SYSTEMATIC ANALYSIS OF AFFORDABLE HOUSING DEVELOPMENT AND PRICING STRUCTURE IN SHENZHEN, CHINA

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ABSTRACT. As a result of urban housing reform in China, it has become increasingly difficult for low and middle income families to purchase a house. In response to the growing demand for affordable housing, the Chinese Government has developed a specific housing policy to enable families to purchase properties from the private sector. The pricing mechanism of such housing is completely based on the family affordability and the profit margin of developers. To ensure the provision of housing for low and middle-income families, the future trend of affordable housing prices has become a concern for developers, consumers and may adversely influence the implementation of the current national housing policy. In this paper a systematic analysis of affordable housing development and its pricing structure is undertaken for the city of Shenzhen. As information pertaining to the factors influencing house prices is imperfect, a Grey model, which requires a limited amount of data to reflect unknown behavior, is constructed to provide a forecast for affordable house pricing. The analysis indicates that the government should adjust their current affordable housing policy to accommodate the forecasted upward trend in house prices.

KEYWORDS: Affordable housing; China; Developers; Grey model prediction; Housing policy

1. INTRODUCTION

Prior to 1950s, housing in China was predominately owned by private individuals or families (Davis 2005). After the establishment of the People's Republic of China ('China'), residential structures in the cities were awarded to the State. The housing system in China consists of low-rent, affordable and commodity housing (Wang, Murie 1999). Low-rent housing was originally designed for households with low income levels. Essentially, low-rent housing required no form of payment from the low-income households, as it was subsidized by the government. Affordable housing was constructed with government support for low- and middle-income groups and enabled developers selling such properties to acquire marginal profits. The government has aimed to provide and make accessible this type of housing to 70 to 80% of urban residents (Wang 2001). In contrast, commodity housing was designed for middle and high income families, which is market-orientated.

Increasing migration of people from rural regions in China to large cities such as Shenzhen (designated as a Special Economic Zone) in search for economic prosperity has resulted in a growing demand for affordable housing. Unfortunately, most people are unable to purchase commodity housing in Shenzhen, as a result the government has initiated a number of affordable housing projects. A study in 2008 revealed that the per capita disposable income of households in Shenzhen, for example, was RMB\$ 26,729 (SSB 2009). The average sale price of newly-built commodity housing in Shenzhen in 2008 was RMB\$ 12,820 RMB/m^2 (SSB 2009). With this in mind, the ratio of the average sale price of commodity (90 m^2 per household) to the average annual disposable income (ADI) per capita of urban household is approximately 43:1.

