**In support of circular economy to evaluate the effects of policies of construction and demolition waste management in three key cities in Yangtze River Delta**

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**Abstract**

As the driving force of social and economic development worldwide, a vibrant and environmentally friendly construction industry in every country is a necessary element for a successful and green global economy. China has a vibrant construction industry but faces environmental challenges posed by rapid urban redevelopment that generates huge quantities of construction and demolition (C&D) waste in most of its key cities. An understanding of C&D waste management in such cities, including the effectiveness of low carbon and waste reduction policies, can provide the basis for the sustainable development and economic growth of China’s construction industry. This study therefore evaluated the effectiveness of the C&D waste management policies of three key cities in China’s Yangtze River Delta region: Nanjing, Shanghai, and Hangzhou. Information was collected and presented based on statistical analysis and qualitative assessment of the total C&D waste and governance policies of each of the three cities between 2007 and 2018. The results show that Shanghai’s C&D waste annual total difference over the 11 year period is the largest at 2.85 million tons, a decrease of 36.8%, while Hangzhou has the largest difference in the total annual amount of C&D waste of 0.82 million tons, a reduction of 11.8%. Findings from the study provide scientific-based decision support for local and central government when strengthening construction waste management policies in China, as the country works towards a circular economy.

**Graphical abstract**



**Keywords**: Construction and demolition waste management; waste reduction policies; China’s key cities; Yangtze River Delta; circular economy

1. **Introduction**

With China’s rapid economic development, large segments of the rural population have migrated to the cities looking for work opportunities and better living conditions; accordingly, the urban population has increased dramatically. This means that the low-rise buildings in the old urban areas, which were built more than 40 years ago, need to be demolished to make way for high-rise buildings that can house more people. The fast urbanization and city renewal have led to a thriving real estate market and vibrant construction industry in recent years (Cai et al., 2020). The newly completed construction area of China reaches about 2 billion square meters every year, accounting for more than half of the global annual increase in construction area (Song, 2020). Although the construction activities help to build new infrastructure and buildings, and upgrade old urban areas, a considerable amount of construction and demolition (C&D) waste is generated during the process every year (Hao et al., 2020), such as the 100.53 million tons of C&D waste produced in Shanghai in 2020 (ZDSH, 2020). The dramatic growth in the amount of C&D waste over the last few years has brought about severe environmental and social pressures along with economic loss (Souza et al., 2022). Given that the COVID-19 pandemic has immensely impacted the economic, social, and environmental aspects of sustainable development (Ranjbari et al., 2021), there is greater urgency than ever to minimize C&D waste generation.

To secure the environmental and social sustainability, one of the essential strategies is to minimize waste and enhance material circularity (Matlin et al., 2020). The realization of this solution depends on support from multiple sources, including management, technology, government, and industry (Soltanian et al., 2022). Although there are deficiencies in C&D waste processing equipment in China, such as for crushing and screening (Li et al., 2020), most researchers have focused more on problems associated with the management of C&D waste. These problems include inadequate management systems, a dearth of adequate laws and regulations, lack of implementation and enforcement by local and central government, and no suggestions for improving the management of C&D waste (Wang et al., 2021). In response, the Chinese government has issued a plethora of policies, since effective construction and demolition waste management (CDWM) has a large bearing on sustainable economic development and the implementation of the “13th Five-Year Plan” (Yang et al., 2021). To encourage C&D waste reduction, recycling, and landfilling, government policies regarding CDWM have been implemented and enforced in many cities. However, the successful implementation of the policies depends on a series of factors, including policy incentives, efficiency of separate collection systems, and government supervision (Cesaro and Belgiorno, 2021). The total amount of C&D waste is still growing, which is hard to ascribe to ineffective policies since little is known about the effectiveness of government policies after they have been implemented.

Accurate understanding of the impacts of government policies on CDWM can serve as a valuable reference when preparing for the “14th Five-Year Plan”. As one of the most developed regions in China, the Yangtze River Delta (YRD) region produces a large amount of C&D waste every year (Wang et al., 2021). Therefore, investigating government policies and CDWM in the YRD region can be very useful for not only formulating a development strategy for a low carbon circular economy, but also for promoting development and integration of the YRD region (Ding et al., 2020). Accordingly, this study examined the effectiveness of newly implemented C&D waste policies on the quantity of C&D waste generated in the key cities of Nanjing, Shanghai, and Hangzhou in China’s YRD region from 2007 to 2018.

