Prediction of construction waste in representative cities of North and South based on Grey Model

PengFei Wang1,a, Yang Liu1,2,3, SiYan Gao1, Shaohua Luo1, JingJue Jia1, Heng Yang1, XiaoYu Liu1

1School of Geomatics and Urban Spatial Informatics, Beijing University of Civil Engineering and Architecture, No.15 Yongyuan Rd., Daxing District, Beijing, 102616, China
2Beijing Advanced Innovation Center for Future Urban Design, Beijing University of Civil Engineering and Architecture, No.1 Zhanlanguan Rd., Xicheng District, Beijing, 100044, China
3Beijing Key Laboratory of Urban Spatial Information Engineering, No.15 Yangfangdian Rd., Haidian District, Beijing, 100038, China
4liuyang@bucea.edu.cn

*Corresponding author’s e-mail: 1339630594@qq.com

Abstract: With the orderly promotion of construction waste treatment in China, the process of construction waste reduction is also gradually launched. At present, the production of construction waste in many cities is in the historical high decline stage. In order to better plan the capacity of urban construction waste treatment and recycling, it is necessary to forecast the output of construction waste in a period of time in the future. Based on the historical data from 2012 to 2018 in the statistical yearbook, this paper forecasts the construction waste production from 2020 to 2023 in Shenyang Dalian, the core city of Northeast China, and Guangzhou and Shenzhen, the provincial capitals of Guangdong Province. By comparing the growth trend of population with the growth trend of construction waste, it is found that the growth of construction waste is along with the increase trend of population. Meanwhile, four suggestions for urban waste disposal are provided.

1. Introduction
With the development of the times, my country's economy is advancing rapidly, and the construction industry has also accelerated its pace [1]. In the context of supply-side reforms and the new economic normal, the output of construction waste in some cities has also experienced a process from rapid growth to decline year by year. Especially in my country's northeast old industrial base, the construction area basically reached its peak from 2012 to 2015.

In order to better plan the capacity of urban construction waste treatment and resource utilization, it is very necessary to predict the output of construction waste in the future. At present, domestic scholars mostly use multiple regression analysis method, BP network neural model prediction model, Grey Model prediction and other methods when predicting construction waste [2]. For example, BaiHan Gong and others used multiple regression analysis method to predict and analyse construction waste. Multiple regression analysis method refers to that in the vector, one variable is regarded as the
dependent variable and the other variables are regarded as independent variables. A statistical method by establishing linear or nonlinear mathematical models between variables and analysis sample data. However, this method needs to be combined with related factors to make predictions. At the same time, due to the large amount of data calculation, the results are prone to deviation. The BP network neural model prediction model analyses a large amount of data to make predictions. This method requires a large amount of data. Although accurate, it is not practical. The grey model prediction method created by the famous scholar JuLong Deng in my country uses known data as a technique to accumulate the data to obtain a regular time series, and then uses the model to predict on this basis [4-5]. Many domestic researchers, such as CaiYun Ma, use the Grey Model to predict construction waste. Therefore, this paper mainly chooses the Grey Model to predict. The Grey Model does not require a large amount of data as the basis for prediction. The sample does not need to have a certain law and the workload is small, so it is very practical for the prediction of construction waste.

2. Prediction model of construction waste

2.1. Production estimate
According to the "Regulations on the Management of Urban Construction Waste and Engineering Waste (Revised Draft)" issued by the original Ministry of Construction in 2003, construction waste and engineering waste refer to the construction and construction of various buildings, structures, etc. by construction, construction units or individuals Residues, slurries and other wastes produced by such products [7-9]. Because there are so many types of construction waste, it is impossible to accurately calculate and predict. Therefore, this article uses the construction area to estimate. There are two main ways of generating construction waste, one is the construction waste generated by the construction of new houses, and the other is the waste generated by the demolition of old houses. Regarding construction waste generated during construction, my country currently generates an average of 500-600 tons of construction waste per 10,000 square meters during construction. The production rate of construction waste in this paper is 550t/10,000 square meters. At the same time, in the process of demolition, the output of demolition waste is based on the domestic construction situation and the understanding of various documents [10]. This article mainly proposes that the generation rate of demolition waste is 1.2t/m². This article mainly uses the following formula to estimate the total amount of construction waste in four cities including Shenyang, Dalian, Changchun and Harbin.

\[ a_1 = b_1 \times c \]  \hspace{1cm} (1)
\[ a_2 = b_2 \times d \]  \hspace{1cm} (2)
\[ A = a_1 + a_2 \]  \hspace{1cm} (3)

