Housing Price Research Based on System Dynamics Model

Jingyi Guo¹, Junwu Wang²
¹School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan, China
²School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan, China
*Corresponding author’s e-mail: webmaster@whut.edu.cn

Abstract: Based on the theory of system dynamics, a system dynamics model regarding to housing price is constructed. The changes on housing price are simulated via Vensim DSS software, and the effectiveness of the model is verified. Policy regulation experiments are conducted from the prospective of population, land and taxation that are mostly concerned by the government. It can be concluded that the land policy and taxation policy are the main methods for regulation. It provides macro-direction for the government to manage the commercial housing market and control the price of commercial residential house, as well as corresponding decision basis for house purchasers and commercial housing developers in their purchasing and investing. It also provides a systematic prediction method for the comprehensive simulation system of the commercial housing market.

1. Introduction
Commercial housing is a critical component of the real estate industry, and it is also the main project of contemporary civil engineering. The price of commercial housing is a hotspot issue that has drawn many attentions during the development of the real estate industry. Discussing the internal mechanism of the housing price, as well as controlling its excessive fast growing are the keypoints for a continuous and healthy development of the housing industry. As a building that is closely related to daily life, commercial building must be equipped with the features of necessity, endurance, stationarity, value preservation and increment. Those features have determined that there are many factors that could influence its price, and the relationships between each other are complicated. It is clearly not enough to adopt mathematical research method from the general economy theory. The theory of system dynamics and the model construction principles and methods provide powerful tools for solving issues in complicated systems or even mega-systems. [1]

This paper takes commercial housing as the research target and builds a commercial housing price model by system dynamics methods. Through simulation, it provides theoretical basis for government’s macro regulation on the commercial housing price, the real estate developer’s investment decision and purchaser’s purchasing decision. Instead of having detailed classification on the research topics like other subjects, the system dynamics considers all issues as an integrated one. Then through qualitative and systematic analysis, a system structure model is constructed. Then the relationships between each factor are described mathematically. Finally, the overall mathematical description is realized via simulation.[2]
2. Methodology

2.1 Indicator Selection and Data Source

The price of commercial housing is mainly determined by the supply and demand relationship and is the result of the combined effect of social, economic and policy factors. Through the analysis of the price system of commercial housing, several main factors affecting the price of commercial housing are selected [3], for example: population growth, comprehensive cost, housing demand, housing supply, land grant area, per capita living area, GDP, etc.

The commercial housing market in Wuhan from 2003 to 2017 are selected as the research sample. The main sources of data are the Wuhan Statistical Yearbook and the website of the National Bureau of Statistics. The relationships between most variables are given in the form of various functions.

2.2 Building Model

2.2.1 System Causality-feedback Diagram

Based on the summary of research results of relevant scholars, and according to the actual situation of the commercial housing market in Wuhan, this paper conducts analysis and model building starting from several aspects including housing supply, housing demand, price composition, land supply, population, economy, leasing, and macro-control. Then the causality-feedback diagram of each subsystem is acquired. Considering the limited paragraph, only the supply subsystem, price subsystem, and land subsystem are specified as examples.

Figure 1 Causality diagram of residential supply subsystem
Figure 2 Causality diagram of residential price subsystem
2.2.2. The relationship between main variables in the model are as follow:

1) The vacancy rate is 0.1. According to international common practice, the reasonable vacancy rate of commercial housing should be between 5% and 10%, and the supply and demand of commercial housing is balanced. Since it is not able to obtain the specific value of the vacancy rate in Wuhan over the years, the objective value is considered as 0.1.

2) The plot ratio is 2.5. According to the information on the website of the Wuhan Municipal Bureau of Land Resources and Planning, the plot ratio is 2.5 when the land is graded.

3) Unsold construction area = newly started residential area *(1- pre-sale ratio)

4) Housing pre-sale area = pre-sale ratio * newly started housing area.

The pre-sale mechanism is the most important way to sell commercial housing in China. According to relevant data from the National Bureau of Statistics, the sales proportion of the country’s forward delivery housing sales (pre-sale) in the total sales has gradually increased from 63% in 2005, and the proportion of pre-sale in 40 large and medium-sized cities has always remained higher than 80%. Therefore, the pre-sale ratio is taken as 0.8.

