An Empirical Study of Perceptions towards Construction and Demolition Waste Recycling and Reuse in China

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Abstract: This study was designed to investigate the recent movement and current stage of China's construction and demolition (C&D) waste recycling and reuse. Specifically, the research aimed to provide the big picture of recent C&D waste diversion practice in China, as well as to offer insights from Chinese field practitioners' perceptions towards benefits, challenges, and recommendations of C&D recycling and reuse. This research was conducted based on a review of existing practice and a holistic approach by collecting feedback of professionals from multiple disciplines through a questionnaire-based survey. Totally 77 valid responses were received from 592 questionnaires sent. Both quantitative data and qualitative information implied that China was still at the early stage of recycling C&D wastes. Lack of client demands was identified as one of the main difficulties in C&D waste diversion. The study revealed that engineers and consultants had a more positive perception on promoting industrial training in C&D waste recycling, while construction management professionals held more conservative opinion on it. It was also found that gaining experience in C&D waste recycling and reuse would offer professionals more positive perception on the quality of products containing recycled contents. It was further implied that although governmental

supervision had a high impact on China's current C&D waste management practice, the economic viability should eventually dominate the C&D waste diversion.

Keywords: Construction waste; Sustainability; Recycling; Reuse; Policy; Questionnaire survey

1. Introduction

Construction and demolition (C&D) waste was defined as a mixture of surplus materials generated from construction, renovation, and demolition activities, for example, site clearance, land excavation and roadwork, and demolition (Shen et al., 2004). It accounts for around 40% of total urban waste in mainland China (China Strategic Alliance of Technological Innovation for Construction Waste Recycling Industry or CSATICWRI, 2014), 26% of total solid waste in the U.S. (U.S Environmental Protection Agency, 2009), and 34% of all industrial waste within Europe (Eurostat, 2016). The construction industry in China is continuing its considerable growth, and billions of tonnes of C&D waste have been produced in recent years due to the large-scale urbanization programs (Duan and Li, 2016). The enormous amount of C&D waste generated in China over the past decades has caused severe damage to the environment (Lu and Yuan, 2010; Wu et al., 2016). Duan and Li (2016) used, Shenzhen, one of China's most developed municipalities as the example, showing that 84% of C&D waste were landfilled in recent years far exceeding the local landfill capacity. It was further stated by Duan and Li (2016) that over half of C&D waste in Shenzhen was disposed to unlicensed landfill sites or by dumping. The urgency in reducing C&D waste to decrease the pressure on landfills and to enhance waste diversion has driven the movement towards the environmental sustainability from both government and industry perspectives in mainland China.

Wu et al. (2016) found that in China, government played an important role in guiding and promoting contractor's behavior in C&D waste management. Several researchers (e.g., Zhao et al., 2008; Zhao et al., 2010; Wu et al., 2016) proposed that besides governmental policy, economic instruments (e.g., tax and subsidy for fostering the recycling industry), and economic viability in terms of business profitability also influenced C&D recycling practice. Technical issues with recycling C&D wastes such as quality of recycled concrete aggregates and their applications were also evaluated in the studies of Li (2008) and Li (2009). Lu and Yuan (2010) suggested the importance of having the active participation of all stakeholders (e.g., government, clients, contractors, and suppliers, etc.) in C&D waste management. Nevertheless, lack of communication and coordination among parties was identified by Domingo and Luo (2017) as one of the major barriers. It was further identified by Saez et al. (2013) that limited comprehensive strategies have been studied in effective waste management and individual attitudes towards the C&D waste management evaluation could vary. Whether multiple parties involved in the C&D waste diversion share consistent views on this subject could impact the effectiveness in communication, as the C&D waste management requires team effort in recruiting participants from different disciplines. The other concern was whether the prior project experience would affect professionals' perceptions on C&D waste management.

Research gaps could be identified from a review of these existing studies (e.g., Zhao et al., 2010; Saez et al., 2013; Wang et al., 2014; Domingo and Luo, 2017) in that: 1)there is still limited research on investigating the overall experience of recycling and reusing C&D waste crossing regions in China; 2) there has been insufficient feedback on policy and economy related issues from practitioners and stakeholders who are directly involved in the C&D waste treatment; 3) limited studies have addressed the question regarding the influence of professionals' occupation and prior experience on their perceptions, which could further impact their behavior on C&D waste treatment.

This study targets on investigating the current movement and practice of C&D waste recycling and reuse in China. The objectives of this empirical study are: 1) to gain the overall picture of more recent changes in China's governmental policy and industry practice towards sustainable treatments of C&D waste; 2) to study benefits and difficulties related to C&D waste recycling and reuse from the perspectives of professionals within relevant fields; 3) to explore whether practitioners' perceptions towards C&D waste management related items would be dependent on their occupations or prior experience; and) to provide suggestions on enhancing the existing practice of C&D waste diversion based on the responses received from the questionnaire survey. Survey participants from this study consisted of practitioners or researchers from multiple relevant fields (e.g., material supplier, construction management, and engineering consultants). The following sections of this paper include: 1) background information regarding benefits, barriers, and recommendations in C&D waste recycling and reuse in Section 2; 2) a description of research methodology in Section 3 involving a review of China's C&D waste diversion practice in terms of both quantitative data summary and qualitative policy change, as well as a questionnaire-based survey to collect insights from professionals involved in C&D waste treatment; 3) results and discussion in Section 4 with subgroup tests conducted to determine whether the perceptions on C&D waste recycling and reuse would be affected by survey participants' occupations or their prior experience.; 4) summary from findings in Section 5 providing information on whether stakeholders and practitioners from various disciplines, either with or without relevant experience, would share the consistent views on C&D waste management related issues.; and 5) conclusion in Section 6. The findings from this study serve as insights to stakeholders including governmental authorities, especially those from developing countries, on the current practice and trend of C&D waste management in China, as well as provide directions on sustainable treatment of C&D waste in developing or populous regions.

2. Background

2.1. Benefits of Recycling and Reusing C&D Waste

Numerous studies (e.g., Li, 2008; Marzouk and Azab, 2013; Vieira and Pereira, 2015) have recognized several benefits of recycling and reusing C&D waste. These benefits are summarized below:

- Reusing of materials on-site and saving natural resources (Poon and Chan, 2007; Rao et al., 2007; Tam, 2008[a]; Zhao et al., 2010; Sabai et al., 2012; Duan et al., 2013; Huang et al., 2013; Vieira and Pereira, 2015);
- Decreasing the needs on landfill spaces (Hsiao et al., 2002; Poon and Chan, 2007; Marzouk and Azab, 2013);
- Saving energy and reducing greenhouse gas emissions (Huang et al., 2013; Marzouk and Azab, 2013);
- Reducing health-related risks associated with landfilled C&D wastes (Marzouk and Azab, 2013);
- Coping with governmental strategy or industry standard to achieve environmental sustainability (Fatta et al., 2003; Li, 2008).

It can be indicated that the recycling and reuse of C&D wastes could generate environmental, social, and economic benefits. For example, recycling programs can save landfill charge and build the social sustainability image (Doan and Chinda, 2016), and construction companies could benefit from reduced waste by lower costs to purchase virgin materials (Bossink and Brouwers, 1996).