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This ratio is significantly higher than the international standard of 5:1 to 6:1 (Bruegmann 2009). With such a high housing price to income ratio, it is almost impossible for low-and middle income families to purchase commodity houses directly from the market. The implementation of an affordable housing policy has contributed, somewhat, to alleviating the housing problem for low-income families. A key issue facing the Shenzhen housing policy is the current is increasing cost of housing for low and middle-income families. A Grey-model is used to forecast future affordable house prices in Shenzhen and identifies strategies to address this pressing issue.
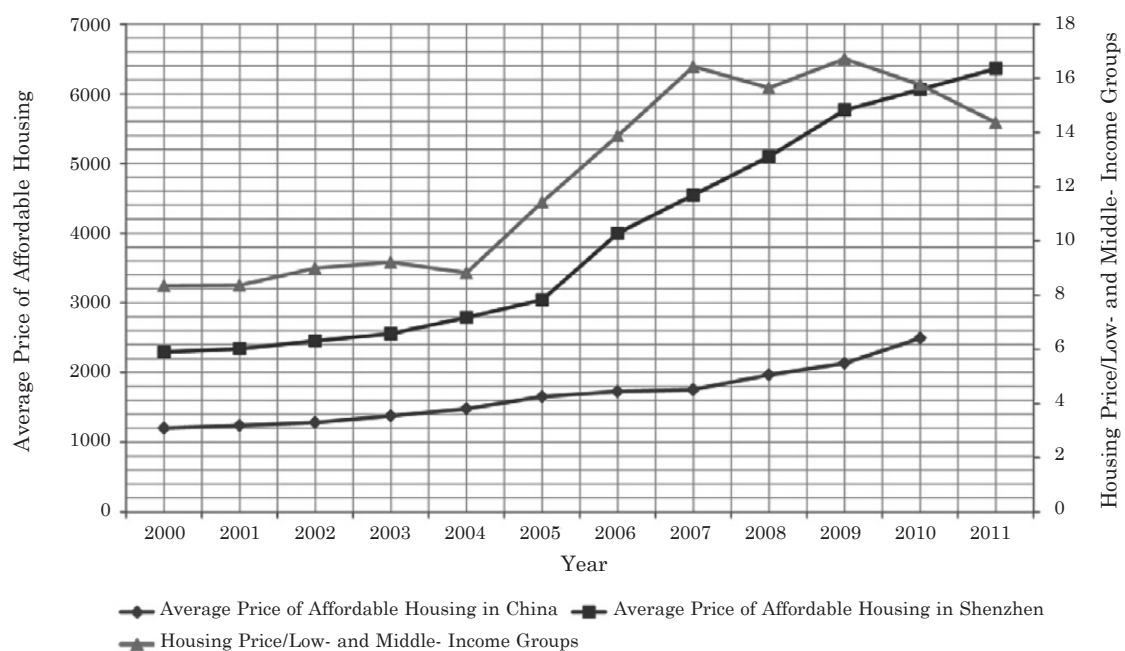
2. AFFORDABLE HOUSING IN CHINA

The implementation of an affordable housing policy is a critical component of the Chinese government's strategy. Affordable housing is subsidized by the government and is assigned and sold to low- and middle-income families. The underlying philosophy of the affordable housing policy in China is to make use of government preferential policies such as controlling the dwelling sizes, which reduces the total cost of a development. As a result, houses at lower prices can be provided to the low and medium income earners. Meanwhile, it still enables developers to obtain a marginal profit.

Only those who are unable to purchase a commodity house are provided access to affordable housing. With increasing demand for affordable housing and a limited supply, there has been a propensity for their prices to progressively increase. This is becoming a problematic issue for the government and therefore there is a need to control and manage houses prices.

The pricing principle of affordable housings is cost based and combining the overall average market level. The price structure of affordable housing can be divided into two parts:

1. *Development costs*: fees paid for land acquisition and relocation compensation according to relevant law and regulations; cost of preparatory works such as engineering survey and architectural design; construction cost; management fee; loan interest and administration fee.
2. *Profit*: the cost of affordable housing is under strict control of China government (Zhang 2013). Profit generated from affordable housing construction, which is managed by private developer, should not exceed more than 3% of the development costs.

Since 1998, the price of affordable housings has constantly risen. The average price of affordable housing in Shenzhen is considerably higher than the national average (Fig. 1). In terms of ADI per

Note: The average price of affordable house in China for year 2011 is not available in National Bureau of Statistics of China.

Fig. 1. Average price of affordable housing
Sources: National Bureau of Statistics of China (1999–2011), Shenzhen Statistics Bureau (1999–2012).

capita, it is difficult for many low-and middle-income households to afford a house in Shenzhen. Shen Yun Village is an affordable housing development that was launched in year 2009, with dwellings selling at 4541 RMB/m^2 where the exchange rate of RMB/USD = 0.16, that is 727 USD/m^2 (as of July 2013). For a suite of 60 m^2, the total price is RMB$ 272,460 (USD 43,594). In 2009, the ADI per capita of low-and middle income household was RMB$ 14,352 (USD 2296) and RMB$ 27,023 (USD 4324), respectively. The housing price to income ratio for low-and middle-income groups in year 2009 was around 13:1 (Fig. 1).

