city in Northern Henan. Anyang city has an urban area of 1218 square kilometers and a built-up area of 115 square kilometers in the central urban area. There are four municipal districts, namely Yindu District, Long'an District, Beiguan District and Wenfeng District. By the end of 2019, the city's total population was 5.9479 million and the urban resident population was 1.7397 million. However, the urbanization rate of the resident population was 53.3%, far lower than the national average of 60.6%. In recent years, the real estate industry in Anyang city has developed rapidly, especially since the implementation of the "comprehensive two child" policy, Anyang city real estate has ushered in a new round of development climax.

Therefore, this research attempts to use GM (0, N) linear static prediction model, take Anyang city as the empirical object, and reliably estimate the price of a single real estate with limited quantitative data, so as to provide a new idea for the price estimation of urban commercial housing. Firstly, based on the needs of modeling, the key factors are selected through query information and qualitative analysis; Then, based on the basic form of GM (0, n) model, through the selected key factors and the set number of samples, the process of establishing GM (0,5) model for commercial housing price estimation in Anyang city is written step by step, including complete error test and modeling success standard; after that, based on the established GM (0,5) estimation model, an empirical estimation model is established by substituting the collected specific sample data of Anyang city, and the accuracy test is carried out to ensure the reliability of the model; finally, Combined with the high-quality development needs of China's urban real estate industry, this paper puts forward constructive suggestions for the popularization and application of Anyang commercial housing price GM (0, N) estimation method proposed in this paper.

## 2. Key Factors Screening of Commercial Housing Price in Small-medium Cities

There are many factors affecting the price of commercial housing, and the relationship between factors and commercial house price is also complex. By consulting relevant literature [9-12], government portals, enterprise official websites and network resources, seven representative factors were selected for analysis according to data availability principle.

### 2.1. Auction Price of Residential Land

Real estate developers first need land plots to develop commercial houses. The land plots are sold by auction by government departments and obtained by developers through auction. The cost of bidding plots accounts for a large part of the cost of the whole commercial housing development project, which has an obvious impact on the subsequent housing price. The land transfer results of Anyang City can be obtained from the website of Anyang Natural Resources and Planning Bureau, with high data reliability.

### 2.2. Plot ratio of Residential Area

Floor area ratio is a commonly used and important concept in residential buildings. It refers to the ratio of the total building area on the ground to the area of constructible land. For developers, the plot ratio determines the proportion of land price cost in the house. In addition, the plot ratio is directly related to the comfort of living. The smaller the plot ratio is, the better

the environment of the community, and the more greening and public facilities. Obviously, the plot ratio can represent the living environment of commercial housing to a certain extent, which has a significant impact on the subsequent housing price. The plot ratio is public information with high reliability. The plot ratio of Anyang real estate can be found by the real estate information service platform.

### **2.3. Greening Ratio of Residential Area**

The greening rate is the ratio of the greening area within the planned construction land of the project to the planned construction land area. Greening rate is a concept used by developers to publicize real estate greening. There is no legal and regulatory basis, but this index can also reflect the Greening Status of residential areas. The greening rate is high, the building density is low, and it is more comfortable to live. The greening rate has a significant impact on the price of commercial housing. The greening rate of Anyang real estate can be found by the real estate information service platform.

### **2.4. Distance from Urban Business Center**

The urban business center is a business gathering area of a city, with perfect facilities, convenient transportation, complete industries, complete functions, diverse services and economic prosperity. The distance between commercial housing and urban commercial center largely reflects the degree of urban infrastructure construction and prosperity of residential areas. The distance from urban commercial center has a profound and far-reaching impact on the price of commercial housing. Generally, the closer to urban commercial center is, the higher the price of commercial housing. The distance data can be obtained by the route planning of map software and the data is intuitive and easy to obtain. In this research, Wanda Plaza (Anyang store) can be designated as the city business center of Anyang city.

### **2.5. Per-capita Disposable Income**

Commercial housing has the general attributes of commodities, and the purchasing power of buyers has an important impact on its pricing. Purchasing power can be expressed by per capita disposable income. The increase of per capita disposable income often indicates the economic and social development and the improvement of consumption level, which will promote the increase of people's demand for commercial housing, which will drive the rise of commercial housing prices. The per capita disposable income of a place is closely related to the local commercial housing price. The per capita disposable income data of Anyang City can be obtained from the website of the Statistics Department of Anyang Municipal Government.

