Investigation and Research on Utilization Rate of Construction Waste Resource in Wuhan

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Abstract. With the continuous development of the construction industry, the utilization rate of construction waste recycling is still at a low level. Therefore, the government has issued relevant policies to reduce construction waste and take measures for resource utilization. Based on the estimation of the output of construction waste in Wuhan in the past ten years, the current utilization level of construction waste in Wuhan is obtained. In combination with the current policy and Wuhan city construction waste recycling enterprise's game, it is concluded that the government needs to enhance the construction waste recycling enterprise of rewards and punishments, so as to improve the utilization of construction waste.

1. Introduction
In the background of the continuous improvement of science, technology and productivity, green environmental protection and circular development have gradually been valued by people. The green cycle development in the construction industry is also a part that cannot be ignored. Therefore, the reduction and resource utilization of construction waste has become an important research direction. In this paper, by studying the construction waste materials production, Wuhan city construction waste recycling utilization of favorable conditions is analyzed, combined with the government's policy of construction waste recycling enterprises, to provide the basis for the policy of next phase and improve resource utilization, in order to implement the concept of green, low-carbon and circular development has been implemented and achieve the sustainable development of construction industry.

M A Shallo et al. (2010), believed that the Canadian government should apply both green evaluation standards and LEED standards to the utilization and management of construction waste resources, referring to the development process of policies and laws and regulations on construction waste in Japan and Germany[1]. Nicolas Roussat et al. (2008) conducted a comparative analysis of construction waste management schemes in the demolition process of 9 different buildings through practical cases, and concluded that construction waste should be selectively deconstructed and recycled according to different waste components after the treatment of harmful substances[2]. Shuai Fang (2017) made a detailed analysis on construction waste recycling to the United States, Japan, Germany and other countries which concluded that the laws and regulations of developed countries are more complete, the classification and utilization of construction waste are more scientific, the technical standards and guidelines are relatively complete, the reprocessing is market-oriented, and the degree of scale is higher, putting forward the enlightenment for the utilization of construction waste in China[3]. Guotian Wang (2019) analyzed the practices of the United States, Japan, Germany, South Korea and other countries from the perspective of source emission reduction and resource utilization.
of construction waste, summarized the basic experience of overseas construction waste treatment, and put forward the enlightenment for China's construction waste treatment[4].

2. Estimation of construction waste output in Wuhan
Since there are a lot of relevant data onto Wuhan Statistical Yearbook 2020 issued by Wuhan Municipal Government, the data are preprocessed first. In the Wuhan Statistical Yearbook 2020 completed 5-4 housing area of relevant data contains two parts, namely urban investment and rural investment, which has already contained the related content. The data is creditable and time-efficient, so it is processed to get construction waste production, building area of demolition waste output and building decoration waste production.

Studies have found that the construction waste generated per 10,000 square meters of construction area is about 500-600t in the process of construction. The coefficient in this paper is 0.55[5].

Construction wastes output.

\[ Y_1 = X_1 \times 0.55 \quad (1) \]

\( Y_1 \) is the construction waste output (10,000 tons), and \( X_1 \) is the floor area of the completed house (10,000 sq. m). Based on the relevant data onto the floor area of completed houses in Wuhan Statistical Yearbook 2020, the estimated annual production of construction waste in Wuhan from 2010 to 2019 can be obtained. See table 1.

Table 1. Annual production of construction waste in Wuhan from 2010 to 2019.

| Year | Floor area of completed house Ten thousand sq. m | Annual production of construction waste Ten thousand tons of |
|------|--------------------------------------------------|-------------------------------------------------------------|
| 2010 | 2172.26                                          | 1194.7                                                      |
| 2011 | 2182.98                                          | 1200.6                                                      |
| 2012 | 2776.48                                          | 1527.1                                                      |
| 2013 | 2416.17                                          | 1328.9                                                      |
| 2014 | 2993.46                                          | 1646.4                                                      |
| 2015 | 3326.92                                          | 1829.8                                                      |
| 2016 | 1931.86                                          | 1062.5                                                      |
| 2017 | 1465.93                                          | 806.3                                                       |
| 2018 | 650.02                                           | 357.5                                                       |
| 2019 | 804.67                                           | 442.6                                                       |

In this paper, according to the demolition area of the building, it is 20% of the construction area of the completed building.