3. FORECASTING AFFORDABLE HOUSE PRICES: GREY MODEL

Forecasting is a method by which to determine the uncertain future. It plays a pivotal role in the process of making a rational decision, but it always involves a series of complex procedures (Stekler 2007). Affordable housing price forecasting is vital for the development of a sustainable housing policy in China. Several conventional techniques for forecasting have been developed and can be classified as empirical analysis and quantitative methods. Empirical analysis includes collective opinion and subjective probability methods. The underlying theory of this approach is based on subjective judgment and accumulated experience of experts in the field. This approach is extremely useful for developing forecasts, when historical data is not available or is of poor quality (Richard, Morse 2007). The Australian government, for example, has applied the collective opinion method to examine housing affordability of the low-income groups (Burke, Pinnegar 2007). However, the subjective probability method is to determine the likely outcome from an individual expert's opinion. This form of decision-marking is deemed to be inaccurate as each expert has their preferences which can therefore generate a wide difference of opinion (Lawrence *et al.* 1996).

In contrast to subjective empirical analysis, quantitative methods are fully based on statistical analysis of past data sequence regarding the items to be forecast. The techniques are commonly adopted in the literature include regression mod-

eling and time series analysis methods (Goodman 1988; Horowitz 2006). Such techniques are only reliable if the sample data sequence has been established over a considerable period of time. From a statistical perspective, comprehensive historical data is required to provide accurate forecasts. Regression models, for example, are only effective if all influencing variables are accurately estimated. Moreover, the forecasting power is limited if key variables change. In the Chinese real estate market, imperfect information with regard to law and regulation as well as the innate flexibility can impact the accuracy of price predictions if conventional statistical techniques are used for forecasting.

The Grey model, developed from systems theory, can be used to retrieve the hidden patterns and trends that may exist within a system (Kayacan *et al.* 2010). A system is considered to be a 'black' box if the factors causing changes are completely unknown. In contrast, if all information within the problem is completely known, then it is deemed to be a 'white' system. Complete information is rarely available to model a 'white system' (Rezaei, Khalaj 2005). Yet, a Grey model is able to determine the underlying laws and reveal conditions that can enable the effective analysis of data (Kang, Zhao 2012). In stark contrast to conventional statistical models, a Grey model is able to address problems associated with 'partial information known', 'partial information unknown' and 'sample' as well as 'poor information' (Tsaur 2010). In addition, it can provide an assessment, diagnosis, analysis, modeling, forecast, control and optimization of 'small sample of uncertainty system (Lin, Yang 2003). Its simplicity and high precision by using as few points to provide a projection is commonly found in normative literature (Mohammadi *et al.* 2011).It can even perform better result when small amount of input data are made available to the model (Lim *et al.* 2007). With these, it has been used successfully to medicine, image processing, transportation, military, etc. (Lei *et al.* 2010; E. Kayacan, O. Kaynak 2011). With the grey model, there is no perquisite to fully understand what information or how much information what would cases changes to the price of affordable housing. In order to grasp

Table 1. Historical time series on the affordable housing pricing

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
$X^{(0)}$ (*t*) (RMB/m^2)	2258	2177	2295	2340	2455	2557	2792	3043	3998	4545	5097	5763	6050	6358

Notes: The average affordable housing price of year 2011 is estimated through four major affordable housing projects in Shenzhen. RMB/USD = 0.16 as of July 2013.

Source: Shenzhen Statistics Bureau, 1999–2011.

the trend and development direction of the price of affordable housing, what the model need is the join of new information which would cause changes to the original trend. Constantly adding new information is the driving force of the changing affordable house price. Impact bought by the new information is not formed at instantaneous. It should take time to digest and gradually reflected in the price for affordable housing. It could create inertia effect on the trend of affordable house prices. By determining the development trend and possible changes of the driving force, to predict the future trend of affordable house prices is the problem that proposed grey method should aim to solve. The grey model can provide invaluable insights for policy makers about the future trend of affordable housing price; it can be used to develop strategic planning on affordable housing policy. In this study, the latest available pricing data of past 14 years (from year 1998 to 2011) was retrieved from the government statistics and recently completed affordable housing projects (see Table 1). It forms the original sequence for formulating the grey model.