### **2.6. Resident Population in Urban Areas**

The number of urban permanent residents can explain the size of the city and show the construction level and consumption potential of the city. Generally, the more permanent residents in cities and towns, the more job opportunities, the higher the construction level, the better the economic development, and the larger the commercial housing construction and consumer market. This index has an important impact on local commercial housing prices. The urban resident population data of Anyang city can be obtained from the website of the Statistics Department of Anyang Municipal Government.

### **2.7. Urbanization Rate**

With the advancement of urbanization, the driving ability of urban agglomeration and radiation is enhanced, the urban construction and development of the city, the improvement of public service level, and more people gather in the city, which increases the demand for house purchase. Urbanization is an important driving force to promote the construction and development of commercial housing. A higher degree of urbanization will bring better urban infrastructure, drive the rise of land prices and deeply affect the price of commercial housing.

The urbanization degree data of Anyang city can be obtained from the website of the Statistics Department of Anyang Municipal Government.

The influencing factors of commercial housing price in Anyang city are complex and diverse. Because this study adopts the estimation method of GM (0, N) static model, which collects sample data and realizes static estimation under the same time section conditions, so as to avoid the influence of time factors, such as disposable income, urban permanent population. The impact of urbanization on commercial housing prices is reflected in the time scale of flow, so it is not suitable to be used as the influencing factors of this research modeling, and they are not selected as the key data. In addition, due to the difficult acquisition of some factor data, complex correlation between some factors, difficult quantitative statistics of many factors, and few quantitative or quantifiable factors in the influencing factors of commercial housing price, GM (0, N) model is a good method to estimate the problems of few samples and poor information. It does not involve derivation, the principle is simple, and the model solution is simple.

Therefore, starting from the objective characteristics of commercial housing itself, this study selects the factors that have a great impact on housing price, data quantification or easy to quantify and easy to collect among many factors, and comprehensively considers the importance of influencing factors and the demand for convenient modeling. Finally, four key factors affecting commercial housing price are selected: The auction price of residential land, the plot ratio of residential area, the greening ratio of residential area and the distance from urban business center.

### 3. GM (0, N) Modeling Principle to Rapid Estimation of Commercial Housing Price for Sale in Small-medium Cities

#### 3.1. Gm (0, N) Model

According to Grey System Theory [4], the general form of GM (0, N) model is as follows:

**Definition 1:** Assume that  $X_i^{(0)} = (x_i^{(0)}(1), x_i^{(0)}(2), \dots, x_i^{(0)}(n))$  is a data sequence of a system's characteristic variable,

$$\begin{aligned} X_2^{(0)} &= (x_2^{(0)}(1), x_2^{(0)}(2), \dots, x_2^{(0)}(n)) \\ X_3^{(0)} &= (x_3^{(0)}(1), x_3^{(0)}(2), \dots, x_3^{(0)}(n)) \\ &\vdots \\ X_N^{(0)} &= (x_N^{(0)}(1), x_N^{(0)}(2), \dots, x_N^{(0)}(n)) \end{aligned}$$

data sequences of relevant factors, and  $X_i^{(1)}$  the accumulation generated sequence of  $X_i^{(0)}$   $i = 1, 2, \dots, N$ ,  $x_i^{(1)}(k) = \sum_{k=1}^n x_i^{(0)}(k) (i = 1, 2, \dots, N)$ . Then

$$x_1^{(1)}(k) = a + b_2 x_2^{(1)}(k) + b_3 x_3^{(1)}(k) + \dots + b_N x_N^{(1)}(k) \quad (1)$$

is called the model of GM (0, N). Because this model does not contain any derivative, it is a statistic model. Although its form looks like a multivariate linear regression model, it is essentially different from any of the statistical models. In particular, the general multivariate linear regression model is established on the basis of the original data sequences, while the model of GM (0, N) is constructed on the accumulation generation of the original data.