China’s C&D waste minimization activities started late. Consequently, CDWM in every region of the country is in the early stages of development and needs to be improved (Duan et al., 2015). New laws and regulations need to be implemented to guide local government and recycle enterprises toward better C&D waste minimization activities through the adjustment of influencing factors (Hao et al., 2019). Although China has implemented some policies for controlling C&D waste, they need to be strengthened and more strictly enforced to improve the utilization rate of C&D waste and reduce pollution (Seror et al., 2014; Zhao et al., 2021). In this context, it is argued that the utilization of C&D waste as a resource needs the following two approaches: firstly, raising awareness of the governance of C&D waste, clarifying responsibilities and obligations, and encouraging the participation of all those involved. Secondly, increasing financial and policy support from the government to ensure that as much C&D waste as possible is reused or recycled (Liu et al., 2020).

The current C&D waste situation in China is the construction of large public buildings using green construction, which includes utilizing C&D waste resources (Jin et al., 2017). The success of CDWM depends on a combination of technological, managerial, economic, and social factors (Li et al., 2020; Tam and Hao, 2016). The power to influence this eclectic blend varies from project to project and is subject to the client’s requirements as well as local government regulations. Nevertheless, government intervention as manifested through policies, will have a greater or lesser influence depending on the jurisdictions (Costa et al., 2010; Rendon et al., 2021) and can have a positive or negative impact on the management of C&D waste through reward and punishment mechanisms (Zhao et al., 2020). For example, an off-site C&D waste sorting policy was launched to promote C&D waste minimization in Hong Kong in 2006, which resulted in a substantial decrease in C&D waste (Lu and Yuan, 2012), and the successful implementation of EU waste management policies have also brought about a sustainable reduction of waste (Di Maria et al., 2020). Although it has been claimed that poor regulation and policy will weaken the effort of waste management (Massarutto and Ermano, 2013), and that poor government-issued C&D waste policies can be a significant constraint in the effective application of green techniques (Ma et al., 2020), C&D waste can nevertheless be controlled by reasonable policies, effective implementation, and the compliance of construction industry stakeholders.

The literature relating to C&D policies mostly involves simulation and policy analysis. Lu and Tam (2013) undertook a longitudinal study to examine C&D management policies and their effectiveness in Hong Kong and found that new policies should be devised to promote C&D management, even though a C&D waste disposal charging scheme was effectively implemented in 2016. Li et al. (2014) studied the impact of policies on the application of prefabrication adoption in the construction industry through scenario simulation. The results showed that a subsidy policy was effective for promoting the adoption of prefabrication and that the combined effect of multiple policies is larger than a single policy. Li et al. (2020) undertook a qualitative study to identify key policies in the development of the C&D waste recycling industry and found that tax was the most common policy tool and recommended that a landfill charge should be introduced. Liu et al. (2021) analyzed the influence of policies on CDWM by conducting evolutionary game analysis and found that the government management efficiency was high; however, some policies needed improvement. The implementation effects of C&D waste disposal policies were examined by simulation analysis with the results showing that an incentive policy is effective as a single policy, while a guidance-incentive-mandatory policy is superior as a combined policy (Wang et al., 2021). To this end, although several studies on government policies towards C&D waste have been conducted recently, as summarized in Table 1, most of them applied simulation method rather than focusing on actual data. The foregoing studies reveal that little effort has been devoted to empirical research into the effectiveness of CDWM policies in China. Therefore, this article assesses the effectiveness of policies for CDWM to evaluate the effects of policies of CDWM in three key cities in the YRD region of China.

Table 1. Summary of construction and demolition waste policies from around the world

|  |  |  |  |
| --- | --- | --- | --- |
| Authors | Region | Method | Findings |
| Lu and Tam, 2013 | Hong Kong | A longitudinal study | Hong Kong is actively trying new CDWM policies based on latest waste management philosophies available. These policies have formed an interlocking, and relatively effective policy framework for CDWM in Hong Kong. |
| Calvo et al., 2014 | Spain | Systems Dynamic methodology | This paper finds a broader understanding of the socioeconomic implications of waste management over time and the positive effects of these policies in the recycled aggregates market in order to achieve the goal of 30% C&D waste aggregates in 12 years or less. |
| Ajayi and Oyedele, 2017 | UK | Exploratory sequential mixed method approach | Six key measures are important for waste management legislation and policies to effectively drive C&D waste minimization, including tax breaks, incentives, sustainable design appraisal systems, and increased stringency of legislative measures and fiscal policies. |
| Shen et al., 2018 | China | An evolutionary game model | Only when the perceived benefits of one or both stakeholders for participation under the environmental regulation exceed those for non-participation, can the CDW recycling system eventually evolve to a stable state in which both stakeholders choose to participate.Factors such as the production cost, subsidies, recycling benefits, and the degree of perception of the stakeholders, exert certain influences on the stable state. |
| Mak et al., 2019 | Hong Kong | A comprehensive system dynamics model | The newly modified waste disposal charging fee is ineffective to achieve construction and demolition waste reduction in the long term.  |
| Aslam et al., 2020 | China & USA | A review approach | The C&D waste generation and its management are influenced by several factors including population, urbanization, GDP, and CDWM regulatory measures. |
|  Li et al., 2020 | China | The stepwise regression analysis | Charge or Tax was the most common policy tool (84.6%), but Green Product Label (7.7%) and Technological standards (11.5%) were rather less frequently employed. |
| Doust et al., 2021 | Australia | a qualitative methods approach using a pragmatic research framework | The most effective way to reduce C&D waste in Australia is via regulatory change, requiring policies and procedures that focus on front-end strategies. |

