Discussion on Key Influencing Factors of Construction and Demolition Waste Recovery and Recycling Management in China

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Abstract. Through the literature summary, a list of key factors affecting construction and demolition (C&D) waste recycling and resource governance was identified from three levels: government governance and support, social public participation, and related enterprise participation. By building a collaborative driving model of C&D waste recovery and recycling governance, and based on the system dynamics of C&D waste recovery and recycling governance causal loop diagram, it shows the synergy between various influencing factors of the C&D waste recovery and recycling management. Conclusion: suggestions are come up with promote the development of C&D waste recovery and recycling management by increasing policy guarantees and financial support, encouraging public participation, stimulating the participation of relevant enterprises, and improving the effects of C&D waste recovery and recycling.

Keywords. C&D waste recovery, recycling management, causal diagram.

1. Introduction

In recent years, with the continuous advancement of urbanization in China, various construction activities are developing vigorously, which also leads to the continuous expansion of the output of C&D waste. Random piling of construction waste will not only cause land occupation, environmental pollution, but also cause serious safety problems. Compared with traditional methods such as landfill and incineration, recovery and recycling of C&D waste can not only reduce the exploitation and use of natural resources, but also is an important way to control environmental pollution and safety. However, the current comprehensive utilization rate of construction waste in China is under 5% [1], and the phenomenon of construction waste besieging the city is everywhere, therefore, it is urgent to recovery and recycle of C&D waste. Therefore, it makes a difference for the research of construction waste recovery and recycling.

At present, in the study area of construction waste recycling and resource governance, Wu et al. [2] made a qualitative analysis on the present state and future development of construction waste recycling. Yuan et al. [3] made in-depth research on the obstacles and countermeasures of construction waste recovery and recycling. Chen et al. [4] identified the decision strategic choice of the government and construction waste recycling contractors through the game theory model. Galvezmartos [5] studied the optimal governance policy for C&D waste in Europe. Hu [6] made a big data analysis of illegal dumping. These studies mainly discuss the problem of construction waste management from the perspective of single factor, but rarely from the perspective of multiple factors. This paper
identifies the domestic construction waste recovery and recycling influencing factors through literature summaries and uses the Vensim software to construct a causality diagram of various factors about the C&D waste recycling. According to the causality diagram, explore methods and suggestions for improving the recovery and recycling construction waste in China.

2. Status Quo of C&D Waste in China

2.1. Estimation of C&D Waste Production
C&D waste refers to solid waste generated from construction, renovation, and demolition activities [7]. In most cities in China, C&D waste cannot be calculated at an accurate time, which results in a waste disposal volume that does not match the size of landfills and recycling plants [8]. Therefore, calculating the output of C&D waste is very important. This paper uses Song’s [9] method to estimate construction waste and construction demolition waste based on the construction area (see table 1). Among them, Zhao [10] pointed out in his research that the C&D waste generation coefficient $R_1 = 0.055 \text{ t/m}^2$, the demolition coefficient $R_2 = 10\%$, and the demolition waste generation coefficient $R_3 = 1.2 \text{ t/m}^2$.

Table 1. Calculation method of C&D waste output.

| Parameter Description |
|-----------------------|
| Construction waste $c = a \times R_1$ |
| Demolition waste $d = a \times R_2 R_3$ |
| C&D waste $w = c + d$ |

On the basis of statistics data of the National Bureau of Statistics of China from 2010 to 2019 on the completed construction area and combined with the calculation method (see table 1), the annual output of China’s C&D garbage from 2010 to 2019 is estimated (see figure 1). The results in figure 1 show that the amount of demolished waste is twice as much as construction waste and demolition waste accounts for most total C&D garbage. China’s output of C&D garbage peaked at 2.5 billion tons in 2019.