2.2. Difficulties and Challenges in Recycling and Reusing

Despite the widely recognized benefits, the sustainable management of C&D waste are facing these difficulties and challenges, including:

- Lack of waste-processing facilities or companies (Melo et al., 2011; Domingo and Luo, 2017; Jia et al., 2017);
- Insufficient relevant policies, regulations, and acts (Chung and Lo, 2003; Fatta et al., 2003; Rao et al., 2007; Domingo and Luo, 2017);
- Poor communication and coordination among parties involved (Domingo and Luo, 2017);
- Lack of economic feasibility and viability in recycling and reusing C&D wastes, for example, when the cost of recycling and reuse exceeding the recycled waste value, or when landfilling tipping charge was lower for direct disposal (Zhao et al., 2008; Zhao et al., 2010);
- Poor qualities of recycled products and their limited applications (Rao et al., 2007; Li, 2009; Zhao et al., 2010; Sabai et al., 2012; Duan and Poon, 2014);
- Reluctance or cultural resistance to implement C&D waste diversion (Saez et al., 2013; Esa et al., 2016), for example, illegal dumping still occurring worldwide (Poon et al., 2001; Conceicão Leite et al., 2011; Melo et al., 2011).

It should be noticed that some benefits verse challenges within C&D waste diversion remain inconsistent among different studies. For example, Zhao et al. (2008) and Zhao et al. (2010) were backed by Gull (2011)'s study that incurred labor cost when extracting waste materials and the cost of using extra admixture in the recycled product could downplay the economic benefit of recycling and reusing C&D wastes. In contrast, Tam (2008[b])'s case study showed that reusing recycled C&D materials could be more cost effective compared to landfilling them. Therefore, further studies might be needed to determine the effects of multiple parameters (e.g., desired quality of recycled products) in the economic viability of C&D waste diversion.

2.3. Recommendations on Improving C&D Waste Recycling and Reusing

Existing studies have provided recommendations in enhancing the effective C&D waste management; these strategies and suggestions include:

- Applying economic instruments, such as tax incentive, penalty and subsidy mechanism (Zhao et al., 2008; Zhao et al., 2010; Marzouk and Azab, 2013; Wang et al., 2014; Jia et al., 2017);
- Governmental initiatives to increase C&D waste diversion activities, for example, a landfill ban for unsorted wastes, policies towards more judicious management of C&D wastes, and standards for recycled materials aiming to establish the recycling market (Zhao et al., 2010; Melo et al., 2011; Marzouk and Azab, 2013; Duan and Li, 2016; Esa et al., 2017);
- Innovations in construction technology and management such as fewer design modifications, modular design, on-site sorting out waste categories, and technical regulations of using recycled materials in construction (Lu and Yuan, 2010; Wang et al., 2010; Saez et al., 2013; Wang et al., 2014; Esa et al., 2017; Marrero et al., 2017);
- Investment, research (e.g., economic feasibility), and development in waste reduction, recycling, and reuse (Lu and Wang, 2010; Sabai et al., 2012; Wang et al., 2014);

Training in C&D waste management (Lu and Wang, 2010).It is worth noticing that these suggestions for promoting C&D waste management came from different studies crossing countries. The effects of implementing these recommendations may vary in different countries or regions, and the industry practitioners may hold varied views on the recommendations. For example, the HongKong's Waste Management Disposal Charging Scheme, although with financial incentives to C&D waste generators, did not significantly reduce waste diversion according to Poon et al. (2013). Tam (2009)'s empirical study of waste concrete recycling practice in Australia and Japan also identified several inconsistent perceptions towards relevant recommended methods in enhancing recycling from practitioners between these two countries. It is hence important to investigate the effectiveness and practitioners' perceptions within the context of the targeted country or region such as China in this study.

2.4. *Review of C&D waste diversion in China*

Unlike developed countries such as Japan, where the recycling industry and market have been well established, most C&D waste currently in China is still directly transported to landfills instead of being reused effectively. According to CSATICWRI (2014), there were only around twenty professional corporations in China's C&D waste reuse and recycling market, mainly producing masonry bricks containing recycled contents but with lower quality and limited applications. In comparison, South Korea, with annual C&D waste generation at about 60 million tonnes, has 373 construction C&D waste treatment corporations (CSATICWRI, 2014).

Nevertheless, governmental policies and guidelines are being developed to encourage the C&D waste diversion in China. In April 2015, State Council of China announced *Suggestions on Accelerating Ecological Civilization Development* demanding on the reuse of C&D waste. In the provincial level, the newly enacted *Zhejiang Green Building Regulation* that has taken effect since May 2016 encourages recycled building materials to be applied in building foundation work, retaining walls, road base and subgrade, as well as parking lots. In the municipal level, Chengdu government announced the policy in October 2016 that for all government-funded projects, the percentage of recycled contents should be more than 15% for infrastructure projects and above 5% for building projects. Some other municipal governments, such as Sanya in southern China, has been planning the financial incentive to encourage C&D waste diversion.

3. Research Methodology

A holistic approach was adopted in this study. It was built upon a constructivist knowledge claim with an inclination towards pragmatist paradigm as opposed to a pure positivist approach. It used a mixed method approach where a combination of secondary data analysis with the outcome of a questionnaire survey were used to elaborate on participants' expert opinions' on C&D waste diversion related issues..

The study investigated the current status of C&D waste recycling and reuse in China. Initially existing data (e.g., these related to C&D waste generation) were retrieved from relevant literature sources. This would also enable cross-country comparison of C&D waste diversion practice between China and some developed countries or region (e.g., Japan, U.S., and Europe). Relevant policy changes in China's C&D waste management were reviewed and summarized to provide a big picture of the transitional change towards waste diversion.

A questionnaire-based approach was later adopted to collect professionals' perceptions on C&D waste in terms of benefits, difficulties, and suggestions in waste recycling and reuse. Survey questions, provided in the appendix, were divided into two portions. The first portion aimed to collect the survey population's background information on recycling and reusing of C&D waste. Survey participants were identified based on their occupation and involvement in C&D waste management, for instance, material supplier, contractor, and consultants, etc. They were also asked whether they have relevant prior experience. The second portion adopted Likert-scale questions, which were divided into three categories within C&D waste recycling and reuse, namely benefits, difficulties, and suggestions. There were multiple items under each category, and survey participants were asked to choose the numerical scale from "1" to "5", where "1" indicated "least important" of the described item or "strongly disagree" with it, "3" meant a neutral attitude, and "5" conveyed the option of "strongly agree" or the perception of "very important". Survey participants were also given the extra option of "N/A" if unsure of the given item. At the end of each category, an open-ended question was prepared to capture additional information of survey participants' perception towards the given category in C&D waste diversion.

The questionnaire was developed from January to May of 2016 within the research team of the University of Nottingham Ningbo China and peer reviewed technically in the pilot study. The content of the questionnaire was finalized at the end of May 2016.The questionnaire-based research was approved by the institutional Research Ethics Office before it reached survey participants. Potential survey sample was identified from the professional network of Construction Material Research & Practice Group and Construction Waste Management Forum within mainland China. These professional groups consisted of practitioners and researchers within the field of C&D waste management and material sustainability. The questionnaire was set electronically and sent to potential participants through SOJUMP, a Chinese on-line survey tool (www.sojump.com) to collect responses.

Multiple statistical methods were adopted in the data analysis of survey responses, including Relative Important Index (*RII*) to rank these multiple items under each category related to C&D waste recycling and reuse (i.e., benefits, difficulties, and recommendations), Cronbach's alpha value to quantify the internal consistency of items within each category, and Analysis of Variance (ANOVA) to test whether participants' perceptions would depend on their occupations or prior experience.