1. **Methodology**

Desk research, which is research activity based on publicly available information, was employed in this study (Oberhauser et al., 2015). Government policies on C&D waste released by three key cities in China’s YRD region, Nanjing, Shanghai, and Hangzhou, were collected from relevant official websites (see table 2, 3, 4). The data sources are: Nanjing Housing and Urban-Rural Development Bureau, Nanjing Municipal Government, Shanghai Greening and Amenities Bureau, Shanghai Municipal Government, Shanghai Housing and Urban-Rural Development Management Committee, Shanghai Urban Management Administration and Law Enforcement Bureau, and Hangzhou Municipal Government.

The quantities of C&D waste produced in those cities were calculated based on data retrieved from the 2007-2018 Statistical Yearbooks and official websites (National Bureau of Statistics of China, 2020). A comparative study was conducted to determine the different impacts of government policy on C&D waste in the three cities, and a series of tables and statistics complied to visually present the variation in C&D waste quantities and their relationship with government policies. Policy evaluation was then conducted to examine the effectiveness of government policies on C&D waste in the three cities.

**2.1 Estimation of construction and demolition waste in Nanjing, Shanghai, and Hangzhou**

**2.1.1 Unit output method based on the amount of construction permit funds**

The per capita multiplier method is a relatively simple method of measuring output, which considers only the human impact on C&D waste and no other factors, even though construction activity also makes a significant difference to output. As an alternative measure, Yost and Halstead (1996) developed a method of accounting for C&D waste based on the number of building permits, which provides theoretical support for the choice of address for waste disposal companies. They gave an example of plasterboard to describe the method in detail: a series of interrelated studies on plasterboard manufacturing and related statistics were compared using mathematical methods; the price of a unit of plasterboard was then calculated and the total amount of money spent on the construction of the plasterboard area was determined. Finally, the total amount of gypsum was estimated based on the specified amount in each unit of plasterboard. The advantage of this method is that the money required for construction is considered as a waste generating factor and other factors can be considered. It therefore meets the actual demand more accurately and greatly reduces the difference between theory and practice.

**2.1.2 Statistical data-based unit production method**

A prerequisite for using this method is the collection of accurate and detailed data from the relevant fields and governments, which makes the quantitative assessment of C&D waste easier and more accurate. Kofoworola and Gheewala (2009) used the unit yield method based on statistical data to accurately assess the total amount of C&D waste in Thailand. The sources of data for estimation in this study were the China Statistical Yearbook, the Nanjing Bureau of Statistics, the Shanghai Bureau of Statistics, and the Hangzhou Bureau of Statistics (Nanjing Municipal Bureau Statistics, 2020; National Bureau of Statistics of China, 2021). The main indices of the calculation formula are the transformation rate of the floor area and the amount of C&D waste generated per unit area. The final demolition waste V1, construction waste V2 and total C&D waste V in Nanjing, Shanghai, and Hangzhou are shown in Table S2, Table S3, and Table S4 respectively of the supplementary material. The detailed calculation process is shown in the Appendix. As can be seen from the aforementioned tables, the total amount of housing construction, demolition construction and waste in Nanjing reached 4.18 million tons, the total amount of housing construction, demolition construction and waste in Shanghai reached 12.7 million tons, and the total amount of housing construction, demolition construction and waste in Hangzhou reached 9.55 million tons.