**Theorem 1:** Assume  $X_i^{(0)}$  and  $X_i^{(1)} (i = 1, 2, \dots, N)$  as given in Definition 1, let

$$B = \begin{pmatrix} 1 & x_2^{(1)}(2) & B & x_N^{(1)}(2) \\ 1 & x_2^{(1)}(3) & B & x_N^{(1)}(3) \\ C & C & E & C \\ 1 & x_2^{(1)}(n) & B & x_N^{(1)}(n) \end{pmatrix}, Y = \begin{pmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ C \\ x_1^{(0)}(n) \end{pmatrix}$$

Then the least squares estimate of the parametric sequence  $\beta = (a \ b_1 \ b_2 \ B \ x_N^{(1)}(n))^T$  is given by

$$\beta = (B^T B)^{-1} B^T Y \tag{2}$$

### 3.2. The GM (0, N) Model to Rapid Estimation of Commercial Housing Price for Sale in Small-medium cities

According to the four key factors selected by qualitative analysis, this paper constructs the model of GM(0, N) to rapid estimation of commercial housing price for sale in small-medium cities as follows:

Suppose there are sample data of  $n$  commercial buildings being built or sold, each sample data set consists of the data of average selling price and its four key influencing factors. Take the average selling prices of these  $n$  commercial buildings being built or sold as system's characteristic variable sequence, written as  $X_1^{(0)}$  as given in Definition 1; Take the data of key influencing factors of these  $n$  commercial buildings being built or sold as data sequences of relevant factors, written as  $X_i^{(0)}(i = 2,3,4,5)$  as assumed in Definition 1, and  $X_i^{(1)}$  the accumulation generated sequence of  $X_i^{(0)}$ . Consequently, the GM(0,N) model to rapid estimation of commercial housing price for sale in small-medium cities based on four key factors can be constructed as

$$x_1^{(1)}(k) = a + b_2 x_2^{(1)}(k) + b_3 x_3^{(1)}(k) + b_4 x_4^{(1)}(k) + b_5 x_5^{(1)}(k) \tag{3}$$

The specific implementation steps of GM(0,5) model are as follows:

Step 1: Collect information and data of commercial buildings being built or sold. Find and select the typical samples commercial buildings being built or sold which are suitable for modeling, collect and sort out their data to build sample data set, as shown in Table 1.

**Table 1.** The sample data set of commercial buildings being built or sold

The commercial housing sample	The sample data of system's characteristic variable and influencing factors				
	The average selling price (yuan/m <sup>2</sup> )	The auction price of residential land (10 thousand yuan/m <sup>2</sup> )	The plot ratio of residential area (%)	The greening ratio of residential area (%)	The distance from urban business center (km)
$A_1$	$x_1^{(0)}(1)$	$x_2^{(0)}(1)$	$x_3^{(0)}(1)$	$x_4^{(0)}(1)$	$x_5^{(0)}(1)$
$A_2$	$x_1^{(0)}(2)$	$x_2^{(0)}(2)$	$x_3^{(0)}(2)$	$x_4^{(0)}(2)$	$x_5^{(0)}(2)$
...	...	...	...	...	...
$A_n$	$x_1^{(0)}(n)$	$x_2^{(0)}(n)$	$x_3^{(0)}(n)$	$x_4^{(0)}(n)$	$x_5^{(0)}(n)$

Step 2: Construct the model of GM (0,5) as given in equation (3), and written the matrix  $B$  and  $Y$  as given in Theorem 1:

$$B = \begin{pmatrix} 1 & x_2^{(1)}(2) & B & x_5^{(1)}(2) \\ 1 & x_2^{(1)}(3) & B & x_5^{(1)}(3) \\ C & C & E & C \\ 1 & x_2^{(1)}(n) & B & x_5^{(1)}(n) \end{pmatrix}, Y = \begin{pmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ C \\ x_1^{(0)}(n) \end{pmatrix}$$

Step 3: Calculate the least squares estimate of the parametric sequence  $\hat{\beta} = (a \ b_2 \ b_3 \ b_4 \ b_5) = (B^T B)^{-1} B^T Y$ , and obtain the rapid estimation formula  $x_1^{(1)}(k) = a + b_2 x_2^{(1)}(k) + b_3 x_3^{(1)}(k) + b_4 x_4^{(1)}(k) + b_5 x_5^{(1)}(k)$ . Therefore, the simulation results can be listed as shown in Table 2.