The *RII* value of each given Likert-scale item was calculated according to Eq.1, which had been adopted in some other empirical studies (e.g., Tam et al., 2000; Tam et al., 2009; Eadie et al., 2013; and Jin et al., 2017) in the field of construction engineering and management.

$$RII = \frac{\sum w}{A \times N} \quad \text{Eq.1.}$$

where w denotes the numerical score chosen by each survey participant in a given item, A is the possibly highest score in the Likert-scale item, which is *5* in this study. The parameter N denotes the total number of responses. The *RII* value ranges from 0 to 1, and a higher value of *RII* means a more positive attitude or higher perception of the survey population towards the target item.

Cronbach's alpha value, ranging from 0 to 1, it higher value would indicate a higher consistency among the items within the category, meaning that a survey participant who has chosen a Likert value for one item is prone to select a similar numerical value to other items. According to Nunnally and Bernstein (1994) and DeVellis (2003), Cronbach's alpha value from 0.70 to 0.95 indicates a high internal consistency among all items. Otherwise, a lower Cronbach's alpha would display a poorer inter-relatedness among items (Tavakol and Dennick, 2011).

The survey population in this study was divided into subgroups according to their occupation and prior experience in C&D waste management. ANOVA was applied to test the statistical consistency among subgroups in their perceptions towards items within each category using the null hypothesis that there was no significantly different mean values among subgroups towards the given Likert-scale item based on the 5% level of significance.

4. Results and Discussion

The results of this study are divided into two major sections: the review of current status of C&D waste recycling and reuse in China, and the data analysis of questionnaire-based survey.

4.1. Review of Current Stage of C&D Waste Management in China

Quantitative data related to C&D waste generation and recovery were acquired from multiple existing sources across different countries or region (see Table 1).

Table 1. Comparison of C&D waste management related information within selected municipalities, countries, and region.

City, Country or region	**Population density (number of people per km^2 of land)**	**Annual generation of C&D waste (million tonnes)**	**Generation of C&D waste per unit land area (tonne/km^2)**	**Generation of C&D waste per capita (kg/person daily)**	**Average tipping fee for solid waste ($/tonne)[1]**	**C&D waste recovery (%)**
Japan	337	76	201	1.63	359	80
Australia	3.3	18	2.34	2.13	68	57
Europe	73	870	85.5	3.22	102	75
U.S.	33	485	49.3	4.17	60	82
China	143	1,550 to 2,400	162 to 250	3.14 to 4.86	11	5

Table 1. Cont.						
Shanghai	3,809	100 to 144	15,773 to 22,713	11.34 to 16.33	N/A[2]	N/A[2]
Beijing	1,322	35 to 40	2,133 to 2,438	4.42 to 5.05	N/A[2]	N/A[2]

[1] The average tipping fee has been adjusted to the 2015 U.S. dollar value per tonne of solid waste

Note: The data in Table 1 are summarized from multiple sources including BDA Group (2009), Railey and Greenberg (2009), Japan Environmental Sanitation Center (JESC, 2012), European Environment Agency (2013), Ministry of the Environment (2014), Randell Environmental Consulting (2014),CSATICWRI (2014), Shin (2014), U.S. EPA (2014), EU-Japan Centre for Industrial Cooperation (2015), and Eurostat Press Office (2015), Eurostat (2016), U.S. EPA (2016), and Bureau of Transportation Statistics (2017).

[2] The average tipping fee and C&D recovery rate in Shanghai and Beijing are not available.

The annual C&D waste generated in China is much higher than any other countries or region listed in Table 1. When evaluated from the average generation of C&D waste based on unit land area or per capita, China still topped the countries or region listed in Table 1. It is noticed that the average tipping fee for landfilling solid wastes in China is significantly lower than that of any other developed countries or region. Jin and Chen (2017) identified that the tipping fee would have strongly negative relationship with landfilling rate. This might partially explain the low recovery rate (i.e., 5%) of C&D waste in China, while the same rate in developed countries or region would be close to or over 60%. It is also worth noticing that there are regional differences in C&D waste generation within China. More populous or developed regions, such as eastern coast, may generate more C&D waste than the less populous west inland part of China. Two major metropolitan municipalities (i.e., Shanghai and Beijing) are also listed in Table 1 as examples of how more developed regions in China would differ from the national average in C&D waste generation. It can be found that population density in Shanghai and Beijing are both close to or higher than 10 times of the national average. The C&D generation per unit land area in Shanghai and Beijing are approximately 100 and 10 times of the national average value. The C&D generation per capita in Shanghai is also significantly higher than China's average value.

It can be indicated that guidelines and regulations from authorities could drive the industry practice towards C&D waste recycling and reuse, an example being the "green" concrete masonry blocks made from recycled C&D debris. Fig.1 displays one of the researchers' field investigations focusing on reusing crushed C&D waste in a plant production of masonry bricks in China.

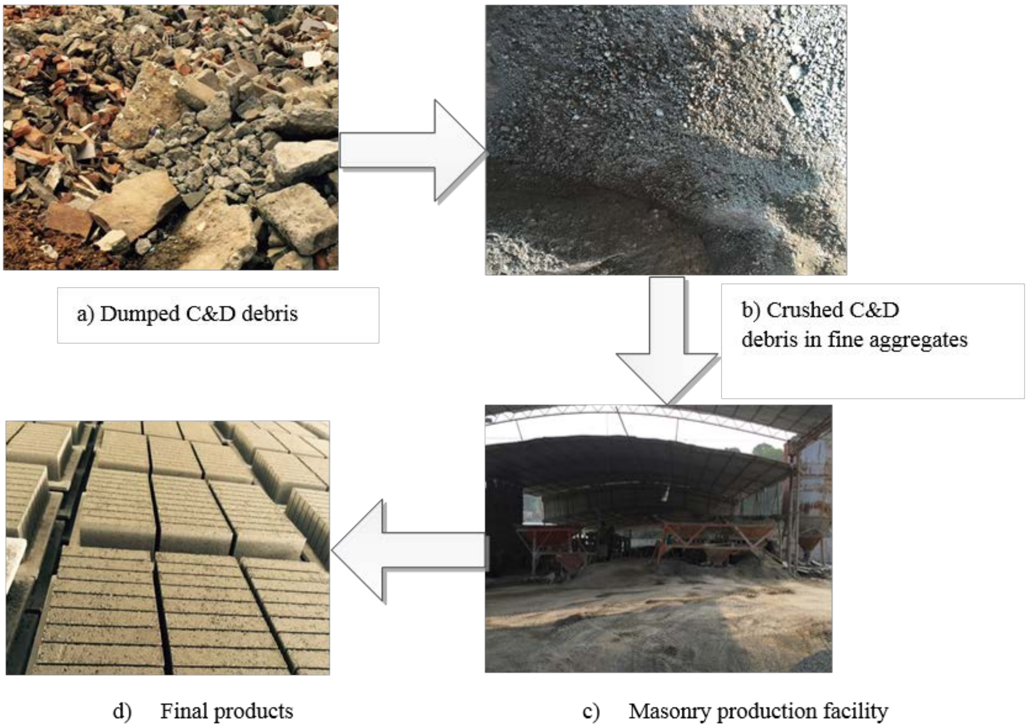


Fig.1. Workflow of masonry brick production using C&D wastes in China

Though similar masonry products containing recycled contents described in Fig.1 are available in certain regions of China such as Zhejiang (a southeastern province near Shanghai) and Beijing, these “green” products are still limited in their applications, such as in non-load bearing partition walls. Some technical problems remain to be solved when utilizing recycled materials, for example, the high water absorption rate in recycled aggregates may cause durability problems in wall products. The recycling market would determine the long-term business of “green” building materials. Besides the commercial “green” masonry production plant shown in Fig.1, some PPP (i.e., public-private-partnership) projects of C&D waste treatment plants have been planned in metropolitan areas including Xi’an and Sanya. These plants would have annual treatment capacity between 0.5 and 2 million tonnes.