**2.2 Comparative research**

**2.2.1 Analysis of the effectiveness of construction and demolition waste management in Nanjing**

(1) Analysis of the proportion of total construction and demolition waste

The amount of housing C&D waste generated, the quantity of demolition waste generated, and the total volume of waste in Nanjing between 2007 and 2018 is shown in Figure 1. It can be seen from the statistical chart that in the 11 years from 2007-2018, C&D waste production in Nanjing reached a maximum of 6.68 million tons in 2016, of which construction waste accounted for 57.5% and demolition waste accounted for 42.5%. In 2018 C&D waste production ranked second, reaching 6.49 million tons, of which construction waste accounted for 66.6% and demolition waste accounted for 33.4%. In 2017 C&D waste production was third reaching 6.78 million tons, of which construction waste accounted for 63.3% and demolition waste accounted for 36.7%. The proportion of demolition waste and construction waste production in Nanjing between 2007 and 2018 shows that the proportion of construction waste is the largest.



Figure 1. Statistical chart of housing construction waste (CW) generation, demolition waste (DW) generation, and total C&D waste in Nanjing 2007-2018 (million tons)

(2) Analysis of fluctuations in the annual construction and demolition waste difference

Fluctuations in the annual C&D waste difference is calculated by taking the difference between the total amount of C&D waste in the current year, minus the total amount of C&D waste in the previous year and dividing the difference by the total amount of annual waste in the current year. Table S5 of the supplementary material shows this calculation for Nanjing’s construction waste V2, demolition waste V1, and total C&D waste V. The analysis is completed by correlating the annual difference with changes in C&D waste policies. Figure S2 of the supplementary material graphically depicts the fluctuations in the difference of the total C&D waste in Nanjing, while Figure 2 indicates that the annual total C&D waste in Nanjing decreased from 2011 to 2012 with 0.570 million tons, a decrease of 10.4%; the total annual amount of C&D waste decreased from 2013 to 2014 by 0.355 million tons, a decrease of 6.4%; and the total annual amount of C&D waste decreased from 2016 to 2017 by 0.251 million tons (3.7%).



Figure 2. Annual difference % area map of total C&D waste in Nanjing 2007-2018

**2.2.2 Analysis of the effectiveness of construction and demolition waste management in Shanghai**

(1) Analysis of the proportion of the total amount of construction and demolition waste

Between 2007 and 2018, the production of C&D waste in Shanghai reached a maximum of 12.07 million tons in 2014, of which demolition waste accounted for 39.2% and construction waste accounted for 60.8%, as shown in Figure 3. In 2011, C&D waste production ranked second, reaching 11.59 million tons, of which demolition waste accounted for 43.8% and construction waste accounted for 56.2%. C&D waste production reached the third highest in 2017 with 11.55 million tons, of which demolition waste accounted for 33.5% and construction waste for 66.5%. The proportion of demolition waste and construction waste production in Shanghai between 2007 and 2018 shows that Shanghai, like Nanjing, has a very large proportion of construction waste.



Figure 3. Statistical chart of housing construction waste (CW) generation, demolition waste (DW) generation, and total C&D waste in Shanghai 2007-2018 (million tons)

 (2) Analysis of the fluctuation of construction and demolition waste difference

Fluctuations in the annual C&D waste difference is calculated by taking the difference between the total amount of C&D waste in the current year, minus the total amount of C&D waste in the previous year and dividing the difference by the total amount of annual waste in the current year. Table S5 of the supplementary material shows this calculation for Shanghai’s construction waste V2, demolition waste V1, and total C&D waste V. The analysis is completed by correlating the annual difference with changes in C&D waste policies. Figure S3 of the supplementary material and Figure 4 graphically depict the annual difference of total C&D waste in Shanghai.



Figure 4. Annual difference % area map of total C&D waste in Shanghai 2007-2018

As shown in Figure 3 and Figure 4, the annual total amount of C&D waste in Shanghai decreased the most from 2008 to 2009, which was 2.85 million tons, a decrease of 36.8%. From 2011 to 2012, the annual total amount of C&D waste decreased by 1.45 million tons, a decrease of 13.5%. From 2014 to 2015, the annual total amount of C&D waste decreased by 0.818 million tons million tons, a decrease of 6.88%. After 2015 the total amount of C&D waste in Shanghai tends to be stable.

**2.2.3 Analysis of the effectiveness of** construction **and demolition waste management in Hangzhou**

(1) Analysis of the proportion of the total amount of construction and demolition waste

It can be seen from Figure 5, which shows the proportion of the total production of C&D waste, that in the 11 years from 2007 to 2018, Hangzhou reached the maximum C&D waste production of 9.07 million tons in 2018, of which demolition waste accounted for 35.2% and C&D waste accounted for 64.8%. In 2016, C&D waste production ranked second, reaching 8.66 million tons, of which demolition waste accounted for 33.3% and construction building waste accounted for 66.7%, and in 2015, C&D waste production reached the third highest at 8.52 million tons, of which demolition waste accounted for 34.7% and construction building waste accounted for 65.3%. The proportion of demolition waste and construction waste produced between 2007 and 2018 in Hangzhou, it can be seen that just as in Shanghai the proportion of construction waste is very large.