4. THE FORMULATION OF GREY MODEL, *GM* (1,1)

The *GM* (1,1) type grey model examines the randomness of an original time series and establishes a mathematical model for projecting the future trend of the data points. *GM* (1,1) indicates that there is only one variable, that is, the affordable housing price and a first order grey differential equation is used to construct the model. The *GM* (1,1) is most suitable for a sequence series with exponential change, but not for those subject to fluctuations (E. Kayacan, O. Kaynak 2011). The affordable housing prices presented in Table 1 are monotonically increasing and therefore the *GM* (1,1) is used to forecast their future value. The prediction algorithm based on *GM* (1,1) model is represented as follows:

Step (1) Non-negative original time sequence

Consider a time sequence $X^{(0)}$ that denotes the price of affordable housing:

$$X^{(0)} = \left\{ x^{(0)}(1), x^{(0)}(2), ..., x^{(0)}(t) \right\}, \ t = 14. \quad (1)$$

Using Table 1, it becomes $X^{(0)}$ ={2258, 2177, 2295, ..., 6358}, where $X^{(0)}$ is non-negative sequence.

Step (2) Preliminaries

The *GM* (1,1) can only be used in positive data sequences as they are collected in fixed in-

terval. In this instance, the annual pricing data are positive, and therefore the Grey model can be used to forecast the future value. Another criteria constraint of the Grey model is that the ratio of $x^{(0)}(t+T) / x^{(0)}(t)$ which must be in the interval of {0.1345, 7.389} (Deng 1989):

$$0.1345 \leq \frac{x^{(0)}(t+T)}{x^{(0)}(t)} \leq 7.389, \quad (2)$$

where: *T* is the sampling period.

Step (3) Accumulating Generation Operator

To obtain the internal regularity, the Grey model has three basic operations: (1) accumulated generation operation (AGO), (2) inverse accumulated generation operation (IAGO) and (3) grey modeling. To establish a new regularly number sequence, the process of accumulated generated operation (AGO) as shown in Eqs (3) and (4) is used to transform the original sequence which it is less regularity into a new sequence, $Z^{(1)}(k)$. Through this process, the new sequence $X^{(1)}(t)$ is obtained as follows:

$$X^{(1)}(t) = \left\{ x^{(1)}(1), x^{(1)}(2), ... x^{(1)}(t) \right\}, \ t = 14, \quad (3)$$

$$X^{(1)}(t) = \left\{ 2258, 4435, 6730, ..., 51738 \right\},$$

where: $x^{(1)}(t) = \sum_{k=1}^{t} x^{(0)}(t), \ t = 1, 2, ..., 14.$

The generated mean sequence is $Z^{(1)}(t)$ of $x^{(1)}(t)$ defined as:

$$Z^{(1)}(k) = \left\{ z^{(1)}(1), z^{(1)}(2), ..., z^{(1)}(t) \right\}, \ t = 14, \quad (4)$$

$$Z^{(1)}(k) = \left\{ 2258, 3347, 5583, ..., 48559 \right\},$$

where: $z^{(1)}(t) = 0.5 \cdot \left\{ x^{(1)}(t) - x^{(1)}(t-1) \right\}, \ t = 1, 2, ..., 14.$

Step (4) Differential equation of grey model

The grey differential equation of the grey model, *GM* (1,1) can be expressed as:

$$X^{(0)}(t) + aZ^{(1)}(t) = b, \quad (5)$$

where: $x^{(0)}(t)$ – grey derivative; a – developing coefficient; b – grey input.

If the number of $t = 2, 3, 4 ..., n$ are introduced in the equation, *GM* (1,1) can be expressed as:

$$x^{(0)}(2) + az^{(1)}(2) = b$$
$$x^{(0)}(3) + az^{(1)}(3) = b$$
$$\vdots$$
$$x^{(0)}(t) + az^{(1)}(t) = b$$

The above equation can be transformed into matrix form of:

$$y_t = B \cdot P, \tag{6}$$

where: $y_t = \{x^{(0)}(2), x^{(0)}(3), ..., x^{(0)}(t)\}$.