![Figure 1. Estimation of China’s C&D production from 2010 to 2019.](image)

2.2. Current Situation and Problems of C&D Waste Governance
Facing with the increasingly serious problem of C&D garbage management, the central and local governments have made positive measures. The Related national department put forward the establishment and improvement of construction waste reduction working mechanism in document No.
46 of 2020: strengthening the construction waste source control, promoting the C&D of engineering production organization pattern transformation, effectively reducing the generation and discharge of construction garbage during construction and the improvement of urban and rural human settlements. Large cities such as Xuzhou, Wuhan, Chengdu have formulated corresponding regulations for C&D garbage governance; many waste recycling plants have been built in Beijing, Jiangxi, and Shanxi. At the same time, many provinces and cities have set targets for the annual use ratio of C&D garbage. These actions and measures show that Chinese governments at all levels have recognized the importance of C&D garbage governance. Nevertheless, because of the short development time of C&D waste treatment in China, there are also the following problems: the relevant legal system is not perfect; the most treatment of C&D garbage in China is simple landfill; the government management is inefficient; the construction waste resource market cannot spontaneously form an industrial chain.

3. Influencing Factors Analysis
Firstly, literature retrieval was carried out, and advanced retrieval conditions were set in the Periodical library of CNKI. Relevant literature was reviewed manually, and those irrelevant to the subject were deleted to ensure the accuracy of subsequent research. Then, the key phrase co-occurrence network diagram is obtained based on the literature measurement tools in the knowledge network to preliminarily identify the key factors, and then the influencing factors are obtained through the selection of high-frequency keywords and the further analysis of the literature content. Finally, the polarities of each influencing factor were summarized by consulting relevant experts and scholars and literature, and the causal loop diagram of the influencing factors was drawn by system dynamics analysis software Vensim according to the above contents.

3.1. Identification of Influencing Factors
To assure the theoretical saturation of the list of influencing factors of C&D waste recovery and recycling, the literature screening was conducted in accordance with the three principles of “advancing with the times”, “industry authority” and “high correlation”, selection finally published between 2010 and 2019 with the construction garbage recycling, “construction garbage resource utilization”, “construction garbage recycling”, “the processing of construction waste”, “the sustainable management of construction waste” topics for example related industry authoritative journal papers, which contains the SSCI, EI, core journals, CSSCI, CSCD articles in journals, 89 papers are selected. Refining the keywords of the sample literature, you can find the development path and changing characteristics of the research field. Through literature measurement tools, we can know that the present recycling and treatment of construction waste mainly focus on the three points of reduction, reusing and recycling.

Through the screening of high-frequency keywords, and a series of work such as repeated comparison, verification and correction of the content of the literature, the paper summarizes and summarizes from the selected literature that the government, the public, contractors, construction units and C&D garbage resource enterprises, which are external factors affecting construction waste recovery and recycling management, and 23 specific factors that impact C&D garbage recovery and recycling (see table 2).

3.2. The Establishment of Causal Loop Diagram of System Dynamics of Influencing Factors
Construction waste and resource recovery is a dynamic system. System dynamics can be used to describe the influence of various influencing factors on the development of C&D garbage recovery and recycling, as well as the interrelationships between these factors. The reduction of construction garbage and the recycling of construction garbage determine the effect of construction waste recovery and recycling and are internal factors that affect the recovery and recycling management of construction garbage. The acting subjects of construction waste recovery and recycling is composed of the government, the public, contractors, construction units and C&D garbage resource enterprises, which are external factors affecting construction garbage recovery and recycling. Through this, the
influence driving model of construction waste recovery and recycling governance is established (see figure 2)

Table 2. Recognition results of factors affecting C&D waste recycling.

| Influencing factors | Government                                                                 |
|---------------------|-----------------------------------------------------------------------------|
|                     | Management efficiency; Improvement of the legal system; Supervision and     |
|                     | enforcement; Financial subsidy; Research investment; Financing support;     |
|                     | Government Procurement; Propaganda power; Construction of information       |
|                     | management platform.                                                        |
| Society             | Purchase intention of resource-based products; Supervision awareness;      |
|                     | Environmental awareness; C&D waste classification awareness.                |
| Construction company| Construction Quality; utilization of recycled building materials; The        |
|                     | application of assembly construction; Factory prefabrication; Willingness    |
|                     | to sort construction waste on site.                                         |
| C&D waste recycling  | Cost of production; Recycled product price; Recycled product quality;      |
| enterprise          | Recycled product sales; Recycling technology.                               |

Figure 2. Driving model of C&D waste recovery and recycling management.

Through the established C&D garbage recycling and resource management impact-driven model, using system dynamics to build using system dynamics to build a causality diagram of the government support subsystem, social public participation subsystem and related enterprise participation subsystem to analyze the government, the public, and related enterprises The effect of factors on C&D waste reduction and recycling and its impact on recycling and resource management.

