Evaluation of Green Residential Housing Market Maturity: Empirical Evidence from Nanjing, China

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Abstract

With the exacerbation of the human living environment and the clear increase in the public's awareness of the need for energy saving, the Chinese government has increasingly been focusing upon the green housing market. The green housing market, however, is developing relatively slowly. The quality of the "green" houses being produced and the current levels of market supply and demand are under-developed. Therefore, this article aims to provide a more comprehensive understanding and evaluation of the green housing market and its degree of maturity in China. Authors achieve this understanding through system dynamics simulation results. Firstly, by analyzing the internal effects and interactions of demand subsystems, development subsystems, and government action subsystems, a system dynamics model (which is used to describe the green housing market) is established. Secondly, our study builds a maturity assessment model, which is based on the theory of maturity. In addition, our study dynamically conducts an evaluation of the development of the green housing market. Thirdly, our study combines the simulation results with the maturity evaluation, in order to achieve a dynamic evaluation and prediction of the development of the green housing market. Finally, this paper puts forward some policy suggestions.

Keywords: green residential housing market; maturity evaluation; system dynamics simulation; fuzzy comprehensive evaluation

1. Introduction

In order to solve the resource and environment problems typically encountered during development, the government has invested considerable resources in an effort to save energy and reduce emissions. Those efforts include addressing issues involving the construction industry, which is a priority among priorities. From the start of construction to the demolition of entire lifecycle, the expansion of green housing should save more energy, increase emission reductions and serve to provide better residential accommodation. Thus, China has recently begun to strongly advocate the development of green housing projects.

Generally speaking, green housing comes in several types. By different types authors mean different energy saving abilities, different levels of comfort and different costs. Taking the three-level classification system in China as an example, there are 25% differences in energy saving capabilities between first-level, second-level and third-level houses. In addition, the differences in incremental costs are almost threefold.

Meanwhile, with regard to the different stages and types of development, authors can accept the fact that green housing incremental cost structures are also different. Therefore, studying the maturity of the green housing market, on the one hand, helps real estate developers analyze recent market developments and then build greenhouses which are up to market demand standards. On the other hand, studying the green housing market is good for the government. The information they receive helps them to value the green housing market, so the government can put appropriate green housing incentives in place. The government can also use this new information to adjust their housing policies in order to accelerate the development of the green housing market and to achieve energy saving targets.

2. Literature Review

In the beginning, the theory of maturity was proposed in relation to the software development field. The theory was used to evaluate the process of software development and the ability of software developers. Then, the theory was gradually extended to other fields and industries. In the field of project management (PM), it was found that the improved understanding of how to implement and apply a PM maturity model contributed to the increased knowledge of drivers and enablers and reduced obstacles when assessing PM maturity (Backlund et al., 2015). Through the empirical research of PM maturity assessments, the process management performance
of many international companies was estimated using a process management maturity model (Rohloff, 2009). In the field of knowledge management and the efficiency measurement of operators, some scholars provided a comprehensive and systematic framework for assessing maturity (Lee et al., 2010). In addition, development in different realms could be assessed by building different maturity models (Chen et al., 2012).

Maturity theory is crucial in the evaluation of the real estate market. When applied to the evaluation of energy efficiency technology, a maturity evaluation prediction model was built. The model was based on the TRIZ theory and used to forecast the development tendencies of building energy efficiency in China (Huang et al., 2010). No direct linear relationship was found to exist between real estate market maturity and the investment outlook. As such, interested parties should pay closer attention to nurturing and improving the maturity of the real estate market, and strive to enhance their city's soft property condition (Zhang et al., 2014).

Simultaneously, relative to the land market, the maturity theory has been widely studied. Through the maturity model, the conclusion was reached that the Chongqing market as a whole remained at mid-level, while each area of Chongqing performed differently (Zhang et al., 2011). In 2012, after constructing a maturity evaluation index and using an entropy weight matter-element model system for the land market, it was found that the quantitative maturity evaluation agreed with the land markets in Hunan (Zhang et al., 2015). Ke & Sieracki (2015) analyzed the maturity of China's commercial real estate market.