 

Figure 5. Chart of housing construction waste (CW) generation, demolition waste (DW) generation, and total C&D waste in Hangzhou 2007-2018 (million tons)

(2) Analysis of fluctuations in the annual construction and demolition waste difference

Fluctuations in the annual C&D waste difference is calculated by taking the difference between the total amount of C&D waste in the current year, minus the total amount of C&D waste in the previous year and dividing the difference by the total amount of annual waste in the current year. Table S6 shows this calculation for Hangzhou’s construction waste V2, demolition waste V1, and total C&D waste V. The analysis is completed by correlating the annual difference with changes in C&D waste policies. Figure S4 of the supplementary material and Figure 6 depict in chart form the fluctuations in the difference of total C&D waste in Hangzhou.



Figure 6. Annual difference % area map of total C&D waste in Hangzhou 2007-2018

It can be seen from Figure 5 and Figure 6 that the annual total C&D waste in Hangzhou decreased the most from 2011 to 2012, 0.827 million tons, a decrease of 11.8%. From 2016 to 2017 the annual total C&D waste decreased by 0.319 million tons, a decrease of 3.62%. Overall, the production of C&D waste in Hangzhou is on the rise, although the rate of increase is gradually slowing down.

1. **Results and Discussion**

**3.1 Status of construction and demolition waste management in Nanjing, Shanghai, and Hangzhou**

It can be seen from Figure 7, which shows a statistical graph of the total production of C&D waste and its fluctuation difference in Nanjing, Shanghai, and Hangzhou, that each year from 2007 to 2018 Shanghai generated more total annual C&D waste compared to the other two cities, followed by Hangzhou in second place and lastly Nanjing. This may be due to the economic strength of each city and other factors including land area and population. From the percentage difference in the total production of C&D waste in Nanjing, Shanghai, and Hangzhou, Nanjing has the largest difference in the total annual amount of C&D waste of 1.07 million tons, a reduction of 34.2%. Shanghai C&D waste annual total difference is the largest at 2.85 million tons, a decrease of 36.8%. Hangzhou has the largest annual total difference of 1.65 million tons of C&D waste, a decrease of 27.1%. Shanghai is more effective than Nanjing and Hangzhou in the management of C&D waste, but the total production of C&D waste in Nanjing, Shanghai, and Hangzhou is on the rise.



Figure 7. Statistical chart of the total production of C&D waste and its difference fluctuations in Nanjing, Shanghai, and Hangzhou (million tons)

**3.1.1 Problems and measures of construction and demolition waste management in Nanjing**

(1) The problems of managing construction and demolition waste

Nanjing produces about 20 million cubic meters of C&D waste sludge, about 4 million tons of demolition waste, and about 4 million tons of waste mud every year. Among them, the proportion of demolition waste is relatively low, and the proportion of C&D waste is relatively high. At the same time, the production of construction machinery and demolition waste has been increasing year by year. There is clearly a trend of annual increase**.**

(2) Construction and demolition waste management measures

Nanjing government released several policies on CDWM between 2009 and 2018 (see table 2). The main disposal methods for C&D waste in Nanjing are at landfills, to mix with household waste and discard it altogether, and to use mobile C&D waste treatment facilities for treatment. In the northeast part of Nanjing, in Jiangning District, Qixia District, Jiangbei Pukou District, Gaochun District, and Lishui District, a total of 15 C&D waste disposal sites and 9 urban waste disposal facilities were established, of which 6 are still in use. The remaining storage capacity is about 72.3 m³.

Table 2. Construction and demolition waste policies in Nanjing

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| **Initial enactment** | **Policy title** | **Key point of the policy** |
| 2008 | Nanjing C&D Waste Disposal Operation Credit Assessment MeasuresNanjing C&D Waste Disposal Bidding MeasuresNanjing Municipal C&D Waste Transportation Enterprise Management Regulations | 1. To standardize the disposal of C&D waste;
2. To specify the amount of C&D waste to be disposed of for that needs to be tendered;
3. To specify the places for bidding and tendering;
4. To implement a credit assessment system for the disposal of C&D waste
 |
| 2014 | Nanjing Municipal Dirt Transportation Management Measures Released. | Provided requirement of access management, construction site management, transportation management, disposal site management, and supervision and inspection. |
| 2017 | Revision of Nanjing Municipal Measures for the Management of Dirt Transportation. |
| 2019 | Implementation Opinions of the General Office of the Municipal Government on Promoting the Resourceful Utilization of C&D Waste (for Trial Implementation) | 1. To implement the classification and disposal of C&D waste;
2. Put forward to accelerate the construction of resource utilization facilities;
3. To strengthen the management of C&D waste resource utilization;
4. To promote the use of recycled products
 |
| 2019 | Nanjing City C&D Waste Resource Utilization Management Measures. | Provided requirement of planning and construction, source reduction, resource utilization, and supervision and management. |