Step (5) Least-square method

The parameter of (a, b) is solved by following set of equation:

$$P = \begin{bmatrix} a \\ b \end{bmatrix} = (B^T B)^{-1} B^T y_t, \tag{7}$$

where:

$$a = \frac{\sum_{t=2}^{n} z^{(1)}(t) \sum_{t=2}^{n} x^{(0)}(t) - (n-1) \sum_{t=2}^{n} z^{(1)}(t) x^{(0)}(t)}{(n-1) \sum_{t=2}^{n} z^{(1)}(t)^2 - \left(\sum_{t=2}^{n} z^{(1)}(t) \right)^2};$$

$$b = \frac{\sum_{t=2}^{n} x^{(0)}(t) \sum_{t=2}^{n} z^{(1)}(k)^2 - \sum_{t=2}^{n} z^{(1)}(k) \sum_{t=2}^{n} z^{(1)}(t) x^{(0)}(t)}{(n-1) \sum_{t=2}^{n} z^{(1)}(t)^2 - \left(\sum_{t=2}^{n} z^{(1)}(t) \right)^2}.$$

Using the affordable housing pricing data ($t = 1, 2, ..., 14$), $P = \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} -0.11406 \\ 1343 \end{bmatrix}$.

Step (6) Whitening equation of the grey model

Using Eq. (6) and solution of matrix P, the whiten differential equation is presented as follows:

$$\frac{dx^{(1)}(t)}{dt} + (-0.11406) x^{(1)}(t) = 1343. \tag{8}$$

The solution of Eq. (8) is

$$x^{(1)}(t+1) = \left(x^{(0)}(1) - \left(\frac{1343}{-0.11406} \right) \right) \times e^{0.11406t} + \left(\frac{1343}{-0.11406} \right).$$

Step (7) Estimated value on affordable house price

To obtain the predicted value for affordable house pricing at time $(t+1)$, the IAGO is used to establish the following grey mode:

$$\hat{x}^{(1)}(t+1) = \left(x^{(0)}(1) - \left(\frac{1343}{-0.11406} \right) \right) \times e^{0.11406t} + \left(\frac{1343}{-0.11406} \right). \tag{9}$$

The estimation on the original sequence can be expressed as:

$$\hat{x}^{(0)}(t+1) = \hat{x}^{(1)}(t+1) - \hat{x}^{(1)}(t). \tag{10}$$

Step (8) Model validation

The estimated value on for affordable pricing, $\hat{x}^{(0)}(t)$ can be estimated through Eq. (10) and the results are listed in Table 2.

The evaluation criterion used in this study is the Mean Absolute Percentage (MAPE), which measure the percentage of prediction accuracy:

$$MAPE = \frac{1}{n} \sum_{t=1}^{t} \left| \frac{\hat{x}^{(0)}(t) - x^{(0)}(t)}{x^{(0)}(t)} \right|. \tag{11}$$

Using the error calculated from Table 2, the MAPE of the grey model is approx. 8%. This demonstrated that the model could provide a high accuracy in predicting affordable house prices.

Step (9) Forecast value of affordable house prices

The $(t+1)^{th}$ forecasting value for the affordable house price is:

$$\hat{x}^{(0)}(t+1) = \hat{x}^{(1)}(t+1) - \hat{x}^{(1)}(t), \tag{12}$$

$$\hat{x}^{(0)}(t+1) = A e^{0.11536t}, \tag{13}$$

where: $A = \left(x^{(0)}(1) - \left(\frac{1343}{-0.11406} \right) \right) \left(1 - e^{-0.11406} \right)$

and $t = 14, 15, 16, ...$

According to the affordable house price statistics and $GM(1,1)$ model, the forecast results can be obtained from Table 3 and Figure 2. If the demand/supply of the affordable housing and government