**Table 2.** The simulation results with errors

Ordinarily	The real data $x_1^{(0)}(k)$	The simulated values $\hat{x}_1^{(0)}(k)$	The errors $\omega^{(0)}(k)$	The relative errors $\delta(k)$
2	$x_1^{(0)}(2)$	$\hat{x}_1^{(0)}(2)$	$\omega^{(0)}(2)$	$\delta(2)$
3	$x_1^{(0)}(3)$	$\hat{x}_1^{(0)}(3)$	$\omega^{(0)}(3)$	$\delta(3)$
...	...	...	...	...
$n$	$x_1^{(0)}(n)$	$\hat{x}_1^{(0)}(n)$	$\omega^{(0)}(n)$	$\delta(n)$

In Table 2:  $\hat{x}_1^{(0)}(k) = \hat{x}_1^{(1)}(k) - \hat{x}_1^{(1)}(k-1)$ ;  $\omega^{(0)}(k) = x_1^{(0)}(k) - \hat{x}_1^{(0)}(k)$ ;  $\delta(k) = \frac{|\omega(k)|}{x_1^{(0)}(k)} (\%)$ ;  $k = 2, 3, \dots, n$ .

Step 4: Test the model accuracy, including simulation accuracy test and estimation accuracy test. Relative error test (RET) method and posteriori error test (PET) method are commonly used method to test the statistical characteristics of model residuals [5].

The calculation formula of RET method is

$$\bar{\delta} = \frac{1}{n} \sum_{k=1}^n \delta(k) \tag{4}$$

The RET standard of model accuracy is shown in Table 3.

**Table 3.** Accuracy gradation criteria for relative error test

Accuracy gradation	Excellent	Good	Qualified	Unqualified
Relative error (%)	$\delta \leq 5$	$5 < \delta \leq 10$	$10 < \delta \leq 30$	$\delta > 30$

Assume  $\bar{x}_1^{(0)} = \frac{1}{n} \sum_{k=1}^n x_1^{(0)}(k)$ ,  $\bar{\omega}^{(0)} = \frac{1}{n} \sum_{k=1}^n \omega^{(0)}(k)$ , then the mean square deviation  $S_1$  of the original data sequence and the mean square deviation  $S_2$  of the residual sequence can be obtained by the following two formulas respectively:

$$S_1^2 = \frac{1}{n-1} \sum_{k=1}^n (x_1^{(0)}(k) - \bar{x}_1^{(0)})^2 \tag{5}$$

$$S_2^2 = \frac{1}{n-1} \sum_{k=1}^n (\omega^{(0)}(k) - \bar{\omega}^{(0)})^2 \tag{6}$$

After that, the mean square deviation ratio of the model is  $C = \frac{S_2}{S_1}$ , and the small error probability of the model is  $p = P(|\omega^{(0)}(k) - \bar{\omega}^{(0)}| < 0.6745 S_1)$ . Consequently, The PET standard of model accuracy in Table 4 can be used as a reference.

**Table 4.** Accuracy gradation criteria for posteriori error test

Accuracy gradation	Excellent	Good	Qualified	Unqualified
Mean square deviation ratio (C)	$C \leq 0.35$	$0.35 < C \leq 0.50$	$0.50 < C \leq 0.65$	$0.65 < C$
Small error probability (p)	$p \geq 0.95$	$0.80 \leq p < 0.95$	$0.70 \leq p < 0.80$	$p < 0.70$

Use the above two methods to test the model accuracy. If the accuracy requirements are not met (the model accuracy is required to be "Excellent" in this paper), return to step 1, rescreen the modeling samples, and check whether the modeling process is wrong until the accuracy of the model meets the requirements.

#### 4. Case analysis of Anyang city in China

The completed amount of real estate investment in Anyang city was 20191.99 million yuan in 2020,, an increase of 16.4%, of which the completed amount of residential investment was 16872.89 million yuan, accounting for 83.6% of the total, an increase of 14.2%; The sales area of commercial houses was 5.938 million square meters, an increase of 22.9%, including 5.75 million square meters of residential houses, accounting for 96.8% of the total sales area, an increase of 26.4%; The sales volume of commercial housing was 31987.71 million yuan, an increase of 25.8%, including 30740.29 million yuan of residential housing, accounting for 96.1% of the total sales volume, an increase of 31.1%. This shows that the real estate industry in Anyang city, especially the commercial housing industry, is full of vitality.