4.2. Questionnaire Survey Results

Among totally 592 on-line questionnaires sent during June and August of 2016, 77 valid responses were received, representing the response rate of 13.0%, which is acceptable compared to previous questionnaire survey-based studies within architecture, engineering, and construction (AEC) industries (e.g., 7.4% in Abdul-Rahman et al., 2006). All these 77 respondents claimed that they had either participated in C&D waste diversion related projects in the past three years or planned to be involved in C&D waste diversion in the near future due to their work needs.

4.2.1. Background Information of Survey Participants

The respondents came from various regions of China. Fig.2 displays the numbers and percentages of responses by provinces or municipalities in the map of mainland China.

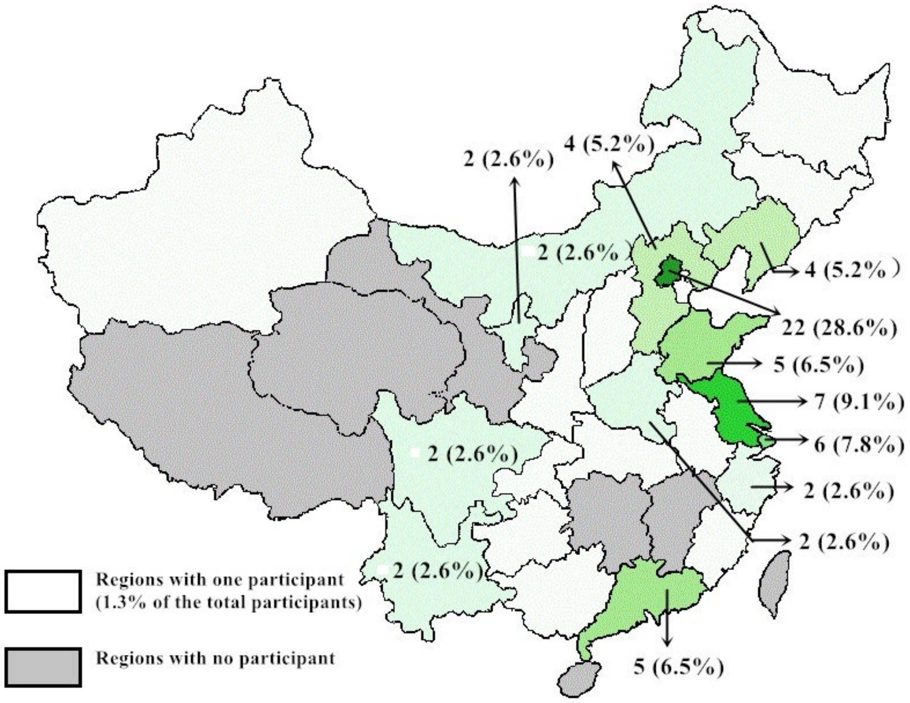


Fig.2. Working location of survey respondents (N=77)

Note: besides the two identified types of regions either with only one respondent or no in Fig.2, the remaining regions have been highlighted in different colors, with each individual region shown the number of respondents and the percentage accounted to the whole survey respondent sample.

The professions of respondents mainly included supply or manufacturing of construction materials, construction management, engineering design or consultancy, research institutes involving C&D waste management, and others (e.g., authority of environmental protection and business development). The percentages of survey participants according to their professions are summarized in Fig.3.

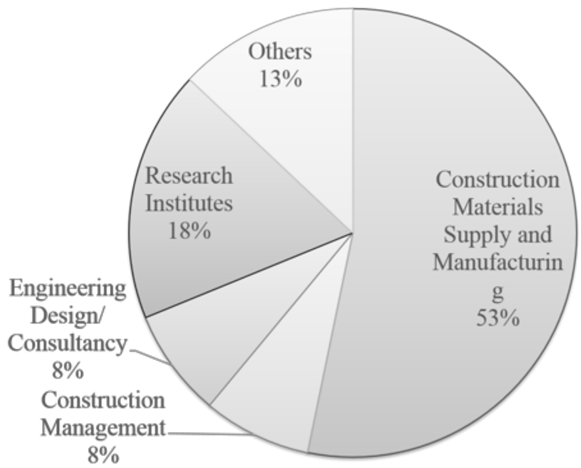
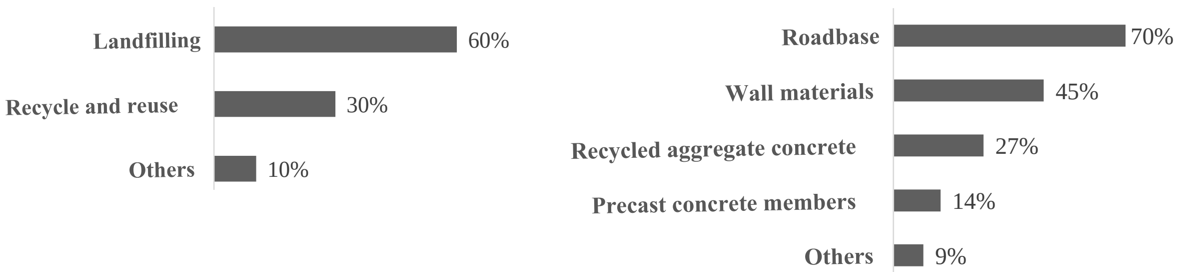


Fig.3. Distribution of Survey Participants' Profession (N=77)

Note: Other professions in Fig.3 include environmental protection agency and stakeholders, business developers in environmental protection, inspection authority, and heavy equipment manufacturer for cementitious materials.

It can be found from Fig.3 that over half of the respondents from this survey came from the construction materials industry. Around 42% of them confirmed that they had worked in projects involving C&D waste recycling and reuse in the past three years, and the rest 58% stated that they did not have direct experience working in a specific project incorporating recycling or reuse of C&D wastes. However, all the rest 58% claimed that they would be involved in C&D waste diversion in the near future. Survey participants were further asked about the treatment of C&D waste in the region where they worked and the existing applications of recycled C&D wastes. The bar charts in Fig.4 display the percentages of each option selected by respondents in the multi-choice questions.



a) C&D waste treatment in respondents' working regions

b) Perceptions from respondents on applications of recycled C&D wastes

Fig.4. Summary of C&D waste treatment and reuse from survey participants (N=77)

It can be seen from Fig.4 that landfilling remained the major treatment approach for C&D waste in China according to the responses received. Only 30% of survey respondents claimed that C&D waste had been widely recycled and reused in their work regions. The majority of the remaining 10% who chose “others” further specified that C&D wastes were mainly applied in road base or backfill. Somewhat similar to the study of Wilburn and Goonan (1998) who identified that 85% of recycled concrete debris was used as road base in the U.S., in this survey, 70% of respondents perceived that recycled C&D waste had been reused in road base. In comparison, recycled aggregate concrete and precast concrete members were not widely identified by respondents. Those who selected “others” provided details that recycled C&D wastes had also been applied in materials for cement manufacturing and site backfill.

