Chapter 113
Exploring a Long-Term Mechanism of Construction and Demolition Waste Recycling: A Case of Chongqing

Qiong He, Shiying Shi, and Mingming Hu

Abstract Based on the analysis of costs and benefits on the construction waste landfill and recycling in Chongqing, the paper focus on discussing three possible environmental and economic policies for establishing long-term mechanism of the construction and demolition waste recycling: disposal charges, recycling subsidy and government purchasing recycling product. The results show that the direct costs of waste recycling will be higher than the landfill, and increasing waste disposal fees may be incentive to reduce waste generation, but it must rely on strict law enforcement, because it increase the risk of illegal landfill; financial subsidy to recycling center is not a long-term policy, because it cannot stimulate technological innovation and cost savings; reasonable government purchasing has a immense potential for improving the application of recycling products by guiding the construction market. The government purchasing should be the most concerned measure for establishing a long-term mechanism of construction and demolition waste recycling.

Keywords Construction and demolition waste • Cost-benefit analysis • Chongqing • Environmental economic policies • Recycling

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Q. He (✉)
Faculty of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: heqiong20025106@163.com

S. Shi • M. Hu
Advanced Construction Management Research Center,
Chongqing University, Chongqing, China
e-mail: quartzssy@gmail.com; mingminghu@cqu.edu.cn

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113.1 Introduction

In recent years, China has enjoyed exceptionally rapid economic growth, achieving a GDP growth of up to 8 % annually. However, in parallel with this rapid economic development has had a serious environmental impact on China's environment, partly because the tremendous amount of waste generated by environmentally unfriendly construction activities, such as earth excavation, civil works, site clearance and formation, demolition activities and building renovation [1]. Wang et al. [2] found that the amount of solid waste produced by construction and demolition works is more than three million tons in China, and more recently Wang et al. [3] found that most of construction and demolition waste (C&DW) were disposed in landfill, having consumed about 6,000 acres of lands. Worse still, With the acceleration of urbanization development and large-scale urban renewal, according to the forecast, China's new residence areas will increase three billion stere, meanwhile, consume about 40 % of cement and steel, and five billion tons of C&DW will be produced till 2020 [3]. The majority of that waste has not been well processed, which has caused serious resource degradation and environmental problems [1]. Under this circumstance, effective management of C&D waste in China's fast-developing construction sector [4], especially making C&DW reduction, recycling and harmless [5] is urgently needed. So far, many experts and scholars pay more attention to the research on solid waste issues, including conserving resources, waste reuse, reclamation, harmless and waste disposal. In addition, numerous papers have been published to discuss construction waste management problems, and try to study those issues in a different light, such as economy, society, technology, regulation, etc. [6–10]. However, most of the existing researches are qualitative discussion and short of systemic and quantitative think for C&D waste, from source control to marketization of renewable product [11], particularly investigating into building a long-effect mechanism of C&D waste recycling.

Even though there has some research on C&D waste conducted in China's several developed cities, including Beijing, Shanghai, Shenzhen and Hong Kong, little attention has been paid to the management of C&D waste in other regions. As China is such a big country with many different levels of economic development, the studies made in one region may not be suitable for others, that's to say, those disposal measures of C&D waste employed in one region cannot be simply applied to other regions regardless of their contextual differences [12]. In that case, by focusing on Chongqing as a typical city of rapid development of economy in China, its C&D waste management is improving, findings are more likely to be relevant to other economically underdeveloped regions of China. The remainder of the paper comprises four parts. The next part provides a general description for the environmental economic policies and its status quo of application, identifies the factors of cost and benefit for waste disposal based on the questionnaire and interviews, and outlines the research methodology used for calculating the of cost and benefit for waste disposal. The third part introduces the Chongqing's status of construction and demolition waste management and its planning. The forth part analyses and discusses the different policies' influence for waste disposal, and the last part draws conclusions.