(3) Effects of government policies of construction and demolition waste management in Nanjing

The Nanjing Municipal Government issued a notice in 2008 for the approval of three documents regarding C&D waste disposal operations, credit assessment and bidding measures, and transportation enterprise management regulations. However, they did not have too much effect on reducing the total amount of C&D waste in Nanjing; in fact, it actually increased by 0.257 million tons. Whilst this increase might be explained by the thriving real estate market in China (Zhang et al., 2018), it does show that not all government policies have a great impact on C&D waste reduction (Mak et al., 2019). The Nanjing Municipal People's Government issued the “Nanjing Municipal Muck Transportation Management Measures” in 2014, which played a role in reducing the overall output of C&D waste by 0.758 million tons, a decrease of 26.91%. However, there was a rebound with a cumulative increase of 1.071 million tons (26.48%) from 2015 to 2016, but there was a downward trend after 2016.

**3.1.2 Problems and measures of managing construction and demolition waste in Shanghai**

(1) The problems of managing construction and demolition waste

Most of Shanghai's development is arranged around economic considerations and urban development plans do not generally include the important goal of establishing an environmentally friendly and resource-saving society. However, since theory is the banner of practice, the environmental problems caused by urban development must be a priority consideration when it comes to standardization of urban construction, waste reduction expenditure, transportation, and processing scientific theory for guidance. It is time that more attention is paid to the theory underpinning the practice of preventing and controlling waste. Policy orientation concerning the management of C&D waste is not very clear, which could be due to the following three reasons: firstly, the laws and rules are not adequately communicated, secondly there is a lack of government support, and thirdly the technical standards are inadequate.

(2) Measures for managing construction and demolition waste

In order to promote the reduction and resource utilization of C&D waste, and ensure the city's urban appearance and environmental sanitation, the Shanghai Municipal Government issued a number of C&D waste-related policies between 2009 and 2018 (see table 3). This is of great significance for the overall deployment of building a resource-saving and environment-friendly society. The integrated use of C&D waste mainly consists of equipment for processing products, crusher and scanning systems, and other environmental auxiliary equipment in Shanghai. These facilities meet the needs of various forms of C&D waste to a certain extent, and the recyclable potential has an international reach.

Since the 11th, 12th, and 13th Five-Year Plans, Shanghai has faced dozens of development challenges in the use of resources for C&D waste, such as research on the durability of processed products, and the strength and safety of processed materials. To improve the development of industries related to CDWM and recycling, a combination of advanced technology, scientific management, scientific disposal, and scientific utilization of C&D waste will achieve environmental, social, and economic benefits as well as achieve harmonious and unified development (Hao et al., 2020). Accordingly, Hangzhou has set up several experimental centers for C&D waste treatment.

Table 3. Construction and demolition waste policies in Shanghai

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| --- | --- | --- |
| **Initial enactment** | **Policy title** | **Key point of the policy**  |
| 2009 | Notice of Shanghai Municipal People's Government on Strengthening the Management of C&D waste and Construction Dirt Disposal in the City. | 1. To put forward C&D waste declaration regulation;
2. To ask the construction company to set aside the C&D waste transportation and disposal expenses.
 |
| 2010 | Notice of Shanghai Municipal People's Government on Strengthening the Safety Management of C&D waste and Construction Dirt Transportation in the City. | 1. To clarify vehicle configuration requirements;
2. To clarify the requirement of a qualified driver.
 |
| 2016 | Urgent Notice on the Effective Implementation of Local Supervisory Responsibility to Further Strengthen the Full Control of C&D waste. | 1. To stop C&D waste cross-region transportation;
2. To improve C&D waste disposal locally.
 |
| 2018 | Implementation of Shanghai C&D waste Disposal Management Regulations. | 1. To expand the scope of application of bidding management;
2. To clarify the number of C&D waste transportation units;
3. To specify the requirements of the bidding conditions.
 |
| Implementation Plan on Accelerating the Disposal of C&D waste in the City. | 1. To Strengthen departmental performance of responsibilities;
2. To increase C&D waste disposal facilities;
3. To enrich the cooperation model.
 |
| Notice on Further Regulating the Collection and Disposal of House Demolition (Demolition of Violation) Garbage and Decoration Garbage in the City. | 1. To improve C&D waste declaration management;
2. To standardize the direction of C&D disposal
3. To strengthen supervision and guidance.
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(3) Effects of government policies of construction and demolition waste management in Shanghai