4.2.2. Benefits of C&D Waste Recycling and Reuse

In this subsection, participants were asked of their perceptions towards benefits related to C&D waste recycling and reuse. Table 2 lists the seven major Likert-scale items, namely B1 to B7, which are ranked according to their *RII* values. The overall Cronbach’s alpha over 0.750 in this category showed generally high internal consistency of these seven benefit-related items, indicating that a survey participant who chose a numerical option to one item in Table 2 would be likely to select a similar option to other items.

Table 2. Data analysis of the overall survey sample regarding benefits of C&D waste recycling and reuse (Cronbach's alpha = 0.7878)

Item	Percentage of selecting each Likert-scale option (%)					N*	*RII*	Item-total correl-ation	Cron-bach's Alpha
	1	2	3	4	5				
B1: Complying with relevant governmental policies	0	0	8	44	48	64	0.881	0.6860	0.7348
B2: Saving space from landfills, reducing the demand for new waste landfills	2	3	3	45	47	66	0.867	0.3672	0.7866
B3: Saving natural materials	0	3	7	48	42	69	0.858	0.6909	0.7303
B4: Motivating the entrepreneurships	0	0	9	59	32	66	0.845	0.3655	0.7853
B5: Increasing business opportunities for AEC companies	1	3	14	51	30	70	0.811	0.4858	0.7664
B6: Saving the transportation cost between construction sites and landfills and saving the disposal cost	3	6	15	46	30	71	0.789	0.5805	0.7488
B7: Lowering project budget by using recycled materials	3	10	17	44	26	70	0.760	0.5204	0.7664

*: The total number of responses received in Table 2 excluded those who chose "N/A" indicating unsure to the given item. The same rule applies to Table 4 and Table 6.

The individual Cronbach's Alpha values in Table 2 display the changed value if the given item is removed from this category. Each individual Cronbach's Alpha value turned out lower than the overall value, indicating that each item in Table 2 positively contributed to the internal consistency. Item-total correlation in Table 2 displays the correlation between the given item and the remaining items. B2 and B4, the two items with higher individual Cronbach's Alpha values, had correspondingly lower item-total correlations, meaning that survey participants were more likely to assign inconsistent scores on B2 and B4, while their perceptions on other items tended to be more internally correlated.

The top ranked item within this category was compliant with governmental policies in terms of green building and environmental protection. Waste minimization and sustainable waste management were identified by Fatta et al. (2003) as basic principles of environmental authorities. Lu et al. (2016) inferred that public policies impacted construction waste management performance in both public and private sectors. Most respondents in this survey also highly emphasized the conformance of C&D waste management to certain governmental requirements or guides. Other highly positively perceived benefits included reducing the demand on landfill spaces and saving natural materials, consistent to the findings of Tam (2009) in the study of concrete recycling practice in Japan and Australia. The cost-related items in Table 2 ranked relatively low in their *RII* values, which conveyed the information that lowering cost by reusing the recycling C&D wastes might still be uncertain compared to other benefit-related items.

An open-ended question was asked in order to gain more perceptions of survey participants on extra benefits not listed in Table 2. The open responses received can be summarized from financial, social, and environmental perspectives:

- In the financial aspect, some respondents specified the tax incentive by recycling and reusing C&D wastes.
- Survey participants also mentioned that recycling C&D waste would reduce the safety-related risks caused by landfilling wastes.
- It was also mentioned by survey participants that C&D wastes had been placed illegally somewhere when local landfill space was full or unavailable. Recycling and reuse of C&D wastes could also reduce the illegal waste placement.
- Respondents also perceived that recycling and reusing C&D wastes could promote the environmental friendliness by reducing pollutions, enabling the benchmarked "green" procedure of recycling and reusing wastes, and turning wastes into useful resources.

The overall survey sample was further divided into subgroups according to participant occupations, shown earlier in Fig.3, and prior experience in C&D waste treatment. Table 3 displays the ANOVA conducted to test the subgroup differences in each of the seven benefit-related items.

Table 3. Subgroup analysis of survey participants' perception towards benefits in recycling and reusing C&D wastes

Item	Overall Mean	Standard deviation	ANOVA analysis for subgroups according to occupations		ANOVA analysis for subgroups with and without prior experience	
			F value	*p* value	*F* value	*p* value
B1	4.406	0.635	0.02	0.999	0.55	0.462
B2	4.333	0.810	0.66	0.625	0.67	0.417
B3	4.290	0.730	0.71	0.589	1.72	0.194
B4	4.227	0.602	1.24	0.304	1.19	0.279
B5	4.057	0.832	0.19	0.943	0.01	0.921
B6	3.944	0.969	0.52	0.723	2.57	0.113
B7	3.800	1.030	2.35	0.064	1.09	0.301

Subgroups from different professions were found without significant differences in their perceptions, according to the low F statistics and corresponding p values all higher than 0.05 in Table 3. Similar results were found in subgroup analysis for survey participants with and without prior experience in C&D waste reuse and recycling. It is therefore inferred that survey participants from different professions shared consistent views on benefits related to C&D waste recycling and reuse, and their perception was not affected by whether they had relevant previous experience or not.

4.2.3. Difficulties encountered in C&D waste recycling and reuse

Survey participants were asked of their opinions on difficulties or barriers encountered during C&D waste recycling and reuse. In total 20 Likert-scale items were provided in this category. They were listed in Table 4 following their *RII* values calculated. The overall Cronbach's alpha value at 0.9275 indicated very high internal consistency of the 20 items within this difficulty-related category.

Table 4. Data analysis of the overall survey sample regarding difficulties in C&D waste recycling and reuse (Cronbach's alpha = 0.9275)

Item	**Percentage of selecting each Likert-scale option (%)**					**N***	***RII***	**Item-total correl-ation**	**Cron-bach's Alpha**
	1	2	3	4	5				
D1: Lack of demand from the client on C&D waste recycling and reuse	1	3	4	54	38	69	0.846	0.6722	0.9234
D2: Lack of supervision and regulations in C&D waste recycle and reuse	2	3	8	52	36	66	0.836	0.5795	0.9246
D3(1)*: Lack of industry standards in C&D waste recycling and reuse	1	7	4	51	36	69	0.826	0.7143	0.9222
D3(2)*: Lack of industrial awareness and support for C&D waste recycling	1	4	9	51	35	69	0.826	0.4635	0.9267
D5: Lack of governmental support	1	7	11	39	42	72	0.825	0.4870	0.9264
D6: High cost and labor-intensiveness in separating industrial wastes	0	4	12	52	32	73	0.822	0.6392	0.9233
D7: Lack of sufficient C&D waste recycling practitioners	0	8	10	48	34	71	0.814	0.5872	0.9243
D8: Insufficient AEC companies' support in developments of technology, resource, training and human resource	0	3	17	51	29	69	0.812	0.5786	0.9245
D9: Lack of participation and training of employees in C&D waste recycling and reuse	3	6	7	57	28	72	0.803	0.7141	0.9225
D10: High cost for transportation between jobsites and waste diversion facilities	0	5	16	51	27	74	0.800	0.6135	0.9238
D11: Lack of balance between demand and supply in the recycling and reuse market	1	4	17	50	27	70	0.794	0.7256	0.9218
D12: The cost for waste diversion is higher than traditional landfilling	1	10	13	43	33	70	0.791	0.7455	0.9207
D13: Insufficient investments in the scientific research of C&D waste diversion	0	6	19	53	23	70	0.786	0.5222	0.9255
D14: Increased work load such as recording and supervising C&D waste diversion	5	5	14	53	23	74	0.765	0.6663	0.9227
D15: Difficult to install and maintain recyclingand reuse machines (e.g. crushers) on jobsites	3	10	16	46	25	69	0.759	0.5793	0.9251
D16: Increased maintenance and management cost spent in C&D waste diversion	4	7	24	38	27	74	0.754	0.5693	0.9251
D17: Difficult to establish a waste recycling plan for an individual project	1	14	14	46	23	69	0.751	0.6047	0.9240
D18: Causing changes in companies' existing management policy and working mechanisms	3	15	13	49	21	72	0.739	0.6447	0.9231
D19: Inferior quality of products containing recycled contents	3	10	24	43	19	67	0.731	0.5274	0.9255
D20: Limited applications for recycled products	3	15	15	49	18	72	0.728	0.5615	0.9249