113.2 Management and Planning of the Construction and Demolition Wastes in Chongqing

In 2007, the Coordinated and Balanced Development between Urban and Rural in Chongqing was set up. The urban construction would further speed up, and the production of construction wastes would grow rapidly in the future. Based on the waste disposal goal of recycle, reuse and reduce, "The Distribute Programming of Construction Wastes in Chongqing District" was issued in April, 2008. The program planned that seven resources comprehensive disposal centers and 19 construction waste landfills would be established in 2020, when the construction wastes would be fully integrated in the disposal center, and 80 % of them would be recycled after sorting and reusing. The total processing capability of treatment centers attained up to 3.2 million tons per year, and the service time was 12 years. However, there are many recycling products appeared including building standard bricks, hollow blocks, concrete aggregates and maintenance materials of municipal facilities (pavers, road edge bricks, asphalt concrete pavements, etc.). The detailed recycling project was shown in Fig. 113.1. According to the Chongqing's status of C&D waste management and its planning, the approaches of waste disposal are trimmed in Fig. 113.2.

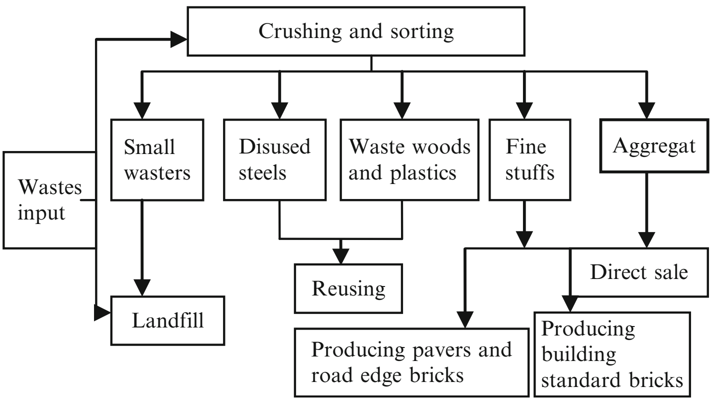

Fig. 113.1 The detailed recycling project of construction wastes in Chongqing

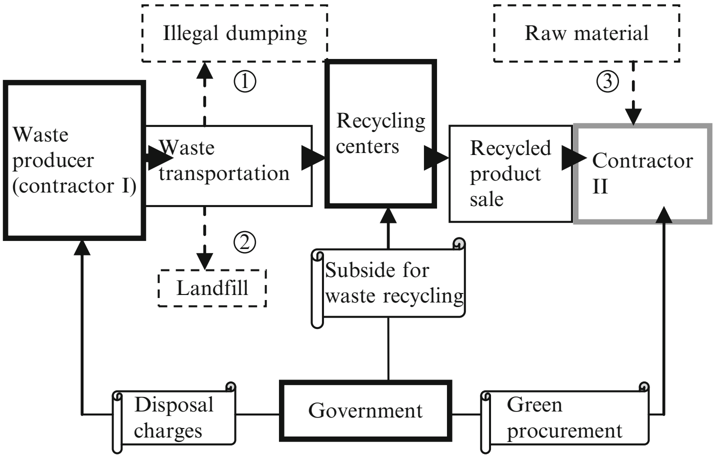

Fig. 113.2 The analysis framework of environmental economic policies on waste recycling

113.3 Research Methodology

Many policies to manage the C&D waste have been proposed, ranging from reducing waste in source, reusing and recycling waste, to landfilling; their goals are minimizing resource consumption and alleviating environmental pollution [12]. However, Vivian W.Y. Tam [5] think that these policies in practice are not as effective as its original intention, which demonstrated by substantial evidence; and lacking of economic incentives is the major factor affected C&D waste management activities. In other words, all parties involved may support the waste reusing or recycling when they get more benefits from conducting C&D waste reusing or recycling than the cost they covered. Therefore, so far the environmentally friendly and long effective management policies have not been high on the agenda. In that case, research into cost-benefit analysis of C&D waste recycling is of great importance to enable us to find answer for the question of which policies is effective to improve C&D waste recycling[12].