##### 4.1. Collect Modeling Data

**Table 5.** The sample data set of commercial buildings being built or sold in Anyang city

The commercial housing sample	The sample data of system's characteristic variable and influencing factors				
	The average selling price (yuan/m <sup>2</sup> )	The auction price of residential land(10 thousand yuan/m <sup>2</sup> )	The plot ratio of residential area (%)	The greening ratio of residential area (%)	The distance from urban business center (km)
ZhongsenYuelong	6300	0.292	2.49	0.45	9.2
Run'an Fenglintai	7900	0.766	2.49	0.40	4.4
Yuantai Jinghua II	6350	0.450	2.89	0.36	6.8
Anyang Jianye Garden	6650	0.451	2.49	0.40	11
Yuanbo Yuhu Chenyuan	8890	0.597	2.49	0.40	4.6
Run'an Jiufu	8500	0.921	2.49	0.40	4.7
Kaixiang Yulong City	5800	0.304	1.99	0.40	11
Jianyuan Xiujiangnan	5500	0.300	2.00	0.40	12
Jinqiu Huafu	5900	0.407	2.49	0.40	11

Next, collect the relevant data of several real estate projects in Anyang city, including five index data such as the auction price of residential land, the plot ratio of residential area, the greening ratio of residential area, the distance from urban business center (Wanda Plaza (Anyang store) is designated as the city business center of Anyang city in this paper) and The average selling price, and carry out GM (0, 5) model modeling and estimation of commercial housing price estimation. In order to maximize the value of modeling information data and make the model more representatives, the selected buildings should be located in different locations in Anyang city as far as possible, and other relevant information should also maintain certain differences. By querying the website of Anyang Natural Resources and Planning Bureau, we found the publicity of land transfer results in recent years, selected 9 plots whose planned purpose is residential land or residential land compatible with commerce, recorded the transfer area and transaction price of these 9 plots, and calculated the auction price of 9 plots. The 9 plots are numbered as ays-2017-44, ays-2018-20, ays-2019-7, ays-2018-42, ays-2018-8, ays-2018-35,

ays-2017-33, ays-2017-34 and ays-2018-28 respectively. Record the addresses and bidders of the 9 plots in the publicity of the transfer results. Combined with the query of Anjuke website, the names of the follow-up development projects of the 9 plots are Zhongsen Yuelong, Run'an fenglintai, Yuantai Jinghua II, Anyang Jianye garden, Yuanbo Yuhuchenyuan, Run'an Jiufu, Kaixiang Yulong City, Jianyuan Xiu Jiangnan and Jinqiu Huafu. Find the specific address of Anyang city where 9 buildings are located through Gaode map APP, We found that these 9 buildings are scattered and cover a wide range of Anyang urban area, which is conducive to modeling. It is very appropriate to select these 9 buildings for modeling and estimation. After that, the average selling price, the plot ratio of residential area and the greening ratio of residential area of 9 buildings were collected through Anjuke website. The above information and data were collected in April 2021, and the modelling data were listed in Table 5.

In order to test the estimation accuracy of the model, the first seven samples are selected as the modeling data, and the last two samples are selected as the estimation test data.

#### 4.2. Construct GM (0, 5) Model and Analysis Results

According to the modelling method as mentioned in section 3.2 and the modeling samples data in Table 5, we can obtain the formula of GM (0, 5) model

$$x_1^{(1)}(k) = -2884.038 - 0.410x_2^{(1)}(k) + 170.852x_3^{(1)}(k) + 25287.685x_4^{(1)}(k) - 397.566x_5^{(1)}(k)$$

Next, the simulation results with errors can be calculated, see Table 6.

**Table 6.** The simulation results with errors of the case in Anyang city

Ordinarily	The real data $x_1^{(0)}(k)$	The simulated values $\hat{x}_1^{(0)}(k)$	The errors $\omega^{(0)}(k)$	The relative errors $\delta(k)$
2	7900	7754.006	145.994	1.85%
3	6350	6893.695	-543.695	8.56%
4	6650	6167.085	482.915	7.26%
5	8890	8711.447	178.553	2.01%
6	8500	8671.558	-171.558	2.02%
7	5800	6081.719	-281.719	4.86%

The estimated average selling price, residual error and relative error of Jianyuan Xiujiangnan (No.8) and Jinqiu Huafu (No.9) are calculated, the results are shown in Table 7.