When it comes to the housing market, dynamics are often used to analyze the residential housing market. Tsai (2013) studied the dynamics of housing affordability, self-occupancy housing demand and housing prices. In addition, a system dynamics approach was also used to analyze green marketing (Khoshkhi & Etehad, 2015). Since the 1992 United Nations Conference on Environment and Development (UNCED), green housing has become one direction of the theory of sustainable development. Through an investigation into the barriers to developing green buildings in Malaysia, Samari et al. (2013) found that the main barriers could be listed as: 1) the lack of credit resources to cover up-front costs, 2) the perceived risk of investment, 3) a lack of perceived demand and 4) the higher final price. Therefore, it has become necessary to study the maturity of the green residential housing market as a means to eliminate these barriers.

Obviously, the maturity model has been widely used in many fields, including market evaluation and project management or process management evaluation. Therefore, this article has a good degree of adaptation for measuring the green housing market. This paper will also innovatively combine a system dynamics model with the element of maturity, which no one has done before. As such, our paper will offer a certain reference value to the study of the green housing market.

3. Theoretical Analysis
3.1 Green Housing Market

Green housing are residential buildings that consider energy conservation, environmental protection and higher comfort from the design development, and whose technical indicators all meet relevant requirements. The green housing market is the sum of the relevant green housing transactions during a specified observation period and within a specified geographic range. The green housing market is a complicated system made up of multiple factors, such as the subject, the object and the external environment.

The green housing market operates in accordance with the characteristics and rules of the general residential market. However, green housing also has several unique differences, compared to the general housing market. Generally speaking, the green housing market has the following three characteristics:

1) A strong degree of interactivity with the housing market. The green housing market is a part of the housing market, so its development is heavily influenced by the overall housing market. For example, when the overall housing market is not performing well, the green housing market will also suffer the impact of that poor performance.

2) Imperfect competition in the internal market. Green housing developers have considerable property experience. Other people who are not as familiar with the green housing market will not understand these developers. This leaves many in a serious state of information asymmetry, relative to the developers. It can even appear in such situations that green housing developers are maliciously promoting the concept of "green" just for the purpose of making additional profit.

3) Positive government intervention. The concept of green housing directly conforms to the government targets of "sustainable development, energy saving and emission reduction", as well as the drive towards a "low carbon economy." Therefore, development of the green housing industry will benefit from government intervention.

3.2 Connotation of Green Housing Market Maturity

According to the life cycle theory, a developing market needs to experience multiple stages, from the newborn embryonic stage to the mature and stable market stage, until the final, disintegration stage. This life cycle theory has gradually been extended to other areas and other industries, based on a wide range of research. As an indicator of a market's development level, market maturity can generally be used to judge any market's stage of development.

Finding the level of the green housing market's maturity can help to measure the degree of market development. This information can also be used to make a comprehensive judgment on the market's efficiency and stage of development. Green housing market maturity reflects the development level of three specific elements which constitute the market. Those three elements are 1) subject, 2) object and 3) exchange
relationship. Here, the subject development level refers to the state of the maturity of supply and demand. The object means the green housing product itself, and the market exchange relationship demonstrates the market's transaction status.

4. Model Establishment

This paper includes two models. One is a system dynamics model, which is used to analyze the green housing market. The other is a maturity evaluation model of the green housing market, which is based on a fuzzy comprehensive evaluation. System dynamics provides a perfect forecast function, while a fuzzy comprehensive evaluation can assess the degree of a market's maturity from a comprehensive perspective. Therefore, a combination of the two methods could obtain dynamic investigation results in terms of the evaluation of the development of the green housing market.

4.1 System Dynamics Model

The green housing market is a complex system. From the point of view of a market component, the system is affected by the transaction participants and transaction prices, as well as government policies and other factors. From a temporal perspective, the green housing market is comprised of decision-making, design and construction, demand and influence on the next development.