*: Two items within this category received the same *RII* value at 0.826 and ranked 3rd among all items. Therefore, they were denoted as D3(1) and D3(2).

All individual Cronbach's alpha values in Table 4 lower than the overall value showed that each item contributed positively to the consistency. Among these items, D3(1), D9, D11, and D12 turned out with higher contribution to the internal consistency according to their lower individual Cronbach's alpha values and higher item-total correlations (i.e., over 0.7000). In other words, survey participants' perceptions towards difficulties related to lack of industry standards, insufficient participation and training, unbalanced between supply and demands, as well as higher cost were highly correlated to the rest of difficulty-related items. In contrast, survey participants' opinions on D3(2) (i.e., lack of industrial awareness and support for C&D waste recycling and D5 (i.e., lack of governmental support) tended to be more independent with what they viewed on the other items in Table 4. It could be inferred that respondents generally had a higher recognition on these two items and their perceptions were not affected by other difficulty-related items.

It is seen in Table 4 that the first ten items had *RII* values equal to or over 0.800, which was corresponding to a mean Likert score value at 4.00, which meant that survey participants tended to have a higher recognition of these difficulties, among which the top ranked item was the lack of client demands on C&D waste. It was stated by Lu et al. (2016) that clients play the leading role in environmental protection and closely monitor contractors' construction waste practices, and hence making a significant difference to contractors' waste management performance. Besides the insufficient client requirements, lack of regulations, industry standards, and industry awareness were also perceived as major barriers in recycling and reusing C&D wastes. These high-ranked items in Table 4 conveyed the information that there could be potentially better-established technical guidelines and standards in mainland China to drive the C&D diversion movement. Similar challenges in terms of lack of governmental legislatives and public practices had been identified in other developing countries' C&D waste diversion, such as that in Vietnam (Lockrey et al., 2016).

Survey participants were further asked about other difficulties or challenges encountered in recycling and reusing C&D wastes. The findings could be summarized in terms of cultural, economic, and other aspects.

- The most frequently mentioned barriers turned to be cultural resistance to products or projects using C&D wastes. Specifically, end-users and public currently had doubt or uncertainty of living or working in a building containing recycled C&D waste streams.
- Economic issue was another barrier in implementing C&D waste diversion, according to open-ended responses received. Survey participants revealed that: 1) the cost of treating C&D wastes other than directly landfilling them was high without financial aids; 2) the return on investment in diverting C&D wastes were low and AEC companies could not see the best economic benefits; 3) it was also costly to categorize different C&D wastes; 4) contractors were unwilling to spend extra budget on C&D waste diversion.
- Some other difficulties included lack of locally qualified companies in dealing with C&D wastes, hard to collect C&D wastes discreetly distributed across different locations, and some individual projects did not generate large amount of C&D wastes and hence not worth the cost of recycling.

Subgroup analysis was also conducted and summarized in Table 5. The overall sample was divided according to their occupations and prior experience in C&D waste recycling and reuse.

Table 5. Subgroup analysis of survey participants' perception towards barriers in recycling and reusing C&D wastes

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to occupations**		**ANOVA analysis for subgroups with and without prior experience**	
			F value	*p* value	*F* value	*p* value
D1	4.232	0.789	1.14	0.347	0.60	0.440
D2	4.182	0.821	0.54	0.705	1.42	0.239
D3(1)	4.130	0.906	0.52	0.724	0.04	0.835
D3(2)	4.130	0.856	0.74	0.569	0.00	0.951
D5	4.125	0.963	0.85	0.500	1.71	0.195
D6	4.110	0.774	1.60	0.186	0.13	0.719
D7	4.070	0.884	2.16	0.084	1.29	0.260
D8	4.058	0.765	0.43	0.786	2.87	0.095
D9	4.014	0.911	0.25	0.908	0.17	0.681
D10	4.000	0.811	1.22	0.312	0.76	0.387
D11	3.971	0.868	1.61	0.183	1.31	0.257
D12	3.957	0.999	1.16	0.337	1.98	0.164
D13	3.929	0.804	1.14	0.345	1.65	0.203
D14	3.824	1.025	0.50	0.733	1.64	0.204
D15	3.797	1.023	3.89	**0.007***	1.07	0.304
D16	3.770	1.054	0.93	0.454	1.19	0.278
D17	3.754	1.020	1.43	0.235	0.05	0.831

Table 5 cont.						
D18	3.694	1.057	1.80	0.139	0.32	0.573
D19	3.657	1.008	1.43	0.236	5.20	**0.026***
D20	3.639	1.039	2.54	**0.048***	2.48	0.120

*: *p* value lower than 0.05 indicates significantly different perceptions among subgroups towards the given item

While generally all subgroups shared consistent views on items related to difficulties encountered in C&D waste management, there were a few significantly different perceptions among subgroups in D15, D19, and D20:

- Material suppliers and construction managers tended to perceive more difficulties in installing and maintaining recycling and reuse facilities on jobsites, with average Likert score at 4.111 and 4.000 respectively. In comparison, the average Likert scores in subgroups of engineers & consultants and others reached 3.600 and 3.778 respectively, indicating that these two subgroups had the perception between "agree" and "neutral" towards D15. In contrast, respondents from research institutions had the perception below "neutral", with average score at 2.923. It could be inferred that material suppliers and construction managers, who had more jobsite experience, would consider more difficulties on placing recycling facilities, compared to those professions with less site exposure, such as researchers.
- All those professionals directly involved in C&D recycling and reuse were prone to have an attitude between "agree" and "neutral" regarding the limited applications of recycled products, with average Likert scores at 3.763, 3.000, 3.200, and 3.286 respectively for material suppliers, construction managers, engineers & consultants, and researchers. However, other professions (e.g., environmental protection agency, authorities, and entrepreneurs) perceived more difficulties on the applications of recycled C&D wastes, with the average score at 4.333. This differed perception from other professions could be due to the fact that they tended to view the difficulty at the macro level from social and economic perspectives and hence might see more barriers in marketing products containing recycled streams. In comparison, the remaining professionals were mostly direct

practitioners within C&D waste management field, they might view the applications of recycled products more from the technical perspective.

- Survey participants with and without prior experience in C&D waste diversion held significantly different views on the quality issue of products containing recycled materials. Those without previous project experience in C&D wastes tended to perceive it more a problem of qualities in recycled products, with an average Likert score at 3.895, while those with prior experience would consider it less a problem in quality issues (average Likert score at 3.345). This could be due to the fact that gaining project experience in C&D waste diversion will provide more confidence to professionals on quality of recycled products.