5) Investment in real estate development =0.2873* investment in capital construction -31.023

6) Development profit rate=IF THEN ELSE( (housing price-comprehensive cost)/comprehensive cost<=0, 0.2, (housing price-comprehensive cost)/comprehensive cost)

7) Land price = ((0.055719* residential land transfer area+1.22197* benchmark land price-259.521)*land price policy+1200*PULSE(2004, 1)+2400*PULSE(2005, 1)+900*PULSE(2007, 1)-2500*PULSE(2008, 1)-2550*PULSE(2009, 1))

8) Developers' willingness to develop=IF THEN ELSE (supply-demand ratio development impact factor*0.215+development profit rate*0.32+bank support intensity impact factor*0.423-0.102*vacancy rate+1>=1:OR:supply-demand ratio development impact factor *0.215+Development profit

Figure 3 Causality diagram of residential land subsystem
rate*0.32+Bank support intensity influence factor*0.423-0.102*Vacancy rate+1<=0.8, 1, Supply-demand ratio Development influence factor*0.215+Development profit margin*0.32+Bank support intensity influence factor*0.423 -0.102*vacancy rate+1)

9) Newly started residential area = IF THEN ELSE (housing land transaction area * floor area ratio * coefficient>=476.33*LN (Investment in residential development)-1586.2, 476.33*LN (Investment in residential development) -1586.2, housing land transaction area *Floor area ratio*5)+0*PULSE(2003, 3)

2.2.3 Simulation Result and Model Test

By using Vensim DSS software, this paper simulates and calculates relevant data in housing from 2003 to 2017, and predicts the specific values of the main indicators from 2018 to 2030.

The simulation effect of the model can be verified by the relative error between the historical value and the simulation value. The formula for calculating the relative error is:

\[ e_i = \frac{y_i^\wedge - y_i}{y_i} \]

(1)

\( i=1,2,\ldots, g; t=2003,2004,\ldots,2017 \)

\( y_i^\wedge \) and \( y_i \) represent the actual value and simulated value of the i-th variable in year “t”, respectively, and “g” is the number of variables in the model. If the number of variables with e<5% accounts for more than 70% and the relative error of each variable is not more than 10%, it is considered that the overall simulation and prediction performance of the model is good. The commercial housing prices and urban GDP are selected as test indicators.

| Year | True value (100 million yuan) | Simulation value (100 million yuan) | Relative error (%) | True value (ten thousand people) | Simulation value (ten thousand people) | Relative error (%) |
|------|-------------------------------|-------------------------------------|--------------------|----------------------------------|----------------------------------------|--------------------|
| 2003 | 1662.18                       | 1662.18                             | 0                  | 2023.00                         | 2023                                   | 0                  |
| 2004 | 1956.00                       | 1949.08                             | -0.35              | 2462.73                         | 2499.38                                | 1.49               |
| 2005 | 2238.00                       | 2266.33                             | 1.27               | 2986.20                         | 3074.79                                | 2.97               |
| 2006 | 2590.76                       | 2711.11                             | 4.65               | 3535.26                         | 3531.32                                | -1.18              |
| 2007 | 3141.90                       | 3400.24                             | 8.22               | 4515.76                         | 4467.98                                | -1.06              |
| 2008 | 3960.08                       | 4131.97                             | 4.34               | 4681.00                         | 4533.65                                | -3.15              |
| 2009 | 4621.00                       | 4917.05                             | 6.41               | 5199.00                         | 4928.45                                | -5.20              |
| 2010 | 5565.90                       | 5960.94                             | 7.1                | 5550.00                         | 5663.21                                | 2.04               |
| 2011 | 6762.20                       | 7158.89                             | 5.87               | 6675.99                         | 6565.13                                | -1.66              |
| 2012 | 8003.80                       | 8250.18                             | 3.08               | 6895.35                         | 6561.01                                | -4.85              |
| 2013 | 9051.27                       | 9244.48                             | 2.13               | 7238.00                         | 7084.88                                | -2.12              |
| 2014 | 10090.48                      | 10144.5                             | 0.57               | 7399.00                         | 7225.17                                | -2.35              |
| 2015 | 10905.60                      | 11018.5                             | 1.04               | 8404.00                         | 7890.65                                | -6.11              |
| 2016 | 11912.61                      | 12192.1                             | 2.35               | 9819.00                         | 9475.54                                | -3.50              |
| 2017 | 13410.34                      | 13682.2                             | 2.03               | 11453.00                        | 10411.2                                | -9.09              |