Demolition area \( X_2 = 0.2 \times \text{Floor area of completed house } X_1 \)

Studies have shown that about 1.01t~1.35t of construction waste will be generated for each demolished building of 1 sq. m[6]. In this paper, the coefficient of waste generation per unit construction area is 1.18t/sq. m.

\[ Y_2 = X_2 \times 1.18 = X_1 \times 0.2 \times 1.18 \quad (2) \]

\( Y_2 \) refers to the annual waste production (10,000 tons) of the demolition area, \( X_2 \) refers to the demolition area (10,000 sq. m), and \( X_1 \) refers to the construction area of the completed house (10,000 sq. m). According to the relevant data onto the floor area of completed houses in Wuhan Statistical Yearbook 2020, the estimated annual waste production of dismantled floor area of buildings in Wuhan from 2010 to 2019 can be obtained. See table 2.

Table 2. Output of construction demolition waste in Wuhan from 2010 to 2019

| Year | Floor area of completed house Ten thousand sq. m | Demolition area Ten thousand sq. m | Dismantled area of construction waste annual output Ten thousand tons of |
|------|--------------------------------------------------|-----------------------------------|----------------------------------------------------------|
| 2010 | 2172.26                                          | 434.452                           | 512.65336                                               |
| 2011 | 2182.98                                          | 436.596                           | 515.18328                                               |
| 2012 | 2776.48                                          | 555.296                           | 655.24928                                               |
| 2013 | 2416.17                                          | 483.234                           | 570.21612                                               |
The annual production of waste in construction decoration is about 10% to 15% of the annual production of construction waste. In 2017, construction decoration wastes output accounted for about 20% of construction waste. In this paper, the output of construction decoration waste is set to be about 30% of construction waste [7].

\[
Y_3 = X_1 \times 0.3 \tag{3}
\]

Among them, \( Y_3 \) is the waste production of building decoration (ten thousand tons), and \( X_1 \) is the waste product of construction (ten thousand tons). According to the relevant data onto the floor area of completed houses in Wuhan Statistical Yearbook 2020, the estimated annual production value of construction decoration waste in Wuhan from 2010 to 2019 can be obtained. See table 3.

### Table 3. Waste output of building decoration in Wuhan from 2010 to 2019

| Year | Annual waste output (Ten thousand tons) | Annual production of waste in construction decoration (Ten thousand tons) |
|------|-----------------------------------------|---------------------------------------------------------------------|
| 2010 | 1194.7                                  | 358.4                                                               |
| 2011 | 1200.6                                  | 360.2                                                               |
| 2012 | 1527.1                                  | 458.1                                                               |
| 2013 | 1328.9                                  | 398.7                                                               |
| 2014 | 1646.4                                  | 493.9                                                               |
| 2015 | 1829.8                                  | 548.9                                                               |
| 2016 | 1062.5                                  | 318.8                                                               |
| 2017 | 806.3                                   | 241.9                                                               |
| 2018 | 357.5                                   | 107.3                                                               |
| 2019 | 442.6                                   | 132.8                                                               |

Then the formula for estimating the total production of construction waste.

\[
Y = Y_1 + Y_2 + Y_3 \tag{4}
\]

\( Y \) is the total production of construction waste, \( Y_1 \) is the annual production of construction waste, \( Y_2 \) is the annual production of construction demolition waste, and \( Y_3 \) is the annual production of construction decoration waste. Combined with the above data, the total production of construction waste in Wuhan from 2010 to 2019 can be obtained. See table 4.