In this paper, the green housing system model mainly consists of a consumer subsystem (demand), a development and decision-making subsystem (supply) and a government behavior subsystem (government investment). The relationships between these subsystems mutually influence supply and demand. At the same time, in order to better realize the system simulation, authors put forward the following assumptions. (1) The newly published house restriction policies have not been taken into consideration. (2) Real estate developers are treated as a whole entity. (3) The development of the real estate market is stable, without any large degrees of fluctuation. (4) Green housing pricing is in accordance with all objective and relevant laws. (5) No force majeure factors exist.

4.1.1 Demand Subsystem

The core of the demand subsystem of the green housing market is the conversion process (through the rate of sales) between potential users and current users. In this process, the most important variable is the sales rate, which determines the transformation speed from potential users to demand users. The sales rate is affected by the sum of target users (STU), reputation dissemination rate (RDR) and acceptance ratio (AR). The sum of the target users determines how many potential users will transfer to becoming users in need. The reputation dissemination rate will have a direct effect on the rate of potential consumers who get close to green housing. The acceptance ratio reflects to what degree the potential consumers accept green housing. The reputation dissemination rate is also affected by the green product performance (GPP), which in turn has a direct impact on reputation (R). In addition, reputation continues to influence the acceptance ratio. The acceptance ratio is affected by factors such as reputation, price additional burden (PAB), family income (FI) and consumer cognition (CC). Consumer cognition is influenced by propaganda and guidance (PG), as well as the development scale (DS). (Other indexes in Fig.1: influence on acceptance from income [IAI], rate of change for sales [RCSa], acceptance for price additional burden [APAB], and sales demand [SD]).

4.1.2 Development and Decision-making Subsystem

In the development and decision-making subsystem, the rate of development change is affected by the demand change. At the same time, the cost additional burden (CAB) is directly influenced by design and construction capability (DCC) and green degree (GD), while the development scale (DS) has a direct effect on design and construction capability. Green housing performance is commonly determined by design and construction capability and green degree, which in turn impacts and effects premium ability (PA). (Other indexes in Fig.2. include reduction rate of sales [RRS], stock [S], growth rate of sales [GRS], and rate of change of supply [RCSu]).

4.1.3 Government Behavior Subsystem

In the government behavior subsystem, government support is one of the most important variables. This support affects the propaganda and guidance and price additional burden. That level of support, meanwhile, is determined by the increment rate and decrement rate. The increment rate of government support (IRGS) indicates that, when the market share is far from expectations, the government will increase its support of the green housing market. If the converse is true, the government will reduce its level of support. The deviation of market share is the difference between
the actual market share and the expected market share. Market share (MS) is affected by the sales rate (RS) and sales demand. (Other indexes in Fig.3. include government subsidies [GS], annual government support [AGS], accumulative government investment [AGI], increment rate of government support [IRGS], expected market share [EMS], deviation of market share which is higher than expected [DMSH], and deviation of market share which is lower than expected [DMSL]).

![Flow Chart of Government Behavior Subsystem](image1)

**Fig.3. The Flow Chart of Government Behavior Subsystem**

The overall flow chart of the green housing market system can be obtained after combining the above three subsystems. This chart can intuitively reflect the relationship between transfer, control and feedback for the whole system, as shown in Fig.4.

![Flow Chart of the Whole Green Housing Market System](image2)

**Fig.4. The Flow Chart of the Whole Green Housing Market System**

### 4.2 Maturity Model

The fuzzy comprehensive evaluation method is widely used in maturity evaluation, which is also applied to calculate maturity and classification. Fuzzy comprehensive evaluation avoids the simple affirmation or negation of evaluation results. Rather, this type of evaluation shows the degree of acceptance by way of a fuzzy set, thus achieving a quantitative judgment and furthermore conducting a more comprehensive evaluation.

#### 4.2.1 Index Selection

This paper selects the LMM maturity model, the structure of which is relatively simple and therefore requiring less manpower when modeling. The basic structure of a LMM maturity model is one of ladder-like distribution.

In Fig.5., each step is represented by a mature stage. Along with the promotion of ladder rank, the figure indicates that the described object is in the process of continuous development.

