Calculation and Evaluation of Construction Land Reduction Potential Based on Correction Model

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Abstract. In the process of urbanization, Jinshan District, Shanghai has been faced with problems of land utilization, including the unreasonable structure of land use, the quantity limit of construction land, etc. The construction land reduction policies have been introduced to address these problems. Thus, the research on construction land consolidation is realistically significant and provides a solution to the utilization of land. Based on the correction model and requirements of general land use planning, this paper mainly studies the reduction potential of rural residential and industrial-mining land which both belong to the construction land. According to the analysis and evaluation, the results show that there is still much reduction space of rural residential and industrial-mining land in Jinshan District. And effective arrangements should be applied for later reduction work of construction land. The correction model method is first to be used for calculating and evaluating the construction land reduction potential in the district of Shanghai, which can provide innovative and outstanding support for later reduction work of construction land.

1. Introduction

In some developed regions of China, economy and culture have developed rapidly. In the process of urbanization, there exist so many problems, including the pressure of population, the shortage of land resources, the irrationality of land use structure, the lower resource utilization efficiency, the quantity limit of construction land and the obvious contradiction between supply and demand. Chinese government has issued a number of policies and proposed general land use objective in 2014 to solve these problems [1]. Many regions of China, represented by some developed areas, such as Shanghai, Jiangsu Province, have taken the lead in the work of construction land reduction, providing experience to carry out related work in the other regions of the country.

Construction land reduction originates from land consolidation. Land construction is a process of land restructuring and improvement, and it is a key way to optimize the allocation of land resources, maximize the efficiency of land use and land utilization. Construction land reduction is part of the land consolidation, mainly reducing the quantity of the inefficient and abandoned rural residential land and industrial-mining land, which was used for cultivated land and profit-oriented land. Domestic and foreign research and evaluation on land consolidation provide technical support for construction land reduction, which is the important foundation to carry out the relevant work [2]. Most researchers assess the effects of land consolidation by means of landscape pattern index [3]. In recent years, domestic scholars analyzed the remediation potential of the different rural living areas by surveying the current situation of rural residential land, constructing restrictive correction factor and mathematical models [4].
This paper takes the potential of construction land reduction in Jinshan District, Shanghai as an example, focusing on practical measurement and evaluation of potential. The research flow diagram of the paper is shown in Figure 1. The measure and evaluation should include two parts, the first is the theoretical potential, referring to the maximum reduction potential of the study area without considering the actual conditions, it mainly takes the method of constructive land standard per capita and land general planning. However, the reduction potential of a region can be excavated is affected by many aspects actually, including natural, economic, and social factors. Therefore, on the basis of the theoretical potential, it obtains the real potential by considering influencing factors, and digs out the real potential in Jinshan District as much as possible [5]. The paper is the first time to take the correction model to modify the potential in the areas, and expects to provide innovative support and ways for construction land reduction work of general land use planning in 2015-2020 in Jinshan District.

2. Theoretical Potential

For the rural residential land, traditional calculation methods of theoretical potential include method of constructive land standard per capita, method of per household [6], the homestead idle rate method, the building volume rate method [7], etc. Method of constructive land standard per capita is most mature, accurate and reliable among them, which was widely used in land consolidation and rehabilitation work because of its simple definition and calculation process. Theoretical potential of industrial-mining land refers to the process of reducing all of industrial-mining land outside the concentrated construction zone, which is used for farmland and operational construction land.

2.1. Rural Residential Land

The method of constructive land standard per capita is usually applied to calculate the reduction potential of rural residential land, taking use of the product of the rural population at the end of planning period and rural land standard per capita to get the rural residential land area. Then the difference between the result and the present rural land area can be obtained. In the short-term planning, the population change is not significant, so the status quo population is equal to the population at the end of the planning period, as shown in equation (1).

\[ S_{\text{theory}} = P \times B - S_{\text{now}} \]  

(1)

where \( S_{\text{theory}} \) denotes theoretical reduction potential, \( P \) represents the rural population, \( B \) is rural land standard per capita, \( S_{\text{now}} \) refers to the status quo population.

According to the "Town Planning Standard", classification of construction land per capita index is based on regulations of construction land standard per capita in different towns, as shown in Table 1 [8].
Table 1  Planning and Construction Land Per Capita Index

| Current construction land per capita index(m²) | Planning adjustment(m²) |
|-----------------------------------------------|-------------------------|
| ≤60                                          | +0-15                   |
| >60-≤80                                       | +0-10                   |
| >80-≤100                                      | ±0-10                   |
| >100-≤120                                     | ±0-10                   |
| >120-≤140                                     | ±0-15                   |
| >140                                          | ≤140                    |

For different reduction areas, Jinshan District can be divided into three parts, including Jinshan Metro Area (JMA, Shihua Street, Jinshanwei Town and Shanyang Town), Suburban areas (SA, Caojing Town, Zhangyan Town, Langxia Town and Lvxiang Town) and Outer suburbs (OS, Tinglin Town, Zhujing Town and Fengjing Town). The details and theoretical potential of the rural residential land in different regions are shown in Table 2. The land area per capita of Jinshan area is significantly higher than that defined by national standard. Therefore, it is necessary to carry out the reduction work of scattered, idle and abandoned rural residential land. This paper takes the upper limit of 140m² as rural land standard per capita. The theoretical potential of the rural residential land which is expected to be excavated in Jinshan District is 1592.95 hm² at the end of the planning period, i.e. 2020.