The cost-benefit analysis is the foundation to understand the motivation of actors and judge the potential effectiveness of environmental management policies. This research is not the first to analyze the cost and benefit of C&D waste recycling, some attempts on this topic have been already made [5, 8, 14, 12, 13]. This paper aims to build a long-effective mechanism through analyzing the cost and benefit of relative subjects (waste producer, recycling firm and government) under some environmental economic policies. The novelty of this study mainly lies in two aspects: the first is to analyze some laws and regulation that are in relevant to waste management, sum up and build the framework of environmental economic policies of waste recycling; the second is to investigate all essential activities that are in relevant to the cost-benefit of C&D waste disposal; the second is employment of the cost-benefit approach, which can not only involve various activities but also calculate their cost and benefit under different policies. According to previous studies that adopted systematic procedures for the cost-benefit analysis [4, 11, 15], this study takes the procedures as following.

113.4 Identifying and Analysis the Factors of Cost and Benefit

113.4.1 Factors of Cost

[Collection and transportation]: the main part of construction waste collection and waste transport is the producer or the removal contractor of CDW. Currently, Chongqing construction waste collection is basically a hybrid approach, that directly transport mixed CDW to landfills without any treatment, and as required to pay admission fees. Therefore, the cost in the collection phase is composed of waste collection cost, transportation costs and admission fees.

[Illegal Dumping]: At present, construction waste management is in poort situation in Chongqing. The planning of Waste disposal site and charge mechanism is unreasonable ,resulting in the contractor's transportation costs and time costs are high; Thus, contractor is lack of waste recycling motivation, willing to take the risk of the law sanctions using illegal dumping nearby. As long as the contractor is not found, he will save the cost of transport and disposal. If legal system is strong, construction waste disposal charge is lower, recycled product has healthy market, the waste disposal company will make policy adjustments according to the cost-effectiveness (such as reduce admission fees, give subsidies to the contractor). Thus waste producers would refuse illegal dumping of construction waste due to the cost reduction of their own, that is, the acts of illegal dumping construction waste is light gradually.

[Simple landfill]: This is a legitimate approach. NOW If the construction site is close to legal simple landfill field, the contractor will transported waste to the landfill field. Contractors sent waste to the legal field and pay admission fees, so, the direct cost of waste disposal which is paid by contractors includes transportation costs and admission fees.

[Waste resource]: According to the " Conditions and procedural requirements for construction waste disposal in Chongqing" and "Construction Waste disposal field distribution planning in Chongqing," we can see that the Chongqing l Government will attach importance to environmental protection industry, increase more investment in environmental protection and promote recycling industry of construction waste in the next 5 years; then, all construction waste will be transported to waste recycling disposal center after collected in the site. Combining field research with experts interviews, we know that the costs of construction waste recycling disposal include separation costs in site, resource disposal costs, landfill costs of remaining waste, producing costs of re-product.

Table 113.1 Formulas of costs and benefits

Key players	Function	Formulas	Remarks
Waste producer or contractor	Waste collection	Labor costs: $C_{11} = C_C$	C_{C}: Labor costs of waste collection in site
	Simple landfill	Transport costs $C_{13} = Tr * D_S$	Tr: Unit transport Cost, D_S: The transport distance
		Payments for landfill $C_{14} = C_S$	C_S: Payments for landfill
	Comprehensive	Transport costs $C_{15} = D_{21} * Tr$	D_{21}: The transport distance, Tr: Unit transport Cost
	Disposal	Payments for comprehensive disposal $C_{16} = C_r$	C_r: Payments for comprehensive disposal
Waste recycling enterprise	Waste	Costs $C_{21} = 0.8 * C_0 + 0.2 * P_F$	C_0: costs for comprehensive disposal P_F: Discounted price of Landfill land
	Reuse	Revenue of sale $B_{21} = P_1 + P_2$	P_1: Price of reusing bricks P_2: Price of reusing concrete aggregates
		Revenue of comprehensive disposal $B_{22} = C_r$	C_r: Payment for comprehensive disposal
Government	Procurement and Subsidy	Green procurement C_{P1} Subsidy C_{P2}	C_{P1}: Cost of procurement C_{P2}: Subsidy