Table 2. The real and estimated values on affordable housing pricing based on $GM(1,1)$

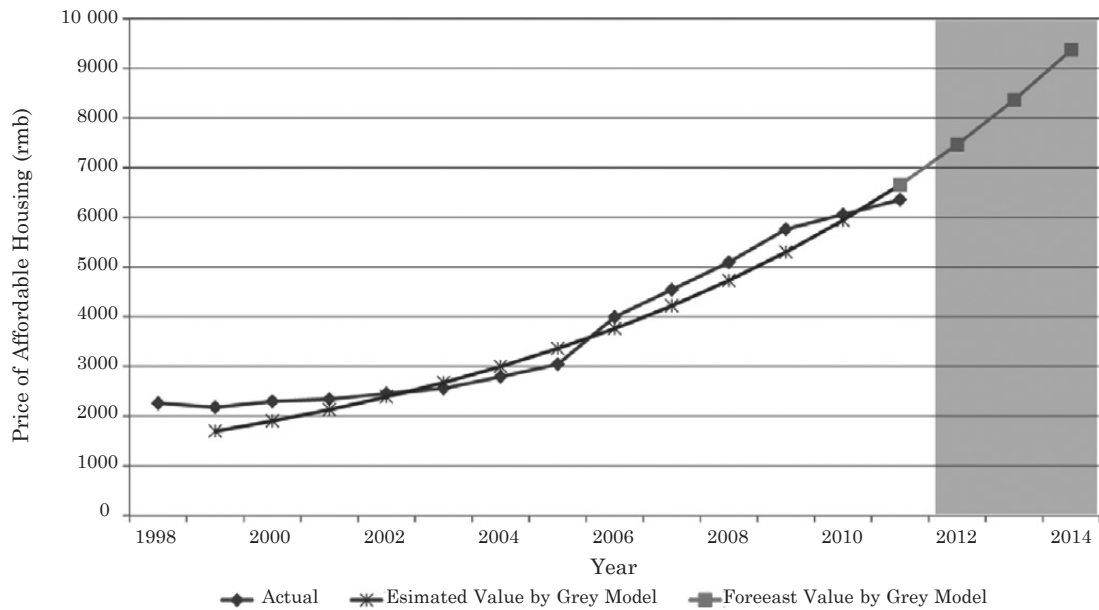| Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
t	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$x^{(0)}(t)$	2258	2177	2295	2340	2455	2557	2792	3043	3998	4545	5097	5763	6060	6358
$\hat{x}^{(0)}(t)$	--	1694	1899	2128	2386	2674	2997	3359	3765	4220	4730	5301	5941	6659
Error, R	--	−22%	−17%	−9%	−3%	5%	7%	10%	−6%	−7%	−7%	−8%	−2%	5%

Fig. 2. The actual, estimated and forecast value of affordable house prices by GM (1,1) model

Table 3. Forecast value for affordable housing prices for period, $t + 1$

t	15	16	17
Year	2012	2013	2014
$\hat{x}^{(0)}(t)$	7464	8366	9376

policy remain unchanged, it can be expected that the pricing of affordable housing would reach 7460 RMB/m^2 in year 2012. This forecast result is in line with the recently completed project in Longgang District of Shenzhen that the apartment of 65 to 90 square meter is priced between 7500 and 7900 RMB/m^2.

5. TEST ON THE AFFORDABILITY OF LOW-AND MIDDLE-INCOME GROUPS

Assuming that the annual disposable income (ADI) in year 2012 has a 5% increase from year 2011, it reaches RMB\$ 27,890 where the exchange of RMB/USD is 0.16, which equates to USD 4462 (as of July 2013). If the family plans to purchase a 60 m^2 affordable house:

The total price of a 60m^2 affordable house

= 60 m^2 (7460 RMB/m^2)

= RMB\$ 447,600 or USD 71,616.