In January 2009, the "Notice of the Shanghai Municipal People's Government on Strengthening the Management of C&D waste and Construction Dirt Disposal in the City" was issued, which had a great impact on the total production of C&D waste in Shanghai reducing it by 2.85 million tons, or 36.8%. In April 2010, the Circular of Shanghai Municipal People's Government on Strengthening the Safety Management of C&D waste and Engineering Dirt Transportation in the City was issued, which also had an offsetting effect on the total production of C&D waste, resulting in a reduction of 1.45 million tons, or 13.5%, in the total annual production of C&D waste from 2011 to 2012; but by 2014 the total annual production of C&D waste had rebounded with an increase of 14.7%. This reflects a mismatch between policies and current practices, which is common in the construction industry (Ghaffar et al., 2020). In July 2016, the Shanghai Municipal Bureau of Greening and Urbanism issued the "Urgent Notice on the Effective Implementation of Local Supervisory Responsibility to Further Strengthen the Full Control of C&D waste", which had a certain impact on the rebounding trend of the total annual production of C&D waste, resulting in a decrease of 0.818 million tons or 6.88% in the total annual production of C&D waste. In January 2018, the Shanghai Municipal People's Government issued the Regulations on the Management of C&D waste Disposal in Shanghai, and on 7 May 2018, the Shanghai Municipal Housing and Urban-Rural Development Management Committee and the Shanghai Municipal Bureau of Urban Management Administration and Law Enforcement issued the Implementation Plan on Accelerating the Disposal of C&D waste in the City, which led to a slow downward trend in the total production of C&D waste. The effectiveness of government policies in Shanghai regarding CDWM revealed the importance of a strong legal framework and effective laws (Fernando, 2019).

**3.1.3 Problems and measures of Hangzhou in managing construction and demolition waste**

(1) Problems of managing construction and demolition waste

Currently, with the demolition and reconstruction of urban villages, the concentration of waste from construction sites in Hangzhou is rising, generating about 12 million tons of C&D waste per year. Within two years, the amount of C&D waste will continue to be relatively high with the development of urban villages, subways, and other infrastructure projects; and the trend is increasing (Ma et al., 2020). The status of CDWM in Hangzhou is mainly due to lack of sorting/segregation and classification that affects the efficiency of use, the pernicious effects of in situ piling on environmental and safety issues, and the complex selection of disposal site addresses with large areas.

(2) Measures for construction and demolition waste management

To promote CDWM, Hangzhou government released several policies between 2009 and 2018 (see table 4). The "shortest transportation distance principle and full coverage principle" should be adopted. At the same time, centers should be located in non-agricultural areas, such as abandoned quarries and quarry pits, and consideration given to administrative zoning. According to the principle of full coverage, it is very costly to transfer C&D waste from the production site to the recycling center in the shortest possible time. The main goal of the center model is to effectively reduce the transport distance of C&D waste.

Table 4. Construction and demolition waste policies in Hangzhou

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| --- | --- | --- |
| **Initial enactment** | **Policy title** | **Key point of the policy** |
| 2009 | Notice of the Office on Jointly Carrying Out Special Rectification Activities for Illegal Transportation, Casual Dumping and Stolen Dumping of Construction Dirt. | 1. To improve the intensity of inspection and strengthen source management;
2. To improve the intensity of punishment and implement strict management and heavy punishment;
3. To strengthen departmental coordination and form a joint force for rectification;
4. To encourage social participation
 |
| 2012 | Notice on the Issuance of the Work Plan for the Promotion of Green Town Action in Hangzhou (2011-2015). | Put forward the main tasks and supporting measures, especially the construction of urban infrastructure and the development of green buildings |
| 2013 | Notice on Hangzhou energy "double control" key work responsibility decomposition. | To adjust and optimize the industrial structure, vigorously develop the circular economy, accelerate the development and application of energy-saving technologies, improve energy-saving economic policies, strengthen energy-saving supervision and inspection. |
| 2015 | Hangzhou Municipal Domestic Waste Management Regulations. | Put forward details of planning and facility management, source reduction, classified delivery, classified collection, transportation and disposal, supervision and management. |
| 2016 | Notice of the implementation of engineering residue management. | 1. To strengthen the C&D waste source management, transportation management, and disposal management;
2. To strengthen territorial management responsibilities and public supervision.
 |