113.4.2 Potential Benefit Factors

According to "The Edict of Construction Wastes Disposal Condition and Procedure in Chongqing", the construction wastes requested for payment of fees before landfilling, which was round profit in wastes comprehensive disposal. At present, the new housing was about 23 million m^3 per year in Chongqing, and which consumed about 5.04 million m^2 of bricks, 23 million tons of sands and 34.5 million tons of stones. If the government stipulated that 15 % reusing products should possess in the new purchasing construction materials of public projects, more than 1.1 million m^3 of reusing bricks and 1 million tons of concrete aggregates should be needed. In addition, the fees of project procurement was about 690 million yuan including concretes, bricks and blocks, which was another round profit in construction wastes comprehensive disposal. Therefore, the payment of fees before landfilling and reusing construction materials were the main benefits for the wastes comprehensive disposal. And the modeling for the comprehensive disposal costs and benefits was shown in Table 113.1.

According to field survey of cdw disposal site, the nine main city zones of Chongqing, the environment sanitation expert interview, literature consult and electronic materials research, gain relevant data such as transport distance of cdw recycling center, the unit cost of transportation, admission fees of cdw landfill, admission fees of recycling disposal, secondary disposal costs of illegal dumping, disposal costs of recycling center and market price of recycled products, and so on, that is summarized in Table 113.2.

Table 113.2 Survey data

Items	Parameter definition	Remarks
Total wastes (t)	Q: Total wastes produced in Chongqing district	$Q = 3.20$ million tons (according to site investigation and the Feasibility Study Report for Comprehensive Treatment Project of Construction Wastes in Chongqing District)
Transport distance (Km)	D_S: The transport distance of simple landfill	$D_S = 20$ km (according to the Location Planning for Simple landfill of Construction Wastes in Chongqing District and Instruction for Simple landfill of Construction Wastes in Chongqing District)
	D_{21}: The transport distance of comprehensive disposal site	$D_{21} = 15$ km (according to the Feasibility Study Report for Comprehensive Treatment of Construction Wastes in Chongqing District)
Waste collection costyuant^{-1}	C_C: Labor costs of waste collection in site	$C_C = 0.47$ yuant^{-1} (according to site investigation and the Fixed Price of Construction Project in Chongqing District, 2008)
Unit transport distance cost (yuant^{-1} km^{-1})	T_r: Unit transport distance cost	$Tr = 3.36$ yuant^{-1} km^{-1} (according to site investigation and the Fixed Price of Construction Project in Chongqing District, 2008)
Payments for landfill (yuant^{-1})	C_S : Payments for landfill	$C_S = 2.5$ yuant^{-1} (according to the Regulation of Paid services Charges on Environmental Health in Chongqing District)
	C_r: Payments for comprehensive disposal	$C_r = 25$ yuant^{-1} (according to the Feasibility Study Report for Comprehensive Treatment Project of Construction Wastes in Chongqing District)
Payments for comprehensive disposalyuant^{-1}	C_0: costs for comprehensive disposal	$C_0 = 64.9$ 7yuant^{-1} (according to the Feasibility Study Report for Comprehensive Treatment Project of Construction Wastes in Chongqing District)
Discounted price of landmillion yuan per hectare	P_F: Discounted price of land	$P_F = 2.4$ million yuan per hectare (base on the Open Transfer Notice about Construction Land Transactions in the Rural Area in Chongqing, and assumed that 1 ha land can hold 0.15 million tons construction wastes)
Price of reusing product (yuanm^{-3}, yuant^{-1})	P_1: Price of reusing bricks	$P_1 = 260$ yuanm^{-3}, $P_2 = 45$ yuant^{-1}
	P_2: Price of reusing concrete aggregates	(according to site investigation and the Feasibility Study Report for Comprehensive Treatment Project of Construction Wastes in Chongqing District)
Quantity of reusing product m^3,t	Q_1: Quantity of reusing bricks	$Q_1 = 1.09$ million m^3, $Q_2 = 0.95$ million tons
	Q_2: Quantity of reusing concrete aggregates	(according to the "Concrete Solid Brick" (GB/T21144-2007), "Concrete