(1) The participation for government is multidimensional (see figure 3), including: the establishment of the management system and legal system, the government supervision and law enforcement; he government’s financial support includes financial subsidies, research input, financing support and government procurement. The more perfect the government management system and laws, the more powerful it can provide for government supervision and law enforcement; the government has played an important role in restricting the illegal dumping of construction waste in the society, which also realizes the source control of construction waste and promotes the reduction of construction waste. The government’s financial subsidies include: financial allocation, financial discount interest, tax rebate, etc. The main trend of the government’s financing for C&D garbage disposal is PPP mode; government financial subsidies and financing make the private sector intention to participate in professional construction waste recycling projects with a long payback period, high cost and high debt-to-asset ratio, which also promotes the progress of construction waste recycling to a certain extent. Government procurement of recycled products is to include recycled products in the catalogue of green building materials and the catalogue of government procurement, thus promoting the scale of recycling products, which also promotes the C&D garbage recycling. Government
propaganda can not only stimulate and encourage more groups to join the ranks of C&D garbage recycling and governance, but also can guide and criticize illegal dumping. By building a construction waste information platform, the supervision department can help to realize the sharing of C&D garbage resource data and the circulation of data information, thus promoting the progress of construction waste resource industry. In addition, the effect of construction garbage recovery and recycling can be fed back to the government, so that the government can make further policy arrangements based on the current situation.

(2) Social public participation includes: social supervision, environmental protection awareness, willingness to sort construction garbage, as well as, willingness to purchase resourced products. Social public mainly supervises the illegal dumping of construction garbage through basic methods such as suggestions, reports, and disclosures, thereby promoting the development of construction waste reduction (see figure 4). Now, because the hazards of construction waste are still not understood by the public, this leads to a weak awareness of construction-level recycling among social residents, resulting in many acts of randomly stacking construction waste. The public’s environmental intention of construction waste can reduce the randomness of construction garbage stacking in turn promotes construction waste reduction. Majority of the public consider that the quality of construction waste is not safe and the service life is not high. Such preconceptions have led to a low willingness to purchase construction waste recycling products, which also hinders the sale of construction waste recycled products. Therefore, the higher the purchase intention of the public can change this kind of situation, thus facilitate the progress of regeneration product market, and promote the management of construction waste resource utilization. In addition, the classification of construction waste can not only recover some valuable building materials, but also improve the efficiency of later recycling.

(3) Enterprises related to construction waste recycling and resource management include construction garbage generating units, recycling enterprises. C&D garbage mainly is made in the construction and demolition process, and the construction enterprise is the performer of this process (see figure 5). Construction enterprises can improve the life of buildings by improving construction quality, so as to achieve the purpose of decreasing; the classification of construction waste at the construction site of construction enterprises means the classification and collection of C&D garbage, which can not only reduce the environmental problems caused by subsequent treatment, but also effectively decrease the cost of transportation and handle, thus facilitating the efficiency of C&D waste recovery and recycling. Construction enterprises are potential users of recycling products. The more willing construction enterprises are to buy, the higher the sales volume of construction-level recycling products will be, and the more development of recycling will be promoted. C&D garbage recycling enterprises are the implementers of recycling and disposal and the marketization of recycled
products. The cost of the recycled product includes the cost of classification, transportation, etc. The higher the cost of the product, the greater is the impact on the product price. Recycling technology not only affects the quality of recycled products but also improves the efficiency of recycling. The price and quality of recycled products impact the willingness to buy. The higher the price of recycled products, the lower is the willingness to buy and the reliable the quality of recycled products, the higher the willingness to buy. To ensure the sustainable supply of construction garbage and the sale of recycled products, construction garbage recycling companies must fully consider the willingness of construction companies to pay.

4. Discussion and Suggestion
C&D waste recycling and resource management is the result of external factors such as the government, the public, and related enterprises that affect the reduction and C&D waste recycling. Analyze interaction between the factors that affect construction waste recovery and recycling from a
system perspective, and clarify the key factors through the relationship between the various factors, so as to provide targeted methods and suggestions for the optimization of construction recovery and recycling management to improve the ratio of C&D garbage recycling and treatment.