![Structure of LMM Maturity Model](image3)

**Fig.5. The Structure of LMM Maturity Model**

In the LMM maturity model, the evaluation system generally has three levels, including the target layer, standard layer and index layer (from upper to lower, respectively), as shown in Table 1.

The standard layer of the market mainly contains the index of market share.

Green housing products include two indexes, namely 1) green product performance and 2) design and construction capability. Green product performance is used to evaluate the energy-saving capacity, comfort and externality of the building. As the market's maturity and development capability strengthen, the product performance aspect is gradually promoted. The design and construction capability index weighs the downstream industry development of real estate, which, in turn, indirectly describes market maturity.

#### 4.2.2 Maturity Classification

According to the product life cycle theory, a process is generally divided into the four stages of formation, growth, maturity and recession. This paper also segments the green housing market life cycle into four stages, as shown in Fig.6.

Due to the fact that the green housing market is still part of a new industry, accurately judging the timing of the industry's recession stage is not yet possible. Therefore, this paper only analyzes the germination period, growth period and mature period.

In the calculation of the green housing industry's maturity, the year 2008 is treated as the initial period, when the maturity level was the lowest. The maximum

| Table 1. Maturity Indexes of Green Housing Market |
|-----------------------------------------------|
| **Target layer**   | **Standard layer** | **Index layer**   |
| Market share       | Green housing product | Green product performance |
| Consumer cognition | Design and construction capability | Acceptance ratio |

The consumer cognition and acceptance ratios are included in the standard layer of consumers. Consumer cognition indicates the measure and evaluation of people's ability to understand the concept of green housing. The acceptance ratio describes consumer attitudes towards green housing. This ratio helps explain how mature the consumers are (in terms of their cognition and understanding of green housing) when they participate in green housing transactions.
possible value of each index is thought to be when the maturity level is the highest. The state of each specific index will indicate the level of maturity. Then, a membership function is obtained. Through the calculation of the membership vector, authors can determine the results of the fuzzy comprehensive evaluation (i.e. the industry's maturity level).

When confirming the industry or market's maturity level, each index will be located in three fuzzy sets, i.e. the germination period, growth period and mature period. By means of a fuzzy calculation, authors can obtain the degree of membership for each fuzzy set. When the index is at the minimum value, the membership level in the germination period is 1, while the membership level in the growth period is 0. As the market develops, the level of membership in the germination period gradually decreases, while membership continues to increase during the growth period. When the index is in an intermediate state, the membership belonging to the germination period falls to 0, and correspondingly rises to 1 in the growth period. Similarly, when the index is at the maximum value, membership in the growth period is 0 and reaches its peak in the mature period, as shown in Fig.7.

5. Empirical Research
5.1 Simulation of System Dynamics

Our case study targets the green housing market in Nanjing, in Jiangsu Province.

Firstly, the SD (system dynamics) model is based on the following premises: (1) The model simulation runs for a period of 52 years, from 2008 to 2060, with time intervals of one year. (2) Based on the assumption relatively stable policies, the real estate market is assumed to be in a normal state of development from 2012 to 2060. (3) Any increase in the property market brought about by low-income housing is not taken into consideration.

After establishing the functional relationship between different factors, Vensim software can simulate the SD model of the green housing market. The results are shown below.
Authors see in Fig.12 that the sales quantity of green housing increases relentlessly. However, from 2032, the growth rate begins to decrease, and then tends to become relatively stable.

From Fig.13, the reduction rate of sales accelerates in the early stages and increases until 2028. After that, the reduction rate of sales slows and then tends to be stable.

In Fig.14, the green housing market share is always rising. The rate of increased market share is rapid in the beginning and then becomes slower, tending to be stable at approximately 90% until 2032.

From Fig.15, authors can be seen that the government's green housing subsidies keep reducing. The rate of decrease becomes more and more rapid until 2024, when the subsidies fall to 0.

In Fig.16, the rate of change for sales describes how fast the sales rate will change. As a result of the green housing market undergoing rapid development and then tending to become stable, the variation rate of the sales rate also shows a change from high to low, then to stable. Before the maximum value appears in 2025, the rise in the rate of sales is accelerating. During the period from 2025 to 2033, the rate of increase slows. When the market's development, supply and demand, design and product quality all tend to become stable, so does the change rate of sales.