Their affordable housing price to income ratio in 2012 would be:

= Total price of a 60 m^2 affordable house / ADI of low and middle-income household

= 447600 / 27890

= 16:1.

The affordable housing price to income ratio is to measure the affordability of low-and middle-income households for affordable housing in a given area. Regarding the livelihood concern in housing, the ratio should be around 5:1 to 6:1 for the developing countries (Bruegmann 2009). Therefore, the strong price to income ratio of 16:1 implies that the price level of affordable housing is far beyond the affordability of low-and middle-income households in Shenzhen.

6. PROPOSED HOUSING POLICY

Based on the proposed grey model, the affordable housing price will continue to rise and exceed the affordability of urban low-and middle-income households in Shenzhen. Besides increasing the future supply of affordable housing, some additional measures should be developed to lower the price and fulfill the need for housing.

Design and construction. To design a rational and affordable housing, comparison needs to be carried out between different design proposals. Arranging the layout of residential buildings towers, public facilities, road and greenbelt should be based on its basic function and planning requirements. Advanced construction technology such as prefabricated construction should be adopted in constructing the affordable pricing to reduce the construction costs and their speed of delivery (Jaillon, Poon 2009).

Strict control on the dwelling sizes. The floor area of single dwelling could not exceed 60 m^2

under 'Management Measures of Affordability Housing' in 2004 (Yi 2008). Profits generated from affordable housing construction, which is developed by enterprises, should also not exceed 3% of the development cost. To increase the profit margin, the developers always design the single suit that is exceeding this standard (Zhang, Zhou 2011). The price of housing is linearly proportional to the construction and installation costs; the larger the area, and the higher the price. Governmental control measures should be implemented to attach this standard, for example, the authority should crosscheck randomly the area of completed dwelling with the approved as-built drawings before the issue of occupation permit. Although this provision does not lower the unit price of house affordability, it would significantly reduce its total price and reduce the burden of low-and medium-income homebuyers.

Controlling on land cost. In affordable housing projects, the land is not bought from the market but allocated freely by the government (Zhang 2007). However, the cost of demolition and compensation to the landowners and residents would be reflected in the affordable housing price under current system. Due to the limited accessibility to existing land management system, the costs of demolition and compensation for land owners are unable to be disclosed to the public. It suggested that the government should monitor the land management system and publicize the basic information of demolition and compensation fees, it would help to find out the reasons behind the high land cost.

Mortgage policy. To reduce the burden of low-and middle-income groups, it is suggest that the government should, like in many other countries, implement controls on the mortgage policies by providing lower interest rates to the purchasers of their first affordable housing. In China, funding problems are the core issue of most low and middle-income families. To control the property bubble, the government has regulated the mortgage down payment of no less than 20 percentage of the property's value (Deng *et al.* 2011). Most affordable housing buyers are not able to provide this 20% lump sum payment and can only resort to bank loans. In addition, their lending rate would usually adjusted within a relatively high range due to low repay ability, it increase the burden of Affordable housing purchaser on top of high housing price. Instead, providing favorable interest rate to purchaser would indirectly reduce cost of their housing price as well as make it corresponding with the affordability of low-and middle income families.

Meanwhile, the objective of affordable housing was to assist low-and middle income families to purchase their first owned housing. The privilege of lower interest rate mortgage to the purchasers of their first affordable housing, could further prevent the greedy investors making the affordable housing market being hot.

7. CONCLUSIONS

As an indispensable component of public housing provision in China, affordable housing is one of the major components used to alleviate the housing needs of low-and middle household. Based on housing provision in Shenzhen, the development and price of affordable housing was introduced and analyzed in this study. Over the past two decades, the price of this housing has been raised year by year. By using grey model, it is one of the modeling techniques that can be applied in the problem with insufficient information and limited points of data. The development trend on the affordable house pricing has been captured accurately. The results showed that the price level in forthcoming year is far beyond the affordability of the targeted household. Suggestions on measure that government should do to reduce the burden of household are recommended.

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