(3) Effects of government policies of construction and demolition waste management in Hangzhou

In September 2009, the notice from Hangzhou Municipal Government on joint special rectification activities of illegal transportation, random dumping and stealing of engineering residues did not have much impact on the total annual production of C&D waste, which increased by 1.65 million tons (27.1%). A few years later, in April 2012, Hangzhou Municipal People's Government issued a notice on the issuance of Hangzhou Green Town Action Promotion Work Plan (2011-2015). The program started with a significant effect on the offset of C&D waste production, resulting in the greatest reduction of 0.827 million tons, or 11.8%, in the total annual amount of C&D waste in Hangzhou from 2011 to 2012. This revealed the great contribution of green construction and the circular economy to CDWM (Hartley et al., 2020). In April 2013, the Hangzhou Municipal People's Government issued a notice on the decomposition of responsibility for the key work of "double control" of energy in Hangzhou, which had almost no effect on the total annual production of C&D waste in Hangzhou. In November 2015, the Hangzhou Municipal People's Government issued the Regulations on the Management of Domestic Waste in Hangzhou, which did not reduce the total annual production of C&D waste, but the growth rate was much slower. In April 2016, after Hangzhou Municipal People's Government issued the notice on the implementation measures for the management of construction residue in Hangzhou, the total annual volume of C&D waste decreased by 0.319 million tons, or 3.62%. The aforementioned reveals the effectiveness of CDWM policies and ineffectiveness of energy related policy on C&D waste reduction, and strengthens the importance of more targeted government policy (Kontokosta et al., 2018). Policy continuity also contributes to the effectiveness on C&D waste reduction in the following years.

**4. Conclusions, limitations, and prospects**

This article presents the current situation and relevant legal policies of C&D waste in China and analyzes the effectiveness of CDWM in Nanjing, Shanghai, and Hangzhou. Based on the findings, the following practical implications could be considered: (i) government policies need to be jointly made by more collaborating administrative departments; (ii) cooperation between different administrative departments need to be more substantial rather than being formalistic; (iii) detailed data about the C&D waste (generation, landfilling, and recycling) need to be released at least annually by the bureau of statistics; and (iv) a web monitoring platform is recommended to be established in each city to record and monitor the whole process of CDWM. Results of the effectiveness of CDWM in the selected cities show that relevant legal management policies are lacking in terms of best implemented with a view to long-term benefits. Almost all of them have only short-term benefits without a long-lasting impact on the quantity of C&D waste. Consequently, the prospects are put forward from this study, which can greatly assist government decision-makers in achieving the goal of C&D waste minimization.

Although the findings are limited within the study’s specified range of years (2007-2018) and within the context of three key cities in the YRD region (Nanjing, Shanghai, and Hangzhou), there is reason to believe that similar policies would also be effective for key cities in some other regions of China. Since the study was also limited by not having covered the totality of interactions between government policy and CDWM, future studies could explore the detailed response of construction enterprises and C&D waste transportation companies to government policies on CDWM. Given the impact of China’s fast-growing real estate market on its construction industry, further related research should attempt to illuminate this and other such impact to focus exclusively on policy effectiveness. In addition, future research could explore the views of experts from government departments and industry on the relationship of CDWM policies to a circular economy.

A very basic C&D waste disposal charging system was implemented in China many years ago, but it is lacking enforcement due to its unclear benefits. To improve the situation, it is recommended that the collected fees are used for the recycling of waste construction materials, and the purchase and maintenance of equipment for resource treatment. At the same time, establishing C&D waste production supervision and dynamic management systems should be strictly monitored. It is, therefore, crucial to integrate comprehensive legal policies, implement a diversified C&D waste compensation mechanism, and develop a green practice that utilizes C&D waste as resources for improving the effects of CDWM in support of circular economy.

**Author contribution statement**

**Shiwang Yu**: Conceptualization, methodology, data curation, data analysis, original draft writing, and revision. **Abhishek Kumar Awasthi**: Writing and editing. **Wenting Ma**: Data curation and data analysis. **Mingkang Wen**: Data curation and original draft writing. **Luigi Di Sarnod**: Review and editing. **Conghua Wen**: Data analysis. **Jian Li Hao**: Supervision, review, editing and revision.

**Declaration of competing interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

List of abbreviations

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| **List of abbreviations** |  |
| C&D | Construction & Demolition |
| CDWM | Construction and demolition waste management |
| COVID-19 | Coronavirus disease 2019 |
| GDP | Gross domestic product  |
| YRD | Yangtze River Delta |
| ZDSH | ZhoudaoShanghai |