For real estate developers, the way to determine the amount of supply is based on the market sales change, i.e. the rate of change for sales. However, due to the fact that developers may sometimes not have a comprehensive understanding of the market, or that they may make mistakes with their judgments and decisions, the supply rate will probably fluctuate around the sales rate. At the same time, because it may take up to two years to realize the market supply (since the developers made supply decisions), the changes in the rate of supply are always two years behind the changes in sales. However, the overall trend is roughly the same.

5.2 System Test

5.2.1 Mental Model Test

A mental model test is designed to verify that the results of a system simulation are consistent with the actual data. The results are shown in Fig.17.

First of all, the market share has "S" growth and then tends to be stable, which is consistent with the general development process of new products. Both the rates of change for sales and supply first rise and then dip before finally becoming stable. This change process is consistent with the reality of the market. At the same time, the simulation data results are generally approximate to the actual situation. Therefore, the SD model passes the mental model test.

5.2.2 Extreme Test

An extreme test is commonly used to verify whether or not the equations in the SD model are reliable and if the system can operate normally and achieve the right results under extreme conditions.

Here, taking government policy as an example, authors suppose that the government does not implement any support policies whatsoever (i.e., neither government subsidies nor advocacy guidance for consumers). The system changes results are shown in Fig.18.

Under extreme circumstances, overall sales will have been postponed for two years. However, the line form is consistent with the original result, which is in
turn consistent with the idea that if authors assume the
government does not provide any support for green
housing development, sales will slow down but will
still develop, just over a longer period of time.

5.2.3 Sensitivity Test

The sensitivity test is mainly used to test how
sensitive the green housing market is to some of
the model parameters. This paper selects design
construction capability and consumer cognition as the
parameter examples, as shown in Figs.19. and 20.

By comparing the above two figures, authors can see
that the system is more sensitive to consumer cognition
than to design construction capacity. Therefore, the
former has a greater effect on the green housing market.

5.3 Maturity Calculation

The parameters of the five indexes included in the
maturity model are available by means of simulation
results from the SD model. Due to space limitations,
Table 2. demonstrates the parameter values from the
years 2015 to 2020.

Table 2. Maturity Indexes of Green Housing Market

| Year | Market share (%) | Green product performance (%) | Design and construction capability (%) | Consumer cognition (%) | Acceptance ratio (%) |
|------|------------------|-------------------------------|-------------------------------|-------------------|-------------------|
| 2015 | 15.70            | 59.20                         | 62.31                         | 6.73              | 59.67             |
| 2016 | 17.88            | 59.91                         | 63.06                         | 8.11              | 60.97             |
| 2017 | 20.05            | 60.85                         | 64.05                         | 9.64              | 62.37             |
| 2018 | 22.23            | 62.14                         | 65.41                         | 11.30             | 63.89             |
| 2019 | 24.41            | 63.90                         | 67.26                         | 13.05             | 65.56             |
| 2020 | 26.59            | 66.29                         | 69.78                         | 14.83             | 67.40             |

In this paper, an Analytical Hierarchy Process (AHP)
method is used to determine the weight of the maturity
index. By taking the experts’ marking (as shown in
Table 3.), authors can obtain the weight of the standard
layers, (0.713, 0.206, 0.081, respectively). Similarly,
the weight of the index layer is also obtained. Finally
the hierarchy population ordering for each index is
shown in Table 4.

Table 3. The Experts Marking

|          | Market       | Green housing product | Consumer |
|----------|--------------|-----------------------|----------|
| Market   | 1            | 4.3                   | 7        |
| Green     | 0.23         | 1                     | 3.2      |
| housing   | product      |                       |          |
| product   | 0.14         | 0.32                  | 1        |
| Consumer  |              |                       |          |
| cognition |              |                       |          |

According to Fig.7., each year will have its own
membership level. Take 2012 as an example. After
obtaining the membership vectors, using the arithmetic
for weight set A and membership vector for set R,
authors can easily find that the membership rate of 2012
is 0.056, which indicates in turn that the maturity is 5.6%.