4.2.4. Suggestions to improve C&D waste recycling and reuse

This category focuses on suggestions to improve C&D waste recycling and reuse. Survey participants were asked of their perceptions on the importance of nine Likert-scale items, which are listed in Table 6 in the order according to their overall *RII* values.

Table 6. Data analysis of the overall survey sample regarding suggestions in enhancing C&D waste recycling and reuse (Cronbach's alpha = 0.8537)

Item	**Percentage of selecting each Likert-scale option (%)**					**N***	***RII***	**Item-total correl-ation**	**Cron-bach's Alpha**
	1	2	3	4	5				
S1: Mandatory requirement or financial incentives from governmental authorities	0	0	6	40	54	63	0.895	0.5910	0.8372
S2: Categorizing recyclable wastes according to the application of recycled products	0	1	3	52	43	69	0.875	0.6204	0.8340
S3: Including C&D waste recycling and reuse in the early project stages	0	1	7	44	47	68	0.874	0.5714	0.8389
S4: Effective communication among clients, engineers, contractors and consultants	0	1	4	51	43	68	0.871	0.7467	0.8208
S5: A comprehensive and accurate evaluation on the return on investment	0	1	9	49	41	69	0.858	0.5098	0.8456
S6: Enhancing C&D waste recycling technologies	0	0	11	51	38	65	0.855	0.6475	0.8311
S7: Promoting training of C&D waste recycling in the industry	1	0	6	59	34	70	0.849	0.6896	0.8289
S8: Enhancing trainings and management of C&D waste recycling within AEC companies	1	3	3	62	31	71	0.837	0.5459	0.8412
S9: Increasing the tipping fee for landfilling C&D wastes	0	3	16	48	33	67	0.821	**0.3409**	**0.8657**

The Cronbach's alpha value at 0.8537 indicated high internal consistency among the nine items. However, S9 (i.e., increasing the tipping fee for landfilling C&D wastes) had its individual Cronbach's alpha value higher than the overall value, indicating that S9 was the only item that did not contribute to the internal consistency. The item-total correlation of S9 also appeared low at 0.3409, which means that respondents tended to have an independent view on it compared to what they did to other eight items.

Excluding those responses claiming unsure to the given item, it can be found from Table 6 that the majority of survey participants chose "4" or "5" in all these Likert-scale items, indicating they would positively suggest or strongly recommend these methods in improving C&D waste diversion. It is seen in Table 6 that all nine suggestions were received with positive perceptions among survey participants, with *RII* values higher than 0.800, or corresponding average Likert scores over 4.000. Similarly to two other categories, the governmental influence was considered one of the top driving factors in moving forward C&D waste recycling and reuse. Governmental support, either mandatory requirement or financial incentives, was ranked as the top recommendation in enhancing C&D waste diversion. Other suggestions perceived highly positive included S2 (i.e., categorizing C&D wastes according to their applications), S3 (i.e., earlier project delivery stage involving C&D waste management plan), and S4 (i.e., multi-party communications on C&D waste diversion).

The open-ended question was asked to collect more insights from participants on extra suggestions in driving C&D waste diversion. The governmental requirement and monitoring was still the most frequently mentioned suggestion. Some other suggestions were also provided from the survey sample and could be summarized below.

- The state-of-the-art practices could be demonstrated in C&D waste recycling and reuse at certain provincial and municipal levels. This could potentially lead to knowledge transfer in the relevant field.

- Public guidelines and effective monitoring to sustainability practice from the authority were important to continuously implement C&D waste diversion.
- Public or government-funded projects should consider it a priority using products containing C&D wastes as the way to show the public the government attitude and effort in promoting C&D waste recycling and reuse.

Survey participants were tested of subgroup perceptions towards the nine given suggestions. The survey sample was divided into subgroups based on their occupations and prior experience in C&D waste management. Table 7 displays the ANOVA results.

Table 7. Subgroup analysis of survey participants' perception towards suggestions in improving practices of recycling and reusing C&D wastes

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to occupations**		**ANOVA analysis for subgroups with and without prior experience**	
			F value	*p* value	*F* value	*p* value
S1	4.476	0.618	0.81	0.526	2.29	0.135
S2	4.377	0.621	0.65	0.629	0.32	0.571
S3	4.368	0.689	0.55	0.699	0.55	0.460
S4	4.353	0.641	0.06	0.993	3.08	0.084
S5	4.290	0.688	2.04	0.099	0.84	0.364
S6	4.277	0.650	0.75	0.560	2.24	0.140
S7	4.243	0.690	2.56	**0.047***	0.00	0.988
S8	4.183	0.743	1.07	0.377	1.99	0.163
S9	4.104	0.781	4.07	**0.005***	1.58	0.213

*: *p* value lower than 0.05 indicates significantly different perceptions among subgroups towards the given item

There were generally consistent views on items listed in Table 7 among subgroups, especially for subgroups with and without previous experience, except that:

- Compared to participants from other occupations who would strongly suggest promoting the industry-wide training on C&D waste recycling, with the average Likert score ranging from 4.111 to 4.600, the subgroup of construction management showed less positive view on the same suggestion with Likert score at 3.500. This could be due to the fact that construction management is the profession that has most exposure and direct experience in C&D waste treatment, and it could be in their perception that relevant training was not the most critical factor compared to other factors in enhancing waste recycling and reuse.

- Professionals from other occupations including material supplier, construction management, research, and others were highly positive on the suggestion to increase the tipping fee for landfilling wastes, with average Likert score ranging from 4.000 to 4.263. In contrast, engineers & consultants had a low recognition on this item, with the average Likert score at 2.750 indicating their perception between "unimportant" and "neutral".

5. Discussion

This study aimed to investigate the current stage of C&D waste recycling and reuse practice in China. It started from describing the big picture of China's C&D waste diversion movement in terms of governmental policy changes and industry practice. The questionnaire-based approach was later adopted to study perceptions of participants, specifically focusing on the three major categories (i.e., benefits, difficulties, and suggestions) in China's C&D waste recycling and reuse.

5.1. The overview of China's C&D waste management practice

China generates a tremendous amount of C&D waste annually compared to some developed countries or regions (e.g., U.S and Europe), and the average generation rate of C&D waste measured by unit land area or per capita is also comparatively high. Compared to developed countries, the landfilling charge in China is significantly lower, which could be one cause of low C&D waste recovery rate in China. It is worth noticing that the average values of C&D waste in China does not reflect the regional status, especially those more developed or populous regions such as Shanghai and Beijing, where the C&D generation per km^2 or per person daily is significantly higher than China's national average value. It is implied that diversion of C&D wastes within these metropolitan regions are more urgent, as C&D wastes, if not properly treated, could further occupy the limited land sources. Recent movements of C&D waste diversion from both governmental regulations and industry implementation in

China has indicated the ongoing trends of technical standard development for waste diversion. It should be realized that although there have been changes in policy and guideline to promote the sustainable treatment of C&D waste from all the three governmental levels (i.e., state, provincial, and municipal) in China, the current C&D waste recycling and reuse in China is still at the early development stage compared to developed countries or region (e.g., Japan). A long-term effort towards the higher recovery of C&D waste could be expected in China starting from these few metropolitan areas (e.g., Chengdu) where the municipal governmental guidelines have been announced.