(1) The government, the public and relevant enterprises influence the recovery and recycling of construction waste through laws, funds, supervision, willingness to participate and action support, which are the basic driving factors of the recovery and construction waste recycling. Therefore, the government’s governance and support, the degree of public participation and the willingness of relevant enterprises to participate make a big difference in the recovery and C&D garbage recycling. Hence, coordinating among the government, the public and relevant enterprises make a significant difference in the recovery and recycling of C&D garbage.

(2) Government governance and support are the key factors for construction waste recovery and recycling governance. The participation of the government itself can directly facilitate the decreasing and recycling of buildings from the macro level; the government’s legal perfection and law enforcement can strictly regulate and suppress the illegal dumping of construction garbage production units, and the government’s level of publicity and education determines in view of the degree of public participation, the government’s financial support can not only promote the willingness of construction waste generation units to decrease construction waste, but also accelerate the development of the construction waste recycling enterprise market. The government’s research investment also contributes to the construction waste recovery and recycling, playing a role for advances in technology. Therefore, government should constantly facilitate the laws and regulations related to the C&D waste management. For the illegal dumping of construction wastes, there must be laws to follow, law enforcement to be strict, and violations to be investigated to provide strong legal protection for recycling C&D garbage. Meanwhile, it is necessary to establish a comprehensive construction waste reduction government working mechanism, strengthen overall management, coordinate the work of various parts, strengthen the source control of C&D garbage, limit the decreasing and generation of C&D waste during construction, as well as, continuously promote the construction of ecological civilization in construction.

(3) Strengthening and ensuring the participation of the public and enterprises is an important means to facilitate the effect of construction waste recovery and recycling. The public can not only monitor the illegal dumping behavior of relevant enterprises, but also give feedback on the effect of construction waste recovery and recycling to provide guidance for the government’s governance work. As the most producer of C&D garbage and the implementer of recycling, relevant enterprises can reduce construction waste from the source and promote the development of C&D garbage recycling market from the terminal only when their fundamental interests are guaranteed.

5. Conclusions
In this paper, based on the literature summary and identification, a list of influencing factors for C&D garbage governance is obtained, and then a driving model for the impact of C&D garbage recycling and resource management is established. Finally, a causality diagram of influencing factors for C&D garbage governance based on system dynamics is constructed. Through the above analysis, it is concluded that it is advisable to increasing policy guarantee and financial supporting, encouraging the participation of the public, support and encourage the participation of relevant enterprises can improve the effect of C&D garbage reduction and recycling to promote the development of C&D garbage recovery and recycling.

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References
[1] Li D, Peng Y, Guo C and Tan R 2019 Pricing strategy of construction and demolition waste considering retailer fairness concerns under a governmental regulation environment Environmental Research and Public Health 16 (11) 20-29.
[2] Yuan H 2017 Barriers and countermeasures for managing construction and demolition waste: a case of Shenzhen in China Cleaner Production 157 (22) 84-93.
[3] Chen J, Hua C, and Liu C 2019 Considerations for better construction and demolition waste management: identifying the decision behaviors of contractors and government departments through a game theory decision-making model Cleaner Production 212 (15) 190-199.
[4] Gálvez M, José L, Styles D, et al. 2018 Construction and demolition waste best management practice in Europe Resources, Conservation and Recycling 136 (33) 166-178.
[5] Lu W 2019 Big data analytics to identify illegal construction waste dumping: a Hong Kong study. Resources Conservation and Recycling 141 (26) 264-272.
[6] Bao Z, Lu W, Chi B, et al. 2019 Procurement innovation for a circular economy of construction and demolition waste: lessons learnt from Suzhou, China Waste Management 99 (24) 12-21.
[7] Yu B, Wang J, Li J, et al. 2019 Prediction of large-scale demolition waste generation during urban renewal: a hybrid trilogy method Waste Management 89 (3) 1-9.
[8] Song Y, Wang Y and Liu F 2017 Development of a hybrid model to predict construction and demolition waste: china as a case study Waste Management 59 (5) 350-361.
[9] Zhao W, Leeftink R and Rotter V 2010 Evaluation of the economic feasibility for the recycling of construction and demolition waste in China—the case of Chongqing Resources Conservation & Recycling 54 (17) 377-389.
[10] Wu H, Zuo J, George Z, et al. 2019 Status quo and future directions of construction and demolition wasteresearch: A critical review Cleaner Production 240 (42) 243-252.