Among them: \( a_1 \) is the annual output of construction waste; \( b_1 \) is the annual construction volume of construction waste; \( c \) is the construction waste generation rate; \( a_2 \) is the annual output of construction demolition waste; \( b_2 \) is the annual demolition volume of construction waste; \( d \) Demolition waste generation rate; \( A \) is the total annual output of construction waste;

2.2. Model selection
There are many types of Grey Models. The GM (1.1) model, which is widely used in this study, is also called the grey correlation prediction model. The model prediction process can be divided into two parts, model establishment and residual testing. The specific steps are shown in Figure 1:

![Figure 1. Grey Model Forecast Technology Roadmap](image)
2.2.1. Establishment of grey forecasting model GM (1.1)
The GM(1.1) model is established mainly by setting the original time series of the annual output of construction waste as \( x^0 = \{ x^0(1), x^0(2), x^0(3), \ldots x^0(n) \} \). Generate a new sequence \( x^1 = \{ x^1(1), x^1(2), x^1(3), \ldots x^1(n) \} \) through accumulation, the new sequence fluctuates relative to the original sequence Lower performance and higher reliability. At the same time, the model is tested on the original data. If the model meets the accuracy requirements, the gray model prediction can be performed. The differential equation corresponding to the GM (1.1) model is
\[
dx^1/dt + \alpha x^1 = \mu \tag{4}
\]
Among them: \( \alpha \) is the development ash number; \( \mu \) is the endogenous control ash number. At the same time, the least square fitting can be used to find the parameter vector to be estimated:
Substituting \( \alpha \) and \( \mu \) into the prediction model, the model formula is as follows:
\[
\tilde{X}^1(k+1) = \left[ x^0(1) - \mu/\alpha \right] e^{-\alpha k} + \mu/\alpha, \quad k=0,1,2,3,4,\ldots,n \tag{5}
\]

2.2.2. Model residual test
Residual error test: The residual error test mainly calculates absolute error and relative error, the formula is as follows:
Absolute error: \( \theta^0(t) = |x^0(t) - \tilde{x}^0(2)|, \quad t=1,2,3,4\ldots,n \tag{6} \)
Relative error: \( \phi^0(t) = \theta^0(t) / x^0(t) \tag{7} \)
Post-residual test: Post-residual test mainly calculates the variance ratio of standard deviation and the probability of small error. The specific formula is as follows:
\[
S_1 = \left( \sum_{n-1}^{[x^0(t) - \tilde{x}^0(0)]^2} \right)^{1/2} \tag{8}
\]
\[
S_2 = \left( \sum_{n-1}^{[\theta^0(t) - \phi^0(0)]^2} \right)^{1/2} \tag{9}
\]
Residual ratio: \( C = S_2 / S_1 \tag{10} \)
Probability of small error: \( P = P \{ | \theta^0(t) - \phi^0(0) | < 0.6745S_1 \} \tag{11} \)
After calculation, the residual error ratio and the probability of small error can be obtained. At the same time, it is evaluated according to Table 1 [7]. If it is unqualified, it cannot be used.

| Model accuracy | Types     | P    | C   |
|---------------|-----------|------|-----|
| First level   | excellent | P>0.95 | C≤0.35 |
| second level  | good      | 0.80≤P<0.95 | 0.35≤C<0.50 |
| Third level   | qualified | 0.70≤P<0.80 | 0.50≤P<0.65 |
| Fourth level  | Unqualified | P<0.70 | C>0.65 |

3. Results and analysis

3.1. Study area
Shenyang is the capital city of Liaoning Province and the economic and cultural center of the Northeast region. As of 2018, the city has 10 districts and 2 counties, with a total area of 12,948 square kilometers, a built-up area of 560 square kilometers, and a permanent population of 8.316 million people. With the development of the economy, the urban conversion rate of Shenyang is 81%.

Dalian is a sub-provincial city in Liaoning and an important coastal city in the northeast. It has a total area of 12573.85 square kilometers, a built-up area of 488.6 square kilometers, a permanent population of 5.952 million, and an urbanization rate of 72%.

Guangzhou is the capital city of Guangdong Province, as well as an important central city in my country, an international trade center and a comprehensive transportation hub. As of 2018, the city has
11 districts with a total area of 7,434 square kilometers and a total population of 15,305,900. After the reform and opening up, Guangzhou’s urban conversion rate was 84.46%.