It can be seen from the above table that all relative error is controlled within 10%, and 70% of the error are controlled within 5%, indicating that the established system dynamic model of Wuhan commercial housing price is well simulated.
3. Result Analysis and Discussion

3.1 Result Analysis

According to the examination on the system dynamics model of housing price in the previous section, it is shown that the model is authentic and reliable. Therefore, its prediction results can be used for analyzing.

![Figure 4 Forecast value of commodity housing price](image1)

![Figure 5 Forecast value of total residential demand](image2)
It can be seen from Figure 4 that since 2003, the price of commercial residential building in Wuhan has always been presenting an increasing trend. The increment was slow from 2011 to 2015, and the amount of increase continues to enlarge until 2021. Since then, the growth of commercial housing prices has tended to be flat, and is expected to reach 1,8207.9 yuan/square meter in 2030. It can be seen from Figure 5 and Figure 6 that the change of total housing demand and total supply in Wuhan are in consistency, which are both showing a rapid upward trend. That is also consistent with the Wuhan’s future economic development.

3.2 Policy Regulation

It can be seen from the model simulation that the housing price in Wuhan will remain the increasing trend in the future. It is a must to conduct reasonable regulation on the housing price. The effectiveness of prepared policies can be observed by policy regulation experiment, thereby providing help to making decision. The regulative experiment is mainly conducted from the aspects of population, land, taxation etc. [4][5]

3.2.1 Natural Population Regulation Policy

It is mainly to regulate the natural growth of population, such as the family planning policy and the policy of allowing having the second child.

Natural population control policy 1: The impact of natural population control policy has changed from 1 to 1+STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the impact of policy will increase by 0.2 from 2018. The natural population control policy mainly regulates the birth rate. According to the equation of birth rate in previous passage, it can be seen that the nature is the birth rate in 2018 has been increased by 20% from 0.012 in 2017 to 0.0144.

Natural population control policy 1: The impact of natural population control policy has changed from 1 to 1-STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the impact of policy will increase by 0.2 from 2018. The natural population control policy mainly regulates the birth rate. According to the equation of birth rate in previous passage, it can be seen that the nature is the birth rate in 2018 has been increased by 20% from 0.012 in 2017 to 0.0096.

The test results on natural population policy regulation using Vensim DSS software are as follows:
It can be seen from the above simulation results that the birth rate decreases and the price of commercial housing decreases accordingly. In the case of a 20% reduction in the birth rate, the largest reduction in the price of commercial housing is 0.14%, which is a small change. The lower birth rate leads to a reduction in the total population, which reduces the demand for rigid housing. In the case of constant supply, the supply-demand ratio increases, which leads to lower housing prices.

3.2.2 Land Policy Regulation

The land price regulation policy is selected for conducting single policy regulation experiment.

Land Price = ((0.055719*Housing Land Grant Area+1.22197*Base Land Price-259.521)*Land Price Policy+1200*PULSE(2004, 1)+2400*PULSE(2005, 1)+900*PULSE(2007, 1) -2500*PULSE(2008, 1)-2550*PULSE(2009, 1 ))

Land Price Regulation Policy 1: The impact of the land price control policy has changed from 1 to 1+STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the impact of policy will increase by 0.2 from 2018. According to the equation of the land price mentioned above, it is essentially equivalent to that the land price will increase by 20% each year from the original forecast value in 2018.

Land Price Regulation Policy 2: The impact of the land price control policy has changed from 1 to 1-STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the impact of policy will decrease by 0.2 from 2018. According to the equation of the land price mentioned above, it is essentially equivalent to that the land price will decrease by 20% each year from the original forecast value in 2018.