Table 4. Hierarchy Population Ordering of Indexes

| Standard layer | Weight | Index layer | Weight | Market share | Green product performance | Design and construction capability | Consumer cognition | Acceptance ratio |
|----------------|--------|-------------|--------|--------------|----------------------------|-----------------------------------|-------------------|------------------|
| Market         | 0.713  | Market share| 1      | 0.713        |                            |                                   |                   |                  |
| Green product  | 0.206  | Green product performance| 0.7 | 0.144        |                            |                                   |                   |                  |
| product        |        | Design and construction capability| 0.3 | 0.062        |                            |                                   |                   |                  |
| Consumer       | 0.081  | Consumer cognition| 0.739 | 0.06        |                            |                                   |                   |                  |
|                |        | Acceptance ratio| 0.261 | 0.021       |                            |                                   |                   |                  |

Then, maturity is rated in a similar way. For the
fuzzy set of the germination period, the membership
of 2012 is 0.89, the growth period is 0.367 and
membership in the mature period is 0.

At this time, the membership vectors in the three
fuzzy sets are (0.89, 0.367, 0), max (0.89, 0.367, 0)
>0.89. Therefore, the germination period owns the
highest membership degree, which explains that this
year belongs to the germination period at this point.
The same method can calculate the maturity degree for
each year.

Using system dynamics, authors can obtain
simulation data for many years. As such, authors can
also make accurate maturity predictions. Our results
show that market maturity is in the rising state. In
addition, the growth rate will increase rapidly and then
slow down, as shown in Fig.21.
6. Conclusions and Discussions

Through the establishment of a system dynamics model of the green housing market, as well as a maturity model, this paper has conducted a dynamic evaluation and prediction of the future of the green housing market's development situation. Authors also find that the government should play an important role in the development of the green housing market. Therefore, combined with and based upon our research results, this paper puts forward some policy suggestions, as follows:

(1) There should be a focus on the development of the green housing market over the next five years. Authors predict that Nanjing is still in the germination stage (from 2008 to 2016). During this germination stage, the government should have paid closer attention to strengthening and supporting investment in the green housing market. The government should also be providing accurate guidance for both developers and consumers. Such support will be significant if the green housing industry is to realize the market's cultivation and development. Government support will also contribute in advance to the green housing industry smoothly entering a fast development stage.

(2) Subsidies should be utilized to control the final price of green residential housing. In addition, the government should provide reasonable guidance in terms of controlling market demand, in order to promote a stable beginning of the green housing market. More mature market safeguard mechanisms should be established, along with and improved market supervision and conduct. Market mechanisms should be introduced after finishing the cultivation of the green residential consumer market. Furthermore, a regional development strategy should be implemented to expand the various regional markets and even the national market.

(3) Efforts should be made to strengthen green housing propaganda. Guidance should be provided to promote consumer cognition of green housing. Our simulation results show that consumer cognition will stay at a relatively low level until 2027. Significantly, the sensitivity test has indicated that consumer cognition is one of the more sensitive variables. Therefore, the government should intensify its propaganda and consumer guidance efforts, in order to give consumers a correct and comprehensive understanding of the green housing concept. The more consumers know about green housing, the more likely they will be to accept green housing. Providing the relevant green housing information to consumers is an essential and effective way to promote the development of the green housing market.

(4) Authors advocate a variety of incentive policies. At present, the main economic incentive policy with regard to green housing is a government subsidy for developers' construction costs. This paper argues that our country can draw lessons from other countries' experiences of economic incentive methods. Authors can use these lessons to simultaneously launch various forms of subsidies. In addition to the subsidies, there are many other effective means to improve supply enthusiasm. Other options could be to give green housing developers financial rewards and appropriate tax breaks based on construction density. Reducing the current requisite down-payment amount or reducing loan interest rates for green housing consumers could also effectively drive market demand from an economic angle. Implementing a variety of incentive policies could improve the direct impact subsidies have on housing finance.

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