Shenzhen is a sub-provincial city in Guangdong Province, with a total area of 1997.47 square kilometers, a built-up area of 927.96 square kilometers, a permanent population of 13,438,800, and an urban conversion rate of 100%.

Figure 2 shows the research area of this article.

The future population growth trend predicted by the gray model is shown in Figure 3:

(a) Dalian population forecast curve
(b) Shenyang population forecast curve
(c) GuangZhou population forecast curve
(d) Shenzhen population forecast curve

Figure 3. Future population growth trend chart
As shown in Figure 3, the population growth rate of Shenzhen and Guangzhou is significantly higher than that of Shenyang and Dalian.

In the context of the gradual increase in the conversion rate of cities and towns, although the vigorous development of the construction industry has gradually increased the conversion rate of the city, the disposal of construction waste has also become the primary problem for the government to solve. This paper predicts the future generation of construction waste in these four cities, which can more accurately reflect the trend of construction waste generation in the four cities, and give the four cities resource management decisions.

3.2. GM (1,1) model establishment

3.2.1. Data collection

This article uses the "China Statistical Yearbook" to calculate the construction area of Shenyang and Guangzhou, and calculate the total output of construction waste through Formula 1, Formula 2, and Formula 3. The specific output is shown in Table 2 below:

| Year  | Shenyang | Dalian | Guangzhou | Shenzhen |
|-------|----------|--------|-----------|----------|
| 2010  | 1549.0037| 885.5945| 1346.2210 | 514.4895 |
| 2011  | 1785.2240| 1083.8415| 1131.2210 | 503.2965 |
| 2012  | 1925.4602| 1083.8415| 1131.2210 | 503.2965 |
| 2013  | 2024.4507| 1083.8415| 1131.2210 | 503.2965 |
| 2014  | 2011.7615| 1083.8415| 1131.2210 | 503.2965 |
| 2015  | 1459.7293| 1083.8415| 1131.2210 | 503.2965 |
| 2016  | 1235.1622| 1083.8415| 1131.2210 | 503.2965 |
| 2017  | 1219.239 | 1083.8415| 1131.2210 | 503.2965 |
| 2018  | 1142.0132| 1083.8415| 1131.2210 | 503.2965 |

3.2.2. Construction waste forecast

Table 2 shows the original data of Shenyang and Guangzhou. Substituting the data into the formula, the prediction models for the two cities are:

Shenyang: \( X^1(K+1) = -16207.580e^{-0.1368t} + 18133.0409 \)

Dalian: \( X^1(K+1) = -19406.3409e^{-0.0621t} + 20291.9354 \)

Guangzhou: \( X^1(K+1) = 27060.6048e^{0.0545t} - 25135.7798 \)

Shenzhen: \( X^1(K+1) = 4560.9859e^{0.5505t} - 4046.4964 \)

Set \( t=0.1 \ldots .9 \) into formula 5, and the predicted values of the four cities are shown in Table 3. The absolute error and the relative error meet the accuracy requirements, and the predicted value line graph is shown in Figure 4:

| Year  | Shenyang | Dalian | Guangzhou | Shenzhen |
|-------|----------|--------|-----------|----------|
| 2020  | 795.4    | 693.7  | 605       | 527.7    |
| 2021  | 905.4482 | 871.2217| 786.1315  | 700.6107 |
| 2022  | 1116.3683| 954.1266| 936.7736  | 762.2907 |
| 2023  | 1311.2210| 1116.3683| 954.1266  | 762.2907 |
Figure 4. Forecast curve of construction waste

Substituting the absolute error and the relative error into the variance ratio C obtained in formulas 10 and 11, Shenyang City: 0.3009 Dalian City: 0.2051, Guangzhou City: 0.1956; Shenzhen City: 0.0397. The small general error P is as follows: Shenyang: 1; Dalian: 1; Guangzhou: 1; Shenzhen: 1. According to the model accuracy grade comparison table, the accuracy of the four cities meets the requirements.

4. Conclusion

Based on the gray model, this paper uses historical data from the "China Statistical Yearbook" to predict the annual construction waste generation from 2020 to 2028 in the representative cities of the north and south, Shenyang, Dalian, Guangzhou and Shenzhen. The results show that due to different population growth trends, the output of construction waste in Shenyang and Dalian is on a decreasing trend year by year, while the output of construction waste in Guangzhou and Shenzhen is on a rising trend year by year. Regardless of whether it increases or decreases, it still needs to be treated with reasonable resources. Through the prediction of construction waste generation, it can provide auxiliary data support for the city's construction waste disposal decision. At the same time, make resource management suggestions for government departments to refer to.

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