### Table 4. Total production of construction waste in Wuhan from 2010 to 2019

| Year | Floor area of completed house (Ten thousand sq. m) | Total construction waste (Ten thousand tons) |
|------|----------------------------------------------------|---------------------------------------------|
| 2010 | 2172.26                                            | 2065.81926                                  |
| 2011 | 2182.98                                            | 2076.01398                                  |
| 2012 | 2776.48                                            | 2640.43248                                  |
| 2013 | 2416.17                                            | 2297.77767                                  |
| 2014 | 2993.46                                            | 2846.78046                                  |
| 2015 | 3326.92                                            | 3163.90092                                  |
| 2016 | 1931.86                                            | 1837.19886                                  |
| 2017 | 1465.93                                            | 1394.09943                                  |
| 2018 | 650.02                                             | 618.16902                                   |
| 2019 | 804.67                                             | 765.24117                                   |

### 3. Relevant Policies of Wuhan

In 2015, the utilization rate of construction waste in Wuhan was only 0.4%. In 2016, the government proposed a policy to improve the utilization rate of construction waste. Nine construction wastes...
processing and demonstration bases were built, including six new urban districts in the main urban area. At the same time, one or two large-scale construction waste recycling treatment plants were built in three towns of Wuhan.

The utilization rate of construction waste recycling in Wuhan is mainly related to the relevant policies of the government. Although the utilization rate of construction waste recycling has been significantly improved due to the relevant policies proposed by the Wuhan government, it is still relatively low, which may be mainly due to the low degree of rewards and punishments given by the government to construction waste recycling enterprises. Therefore, in the following part, the relevant policies proposed by the government, such as the degree of rewards and punishments for the recycling level of enterprises, will be analyzed, mainly discussing the relationship between the government’s own profits and the degree of rewards and punishments, in order to obtain some feasible plans.

The government to the enterprise unit resource utilization level of reward and punishment.

\[ K = \frac{\varphi R_G}{Q + \varphi \lambda} \]  

(5)

The actual recycling level of construction waste recycling enterprises.

\[ R_B = \frac{R_G Q}{2(Q + \varphi \lambda)} \]  

(6)

Profit of construction waste resource enterprises.

\[ \pi_B = CD - \varphi R_B^2 + K (R_B - R_G)Q \]  

(7)

The government profit.

\[ \pi_G = -D - \frac{K^2 Q^2}{2\varphi} + QKR_G - \frac{1}{2} \lambda K^2 Q \]  

(8)

\( R_G \) is the level of resource utilization required by the government, which is the standard value of rewards and punishments implemented by the government. \( \lambda \) is the R&D capability or R&D efficiency of the enterprises. \( K \) is determined by the government \((K > 0)\). \( \varphi \) is the R&D capability or R&D efficiency of the enterprise \((\varphi > 0)\). \( Q \) is the total amount of construction waste \((Q > 0)\)\(^8\). According to the above four formulas, relevant parameters are set to analyze the profit relationship between the government and enterprises under the condition of the recycling of construction waste. According to Equation (5), \( K \) can be calculated, and the profit value \( \pi_B \) when the government implements the reward and punishment system can be obtained from Equation (8). According to Equation (6), the maximum value of \( R_B \) can be obtained, and the profit value of construction waste recycling enterprises can be obtained from Equation (7). It can be found that there is a value of reward and punishment intensity \( K \) that makes the maximum government profit \( \text{Max} \pi_G \). In this case, regardless of the value of the recycling level \( R_B \), the cost \( \pi_B \) of the recycling enterprises is negative.

4. Conclusion

From the data from 2010 to 2019, it can be seen that in the past decade, the production of construction waste in Wuhan had declined, and thus the pollution of urban environment and the waste of resources had gradually decreased. However, according to the data, the recycling rate of construction waste is still at a low level, and it still needs the continuous efforts of both the government and enterprises. In accordance with the relevant model analysis, it can be concluded that in order to further improve the utilization rate of construction waste recycling in Wuhan, the government must not be able to determine the rewards and punishments for construction waste recycling enterprises based on maximizing its own profits, and it needs to further improve the utilization rate of construction waste recycling from a high perspective to formulate relevant policies and propose solutions.

The government can adjust the measures of rewards and punishments and invest more financial support in order to increase the incentives for enterprises to recycle construction waste, so as to
encourage enterprises to recycle resource waste. At the same time, the government should also increase
the punishment, which can not only effectively control the waste behavior of enterprises for construction
waste, but also effectively alleviates the government's capital expenditure in this respect and ensure a
certain profit for the government. Only through the government's adjustment of the system and the better
coeperation of enterprises can society continue to promote the sound development of the utilization of
construction waste resources and improve the utilization level of construction industry.

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