(continued)

Table 113.2 (continued)

Items	Parameter definition	Remarks
		brick"(JC943-2004), "Ordinary concrete small hollow block"(GB8239-1997), "Test methods and quality standards for ordinary concrete sand"(JGJ 52-92) and " Test methods and quality standards for ordinary concrete gravel or pebbles"(JGJ 53-92), assumed that water-cement ratio is 0.28, the concrete aggregates (<5 mm) per 1 m^2 concrete is 650 kg and aggregates (>5 mm) per 1 m^2 concrete is 1,125 kg)

113.4.3 Data Survey

113.4.3.1 Analysis and Discussion the Influences of Different Policies on the C&D Waste Disposal

According to the information in Fig. 113.2, the heavy line represents the major approach of realizing waste reclamation, involving waste producer (construction contractors I), waste recycling enterprise (Integrated disposal center), the user of building materials (construction contractors II). The dotted line stands for the complete way of waste recycling, (1) when the law enforcement is lax, the contractor I is likely to be dump waste illegally. (2) C&D waste is likely to be sending to landfill when the cost of bringing the waste to the recycling centre exceeds the cost of landfilling. (3) While recycled product have not an advantage over primary materials in quality, image and price, which potential client (construction contractors II) may use raw material, it results in no market space for the recycled product. Therefore, in order to promote the scale development of waste reclamations, government should take measures to achieve those results, including keeping the waste recycling enterprise sustainable running and encourage waste producer to take C&D waste to the recycling center. For this purpose, government can adopt three kinds of environmental economic policy, which is disposal charges, subsidies for waste recycling and government green procurement system. However, Different policies have distinct influence on the recycling effects, even grave discrepancy. it’s essential to analyze and assess the waste management policy, choosing the relative effective strategy. Detailed analysis as follows:

(a) *Government green procurement system*

In the guide of public environmental interests, Government should take environmental protection effect into based on Improving procurement quality and efficiency. They should take measures to develop the markets for recycled materials, ensure the sustainability of recycling enterprise.

In terms of the calculation in Table 113.2, recycling enterprise could keep running by benefiting from selling the recycled materials, but some stable material source is necessary for the sustainable operation of recycling enterprise. However, construction contractor send C&W waste to landfill as a result of lower landfilling cost, which result in stagnating production due to shortage of recycling material. In that case, for the sake of improving competitiveness, recycling center could reduce the gate fees C_{r1} ($0 \leqq C_{r1} \leqq 19.3$), alleviate contractor's burden caused by recycling and encourage waste producer send all of C&D waste to recycling center for disposal, keep the recycling enterprise going concern.

(b) *Subsidies for recycling disposal*

Re-production is lack of competitiveness in the economy compared to the raw product. The environmental protection industry needs to be supported from the country's financial policy and requires the government to take measures to guide actively the pr-production market and to encourage users to accept re-production [16]. However, the subsidies policy does not guide the pre-production market through directly green purchasing of public programs, but give financial subsidies to CDW recycling disposal companies to maintain its normal operation; and promote recycling products to take part in fair market competition.