The experimental results of using Vensim DSS software on land price policy regulation are as follows:
Figure 8 Influence of land price policy regulation on housing price

It can be seen from the above simulation results that when the price of land decreases, the price of commercial housing will decrease accordingly. With 20% reduction in land prices, the largest reduction in the price of commercial housing was 18.66%, which is a significant change.

The rising land price and comprehensive housing cost causes the increased housing price. It can be seen from the data results that the land policy regulation has obvious effect, and it will be more obvious over time. The rise in housing prices has increased the profits of developers, driving more developers to be involved. With the increased demand of development, the land, as the basis for development, will also increase. However, land is a non-renewable resource with a limited total amount. The increase in demand will inevitably drive a continuous rising land prices and thus cause a continuous rising housing price. Additionally, granting land is the main source of fiscal revenue for local governments in China. In order to obtain higher fiscal revenue, local governments often push up land prices, which has also led to the continuous increase in commercial housing prices.

3.2.3. Developer Taxation Policy Regulation Experiment

Developer Taxation Regulation Policy 1: The impact of the developer's taxation regulation policy has changed from 1 to 1+STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the policy impact will increase by 0.2 from 2018. According to the equation of the taxation rate in the previous passage, it is essentially equivalent to the developer taxation rate starting from 0.07 in 2018 and increased by 20% to 0.084.

Developer Taxation Regulation Policy 2: The impact of the developer's taxation regulation policy has changed from 1 to 1-STEP (0.2, 2018), meaning that the original policy will be maintained before 2018, and the policy impact will increase by 0.2 from 2018. According to the equation of the taxation rate in the previous passage, it is essentially equivalent to the developer taxation rate starting from 0.07 in 2018 and decreased by 20% to 0.056.

The results of the experiment on the developer taxation regulation policies using Vensim DSS software are as follows:
It can be seen from the above simulation results that when the developer's taxation is reduced, the price of commercial housing will also decrease. When there is a 20% reduction in the developer taxation rate, the price of commercial housing has the largest lowering of 1.31%.

With the increased taxation rate for developers, the comprehensive housing cost increases, which leads to higher housing prices. Developers are the main objects of taxation in the stage of housing development and construction. The government's original purpose of increasing tax rates is to control the rising housing prices through. However, housing developers that aim to maximize profits cannot bear the increased tax rate by themselves. This part of the increased cost will eventually be passed on to purchasers. Therefore, the regulatory policy of raising the tax rate has not only failed to control housing prices, but caused even higher housing price. The regulation experiment lowers the taxation rate and reduce the tax burden of developers appropriately. Without bearing more pressure from taxation, developers only need to ensure their vested profits and will not have too strong desire to increase the price of commercial housing. Therefore, the results of the experiment occurred, that the price of commercial housing fell with the decreased taxation rate of developers.

4. Conclusion

Based on the theory of system dynamics, the main factors that influence the commercial housing price in Wuhan and their relationship are analyzed and studied, and corresponding system dynamics model is constructed. It also has a good simulation on the operation status of the housing market in Wuhan over the years, and forecasts the prices of commercial housing in Wuhan in the next few years. In the same time, policy regulation experiments are conducted from the perspective of population, land and taxation. It can be concluded that the taxation and land policy can guide the price of commercial housing price effectively. This paper takes the commercial housing market in Wuhan as the main research object, which excludes the commercial shop, office buildings and other types of real estates. In next step, the overall real estate system can be involved in the consideration, and countermeasures for regulating the whole real estate market can be provided.

References

[1] Huang Wenjie, Chen Xinglong, Guo Xiaopeng. On the Application of System Dynamics in the Research of Real Estate Market [J]. Commercial Times, 2011(5), 132-134.

[2] Jay W. Forrester. The Beginning of System Dynamics [J]. Views about the Development of System Dynamics, 2003, 23(10): 63-64.

[3] Wang Juan. Research on Influencing Factors and Trends of Real Estate Prices under Macro-control
[4] Zhao Qing. Demand Expansion Analysis of Commercial Housing in Xi’an Based on System Dynamics [D]. Xi’an University of Architecture and Technology, 2017.
[5] Yang gongxiang. Simulation Study of Yangzhou Commercial Housing Price Based on System Dynamics [D]. Yangzhou University, 2018.