**Table 7.** The simulation results with errors of the case in Anyang city

Ordinarily	The commercial housing name	The average selling price(yuan/m <sup>2</sup> )	The estimated average selling price(yuan/m <sup>2</sup> )	The residual error	The relative error
8	Jianyuan Xiujiangnan	5500	5685.863	-185.863	3.38%
9	Jinqiu Huafu	5900	6167.102	-267.102	4.53%

According to the model accuracy methods as mentioned in section 3.2 and Table 6, the simulated average relative error of the model is  $\bar{\delta}(k) = 3.79\% < 5\%$ , the mean square deviation ratio of the model is  $C = \frac{S_2}{S_1} = 0.28 \leq 0.35$ , and the small error probability of the model is  $p = P(|\omega^{(0)}(k) - \bar{\omega}^{(0)}| < 0.6745S_1) = 1 \geq 0.95$ . Therefore, the simulation accuracy grade of the GM (0, 5) estimation model is "Excellent", which meets the accuracy requirements. Finally, the generalization accuracy of the GM (0, 5) estimation model is tested, and the results can be seen in Table 8.



**Table 8.** The generalization accuracy of the GM (0, 5) model of the case in Anyang city

Ordinarily	The commercial housing name	$\delta(k)$	$C$	$p$	Accuracy gradation
8	Jianyuan Xiujiangnan	3.38%	0.25	1.00	Excellent
9	Jinqiu Huaifu	4.53%	0.27	1.00	Excellent

## 5. Application Suggestions of GM (0, N) Model for Commercial Housing Price Estimation

There are large numbers of cities in China, the market prospect of urban commercial housing industry is broad, and the demand for urban commercial housing price estimation will be very strong. The GM (0, N) estimation method proposed in this study has the outstanding advantages of simplicity, high accuracy and can estimate the price of a single real estate. It has great potential to be popularized. The popularization and application of this method will contribute to the high-quality development of urban commercial housing industry. The promotion of this research method should adhere to the actual characteristics of commercial housing development in the studied city, screen key factors, select real estate samples and establish models. The high-quality development of the commercial housing industry is inseparable from the dual role of the government and the market. Next, from the perspective of the government, developers and buyers, this paper puts forward some suggestions on the high-quality development of the urban commercial housing industry and the popularization and application of the commercial housing price estimation GM (0, N) model proposed in this study.

### 5.1. Application Suggestions for Government

The government should do a good job in housing construction planning, achieve orderly development, promote the balance between supply and demand, and guard against housing inventory. Adhere to the principle of housing without speculation and reasonably regulate house prices. In line with the national strategy, promote the structural reform of housing supply side, promote the construction of affordable housing and promote social stability. At the same time, the government should strengthen urban infrastructure construction and support the construction and development of relevant enterprises.

According to the GM (0, N) model proposed in this study, the government can screen the key factors affecting the price of commercial housing, select sample buildings, collect corresponding information, establish the corresponding GM (0, N) model, estimate the price of new buildings opened by real estate developers, realize more accurate control over the price of commercial housing, promote the rational pricing of commercial housing and better carry out market supervision, Promote the prosperity and stability of the real estate market.

### 5.2. Application Suggestions for Real Estate Developers

On the premise of ensuring the profit space, real estate developers should not excessively pursue profits, combine their own strength, cooperate with the medium and long-term planning of local cities, reasonably promote the project, and actively improve the service level and real estate development and construction standards. Combined with the local historical and cultural characteristics of the city and modern urban planning, make differentiation, develop real estate buildings with regional characteristics showing local excellent culture, and develop practical real estate house types loved by the people considering the real life needs of buyers. At the same time, real estate developers should actively bear social responsibility, actively pay taxes and operate in good faith.

According to the GM (0, N) model proposed in this study, real estate developers can screen the key factors affecting commercial housing prices, select sample buildings, collect corresponding

information and establish the corresponding GM (0, N) model to accurately estimate the sales price of new investment buildings, reduce the difficulty of pricing, reasonably price, promote sales and accelerate the return of funds, so as to improve their competitiveness, Better protect their own commercial interests.