Table 2  Land Use and Theoretical Potential of Jinshan District

| Region                  | The current rural residential land area(hm²) | The current rural population | Land area per capita (m²) | Land use standard per capita (m²) | Theoretical potential (hm²) |
|-------------------------|---------------------------------------------|------------------------------|--------------------------|----------------------------------|-----------------------------|
| Jinshan Metro Area(JMA)| 797.29                                      | 16901                        | 471.74                   | 140                              | 560.68                      |
| Suburban areas(SA)     | 1118.65                                     | 55430                        | 201.81                   | 140                              | 342.63                      |
| Outer suburbs(OS)      | 1900.16                                     | 86465                        | 219.76                   | 140                              | 689.65                      |
| Sum                    | 3816.10                                     | 158796                       | 240.31                   | 140                              | 1592.95                     |

2.2. Industrial-mining Land
The area of industrial-mining land reduction mainly refers to the land outside the concentrated construction zone. The theoretical potential is to mine all the land outside the zone, used for the index of operating land and the balance of cultivated land. As shown in Figure 2, 1581.7hm² is the theoretical potential of the industrial-mining land outside the concentrated construction zone in Jinshan District.
3. Discussion on Realistic Potential

3.1. Rural Residential Land

3.1.1. Influencing Factors
In the process of estimating the potential of the region, it is necessary to consider various constraints to determine the actual area that can be reduced, obtaining realistic potential of the study area. This paper mainly combines Geographic Information System Technology with large scale vector, raster and statistics data, supplemented by literature materials of Jinshan District. It mainly considers its economic, social and land factors. The impact indicators of these influencing factors are shown in Table 3.

Table 3  Definitions of Influencing Factors

| Influencing factor | Indicator                          | Meaning                                                                 |
|--------------------|-----------------------------------|-------------------------------------------------------------------------|
| Social factor      | Rural Population(RP)              | The demand for reduction of the area.                                   |
|                    | Rural Labor Force(RLF)            | The urgency of reduction                                                 |
|                    | Urbanization Rate(UR)             | The source of land potential and the demand for reduction.              |
| Economic factor    | Road Network Density(RND)         | Convenience of traffic                                                  |
|                    | Gross Product of the District(GPD)| The sum of the added value of industry                                 |
|                    | Total Cost of the Secondary and   | The economic capacity of reduction                                       |
|                    | Tertiary Industry(TCSTI)          |                                                                         |
| Land factor        | Industrial Tax Revenue(ITR)       | Income from industries                                                 |
|                    | Arable Land per capita (AL)       | Reserved land resources                                                 |
|                    | Residential Utilization(RU)       | The source of reduction                                                 |

3.1.2. Potential Correction System
Taking full account of the influencing factors, the paper takes correction model to modify the theoretical potential, so that the result makes maximum close to the realistic potential of the area. Then it obtains the correction coefficient of the theoretical potential. The realistic potential of the rural residential land can be calculated based on the correction coefficient. The calculation process of the correction coefficient mainly includes quantification of indicators and the determination of the weight of indicators [8].

1) Quantification of indicators
The factors that influence the theoretical potential have different units, making them difficult to compare with each other. Therefore, it is necessary to standardize the indicators of various factors. In view of the factors of the realistic potential in Jinshan District, the paper takes Linear Transformation Method:

$$z_j = \frac{y_{j*}}{y_{j\max}} \quad (j \in \mathbb{N}; j = 1, 2, \ldots, n)$$

where $y_{j*}$ is a special point, it usually takes the maximum, minimum or average of the column $j$ of the decision matrix. In the multi-attribute decision-making problem, if the indicator is a benefit-type index, we define:

$$z_j = \frac{y_{j*}}{y_{j\max}} \quad (j \in \mathbb{N}; j = 1, 2, \ldots, n)$$

The result is compared with its optimal value. In the formula (3), $0 \leq Z_j \leq 1$, the result is more satisfactory if it is closer to 1. If the indicator is a cost-type index, we define:

$$z_j = 1 - \frac{y_{j*}}{y_{j\max}} \quad (j \in \mathbb{N}; j = 1, 2, \ldots, n)$$

2) Determination of the weight of indicators

In the case of attribute decision making, Analytic Hierarchy Process (AHP) is usually used to determine the weight of each index. For the complicated problems of interrelated and interdependent factors, AHP provides a new, concise and practical modeling method for the decision-making of these problems. According to the relative importance of each index, hierarchical structural model is used to construct all the judgment matrix in each level. After passing hierarchical single ordering and consistency checking, the weight of each indicator can be determined finally.