In this environment of the policy, the most incomes of CDW recycling disposal business come from owing to sales revenue of re-production is very small and almost neglectful [14, 17, 18]. At present, admission fees of the CDW landfill is lower, charges of recycling disposal companies is higher, and contractors tend to choose low disposal cost; the recycling center reduces admission fees or subsidizes the contractor for encouraging the contractor to support CDW recycling and transport actively waste to the recycling center, so that waste recycling center has more competitive advantage.

(c) *Disposal charges*

In order to ensure the practicality of the findings, under this circumstance, a precondition is that government can not subsidizes the recycling firm, and don't recommend public project to procure recycled aggregates. But a promise was given to recycling center that may adjust the disposal fee scale in order to achieve breakeven. Recently, with the increasing amount of C&D waste, the limited landfill imposed some restrictions on landfilling. So as to relieve the land demand and facilitate a feasible approach to the C&D waste management, government could utilize economic tools (tax, subside, charge) and legal means (punish, casual inspection, supervision) to raise the cost of landfilling, reduce the cost advantage over landfill, compel waste producer to support reclamation.

However, due to immature market of recycled product and no supportive policy, recycling center has to increase the fee scale for maintaining the business management. Moreover, according to market fairness, the cost of the contractor implementing recycling shouldn't exceed the cost of landfilling, otherwise, recycling approach don't work. Based on the information in Tables 113.2 and 113.3, the critical value of recycling gate fees is estimated, that is 55.18 RMD per ton. However, waste

Table 113.3 The cost-benefit calculation of related subject

Subject	Participation activities	Cost-benefit calculation	Total (ten thousands RMB)
Waste producer	Waste collecting	cost$C_C * Q$	150.4
	Landfill	Transportation cost : $Tr * D_S * Q$	21,504
		Gate fees$C_S * Q$	800
	Recycling	Transportation cost$D_{21} * Tr * Q$	16,128
		Gate fees$C_{r1} * Q$	06,176
Recycling enterprise	Waste recycling	Cost$(0.8 * C_0 + 0.2 * P_F) * Q$	17,656.32
		Benefit$Q_1 * P_1 + Q_2 * P_2$	32,576.5
		Gate fees$C_{r1} * Q$	06,176
Government	Government procurement	CostC_{P1}	0

Record:0≦Cr1≦19.3

Table 113.4 A cost matrix of participating subject under different policies (ten thousands RMB)

Subject policy	Green procurement	Subside for waste recycling	Disposal charges
Producer	16,278.4$\leq C_{A1} \leq$22,454.4	16,278.4$\leq C_{A2} \leq$22,454.4	$C_{A3} \geq$33785.6
Recycling center	17,656.32	17,656.32	17,656.32
Government	0	11,480.32$\leq C_P \leq$17,656.32	>0

Record: CA1,CA2,CA3 represents contractor's cost under three policies;CP represents government's cost under the policy of subside for the recycling

producer cover almost waste disposal cost, this factor may inspire them to take actions to reduce cost. If waste producer reduce waste output by management technology innovation or on-site recycling, the marginal cost of waste disposal may be decreased.

In conclusion, according to the different influence of waste recycling caused by three kinds of environmental economics policies, a cost matrix involving government, recycling enterprise, waste producer, is sum up in Table 113.4.

113.5 Conclusions

The reusing of construction wastes was an important measure in the environment friendly and resource-saving society. Moreover, it was the key link in pollution control standards for solid waste collection, storage, disposal and recycling [19]. The sustainable development of construction wastes reuse was achieved by the government green procurement, policy constraints and economic incentives comprehensively. However, the development of wastes reuse would be hindered in the long term, as charges of construction wastes disposal maybe induce much more illegal wastes landfill. Furthermore, the subsidies for waste producers were unhelpful to wastes reuse, which may induce contractors ignoring wastes management in site and the increase of construction wastes. But, reasonable government green procurement is the most promising policy option to establish long-term mechanism of construction wastes reuse.

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