### 5.3. Application Suggestions for Potential House Buyers

The potential house buyers should buy real estate according to actual needs and consciously resist real estate speculation. Loan purchase should comprehensively consider its own economic situation and income expectation.

According to the GM (0, N) model proposed in this study, the potential house buyers can screen the key factors affecting the price of commercial housing, select sample buildings, collect corresponding information, establish the corresponding GM (0, N) model, estimate the price of commercial housing, evaluate the rationality of its sales price, and better protect their legitimate rights and interests.

## 6. Conclusions

This paper introduced GM (0, N) model to solve the difficult problem to estimate the price of a single commercial building, and at the same time, it also solve the difficult problem to deal with the actual situation of many influencing factors and complex correlation of commercial housing price. Firstly, according to the principles of easy availability and quantification of data, 4 key factors affecting commercial housing price for sale in small-medium cities were qualitatively selected, they are the auction price of residential land, the plot ratio of residential area, the greening ratio of residential area and distance from urban business center. Then, the general form of GM (0, N) model is introduced, and the model of GM (0, 5) based on the above four factors is constructed, which is suitable for estimating the price of a single commercial building in small-medium cities. Finally, Anyang city is taken as an example to case analysis, the simulation accuracy and estimation accuracy of the GM (0, 5) model are both "Excellent", which verify the feasibility and effectiveness of the proposed method. In addition, some suggestions on the popularization and application of GM (0, N) model are put forward from the perspective of government, real estate developers and potential house buyers.

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## References

- [1] Y. Yan and K.R.Liu. Prediction of commodity housing prices based on principal component analysis—take Xi'an for example [J]. Journal of Xidian University (Social Science Edition), 2011, 21(4): 52-58.
- [2] Y.Q. Wu and J.R. Lan. Study on the influencing factors of commodity housing price in Yuncheng City [J]. Journal of Yuncheng University, 2020, 38(1): 74-78.
- [3] Y.H. Duan, C.F. Fang, Y.B. Guo et al. Comparative study on urban housing cost model —based on the selection of rapid estimation method [J]. Price Theory and Practice, 2019, 39(11): 78-81.
- [4] S.F. Liu, Y.J. Yang and J. Forrest. Grey data analysis: methods, models and applications [M]. Singapore: Springer-Verlag, 2017.

- [5] C.C. Zhang, Q.H. Liu, P.C. Du et al. Intelligence radar acquisition cost prediction based on modified GM (0, N) model [J]. Journal of Air Force Early Warning Academy, 2019, 33(4): 244-248.
- [6] C. Ge, Z.G. Fang and G.Y. Bi. The price forecasting of C919 in the view of GM (0, N) model [C]. Proceedings of the 25th national Grey System Conference, 2014, 4: 156-159.
- [7] E.S. Kang, H.D. Meng and X.P. Li. GM(0, N)-ELM prediction of gas emission based on multi-source monitoring data [J]. Mathematics in Practices and Theory, 2021, 51(13): 139-147.
- [8] Y. Gao. Structural prediction and quantitative evaluation based on GM (0, N) grey prediction model [J]. China Coal, 2019, 45(6): 38-42+101.
- [9] H.B. Li, H. Huang and X.H. Yan. Impact factor analysis of real estate price in Chongqing city based on grey correlation and ridge regression analysis [J]. Journal of Geomatics, 2015, 40(6): 82-85.
- [10] Z.Y. Zhang, X.L. Wang, H.K. Li. Spatial distribution of residential price in small and medium-sized cities and its influencing factors--a case study of Ganzhou City [J]. Science of Surveying and Mapping, 2020, 45(6): 172-179.
- [11] Y. Gao, G.F. Tian, Y.F. Guo et al. Study on the impact of population structure factors on urban commercial housing prices -- a case study of Cangzhou City [J]. Business and Economy, 2021, 40(4): 34-35+166.
- [12] S.L. Deng and L.G. Ou. Analysis on Influencing Factors of housing price based on spatial Dobbin model -- empirical data from 105 cities [J]. China Real Estate, 2021, 42(9): 16-25.