3) Determination of the correction coefficient

The calculation of the correction coefficient is the sum of the product of the normalized values and the corresponding weights in each index layer, as shown in (5):

$$K = \sum_{i} W_i \times f_i$$

The potential indicators of the regions in Jinshan District and their corresponding weights, the initial values and standardized results are shown in Table 4.

| Influencing factor | Social factor | Economic factor | Land factor |
|--------------------|---------------|-----------------|-------------|
| Indicator Weight   | RP | RLF | UR | RND | GPD | TCSTI | ITR | AL | RU |
| JM                 | 0.16 | 0.30 | 0.46 | 0.09 | 0.30 | 0.16 | 0.54 | 0.33 | 0.67 |
| SA                 | 0.14832 | 0.96986 | 0.5819 | 0.0086 | 1.104879 | 1.06229 | 3.10114 | 3.5729 | 3.11865 |
| OS                 | 0.2274 | 0.15570 | 0.6311 | 0.0080 | 1.99851 | 1.9465 | 6.0364 | 3.903 | 19.0016 |
| Unit               | -- | -- | % | m/m² | ¥/mil | ¥/mil | ¥/mil | m² | hm² |
| JM                 | 0.35 | 0.35 | 1.00 | 0.74 | 1 | 1 | 0.57 | 0.79 | 0.42 |
| SA                 | 0.63 | 0.62 | 0.65 | 1 | 0.37 | 0.36 | 0.51 | 0.00 | 0.59 |
| OS                 | 1 | 1 | 0.71 | 0.93 | 0.66 | 0.65 | 1 | 0.31 | 1 |

Taking the urbanization rate as an example, the sketch map is shown in Figure 3. The final potential correction results and realistic potential are shown in Figure 4.
After obtaining the theoretical potential of the rural residential land and the correction coefficient, the realistic potential can be calculated by the proposed method, which is 384.2 hm² in Jinshan Metro Area, 159.7 hm² in Suburban areas and 568.3 hm² in Outer suburbs. From Table 4 and Table 5, it can be seen that the coefficients of the rural residential land of Suburban areas, Jinshan Metro Area and Outer suburbs in Jinshan District, Shanghai is 0.82, 0.69 and 0.47, respectively. Reduction of the rural residential land in Suburb areas is the largest, the correction coefficient is also the largest. It means that the possibility of the potential release is the biggest, which may be related to the more rural labor force, the huger income tax, and the larger resettlement of the residential area in Outer suburbs of Jinshan District; Jinshan Metro Area has a higher degree of urbanization, higher GDP, lower arable land per capita; Taking the social, economic, land and other factors into account, Suburban areas do not have more advantages compared with Jinshan Metro and Outer suburbs. For example, stock of their residential land is relatively small, so the final potential correction coefficient and the final release of the potential is minimal.

3.2. Industrial-mining Land

The work that reduces industrial-mining land should take the land planning into account and give priority to the "three lines" within the homestead, polluting industries and other nearby homestead implementation of the reduction. For Jinshan District, the actual potential must be considered in the 2015-2020 overall land use planning. According to the principle of linking the increase and decrease of the land and the overall land use planning of Jinshan District by 2020, by comparing the new construction land demand and future reduction potential in the concentrated construction zone of Jinshan District, the construction land will be reduced to 1931 hm². The realistic potential of residential land has been estimated up to 1112 hm², so 819 hm² is the realistic potential in the planning period of industrial-mining land in Jinshan District, Shanghai.

4. Results and analysis

The general land use planning of Jinshan District, Shanghai in 2015-2020 focuses on the reduction and reclamation of scattered, idle rural residential land as well as inefficient use of industrial land. For rural residential land, this paper applies the method of constructive land standard per capita to analysis theoretical reduction potential. Then it takes correction model to modify the theoretical potential in different areas by calculating the correction coefficient. At last, it analyses the realistic potential of rural residential land. For industrial-mining land, it gets the final realistic potential, according to the requirement of general land use planning.

The results indicate the following: (1) The theoretical potential and realistic potential of residential land in the Outer suburbs in Jinshan District (Tinglin Town, Zhujing Town, Fengjing Town) is larger than other regions. In the near future, the government departments should more focus on the reduction potential of these areas; (2) There still exist a large number of industrial-mining lands outside the concentrated construction zone, which is the important source to carry out the reduction work. The government should pay attention to the inefficient and abandoned industrial-mining land, used for new
index of construction and cultivated land to achieve the maximum use of land resources; (3) In this paper, the method of correction model is the first time to be used to calculate the potential of rural residential land in Jinshan District. The method fully considers multiple impact factors of the potential. Compared with the traditional construction reduction work relying on subjective factors, it is more innovative and scientific and can provide efficient support for policymakers. The government departments should carry out the reduction work based on the realistic potential, in accordance with the orderly time, taking scientific and effective ways to dig out regional reduction potential of construction land and providing experience for other regions' construction land reduction work in China.

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