5.2. Benefits and difficulties within C&D waste recycling and reuse

Practitioners had a high awareness of governmental policies in C&D waste management. All governmental policies, guides, or support related items were ranked as the most important or key issues in each of the three categories with this questionnaire survey. Besides complying with governmental policies, other main benefits of recycling and reusing C&D wastes received with highly positive perceptions included lowering the demands on landfilling space and saving natural resources, which were also considered top benefits of concrete recycling in the study conducted in U.S (Jin et al., 2015) and Australia and Japan (Tam, 2009).

Governmental supportive policies in terms of mandatory requirements or financial incentives, guidelines, and effort in monitoring the industrial behavior of recycling and reusing C&D wastes were perceived as playing a significantly important role in promoting the C&D waste diversion practice. However, it was also mentioned by survey participants that the lack of governmental support and insufficient awareness or effort from the government side would become one of the major barriers. It should be noticed that although policies from the state government and certain provincial authorities have been established in encouraging the sustainable C&D waste treatment, the implementation at local or municipal level could vary significantly depending on some factors such as the local governmental guideline and recycling facilities of local AEC companies. The availability of well-established regulations and standards was also identified as one major concern in treating C&D wastes. In comparison, other potential problems associated with implementing C&D waste diversion, such as increased work load and management cost, the extra cost of recycling wastes, as well as limited applications and lower qualities of recycled products were not perceived as top challenges. Responses from open-ended questions revealed another barrier of applying recycled products due to the public cultural resistance.

Generally, the cross-country comparison revealed that developing countries, such as China in this study and Vietnam in the study of Lockrey et al. (2016), would be more likely to claim governmental support and legislation with top importance in enhancing C&D waste recycling and reuse. In contrast, investigations conducted in developed countries, such as U.S (Jin and Chen, 2015) and Australia and Japan (Tam, 2009) would find governmental restrictions on waste generation with less impact on C&D waste diversion. Economic feasibilities and governmental supervisions were identified as two key factors affecting China's C&D waste management (Zhao et al., 2010; Wu et al., 2016), and this study further implied that survey participants perceived more influence from governmental policy than economic motivations. This could be due to the fact that China is still at the beginning stage of implementing C&D waste recycling and reuse nationwide, and governmental guide would play a more significant role in influencing industry behaviors. Nevertheless, as the recycling market is growing and developing its own economic mechanism, eventually the economic viability would be a determining factor in C&D waste management, as what is now seen in the market of some developed countries such as Japan, where recyclers are more capable to make ends meet without governmental aid.

5.3. Subgroup perceptions towards C&D waste diversion

Although the perceptions of the survey population towards the three major categories within C&D waste diversion were mostly consistent crossing different occupations and generally unaffected by their prior experience, certain significant subgroup differences were identified on survey sample's perceptions. For example, professionals from engineering design and consulting firms had the most positive view on promoting industrial training on C&D waste recycling, but with significantly lower recognitions on increasing the tipping charge of landfilling wastes. Differing from engineers and consultants, construction management professionals held more conservative opinion on promoting the industrial training on C&D waste diversion. Those with prior experience in C&D waste recycling or reuse would hold more positive view on the qualities of recycled products, and those with more direct exposure to C&D waste management were more likely to be more optimistic on the applications of recycled C&D wastes.

5.4. Suggestions to promoting C&D waste management in China

All suggestions listed in this study in improving C&D waste management were positively perceived by the survey sample. Based on the responses collected from the review of existing practice and questionnaire survey, several recommendations to improve China's C&D waste recycling and reuse are provided:

- Continuous work on establishing regulations and standards in sustainable treatment of C&D wastes, especially those related to categorizing C&D wastes according to their applications, and certain policies (e.g., incentives for recycling C&D wastes);
- Enhancements of clients sophistication aiming to increase the demand on recycling and reusing wastes through possible approaches such as demonstration and knowledge transfer starting from public sector projects involving C&D waste diversion;

- Government or authority work in both provincial and municipal levels to be further implemented, including but not limited to specified requirements on site waste recycling and reuse, incentives to encourage waste diversion, and promoting industry-wide trainings in relevant fields;
- Communicating and specifying C&D waste management work in the early project design or procurement stage by involving multiple project parties (e.g., engineers, contractors, and consultants);
- Continuing development of technologies to improve the quality of recycled products and exploring potential applications of products containing recycled streams;
- Further investigation of economic feasibility and governmental supervision strategies aiming to nurture the local recycling markets.

6. **Conclusions**

This study adopted a holistic approach in investigating the current status of C&D waste recycling and reuse in China. Quantitative data including China's C&D waste generation were provided and discussed in comparison with some developed countries or region (i.e., Australia, Europe, Japan and U.S). The urgency of diverging C&D wastes in metropolitan and surrounding regions (e.g., Shanghai and Beijing) was addressed. Some governmental policies and guides from state, provincial, and municipal levels on enhancing diversion of C&D wastes were reviewed together with the existing applications of recycled products (e.g., masonry bricks). It could be foreseen that China is moving towards the sustainable treatment of wastes, although the long-term work in C&D waste diversion can be expected. The second part of the study adopted a questionnaire-based survey by recruiting professionals from multiple occupations involved in C&D waste management. Perceptions of the survey sample towards benefits, difficulties, and suggestions related to C&D waste recycling and reuse were analyzed.

Governmental policies, guidelines, and strategies were perceived as one key driving factor in implementing C&D waste diversion in China. Other key issues identified in impacting C&D waste diversion included clients' demands on waste treatment, availability of relevant industry standards, classifying C&D wastes, and multi-party communication of C&D waste management in the early project stage. Responses collected from open-ended questions also provided insights on suggestions in enhancing C&D waste management practice, for example, demonstrating sustainable use of C&D wastes from government-funded projects, which could be one strategy in handling the public cultural resistance to products with recycled contents.

This empirical study serves as the extension from previous research on C&D waste management by combining review of state-of-the-art implementation and questionnaire-based approach which provides information on whether professionals' occupation or prior experience would affect their perceptions. The findings obtained from this study could provide insights to relevant stakeholders in studying the strategies or making decisions of implementing C&D waste diversion. Critical factors in implementing C&D waste management could be applicable crossing countries, such as governmental influence, cultural acceptance to recycled products, and multi-party communications. It is implied that though a C&D diversion market (e.g., mainland China) at the initial stage might view governmental supervision as a key impact factor in its own development, the economic viability would ultimately become the dominating factor in C&D waste diversion business.

The survey sample in this questionnaire-based study mostly came from more populous or developed regions along the eastern coast of China (e.g., Beijing, Shanghai, Guangdong, Jiangsu, and Shandong), with limited size of sample from less developed or populous inland regions. Although the survey results would be more applicable to these populous regions with more urgent needs of C&D waste diversion, it could be implied that as China is undergoing the continuous urbanization with more C&D wastes generated, other less developed regions could also learn from the experience in these studied populous counterparts in the future. Future research could focus on the follow-up evaluation of C&D waste diversion performance according to relevant benchmarked criteria or governmental regulations, estimating the return on investment of recycling and reusing C&D wastes through case studies, the effects of project delivery method (e.g., integrated project delivery) on enhancing C&D waste diversion in the early project stage, and the application of digital technologies (e.g., building information modeling) in C&D waste management.

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Appendix: Questionnaire Survey on Recycling and Reuse of Construction and Demolition Waste

Background and Experience on Recycling and Reuse of Construction Waste

1. Have you participated in any projects involving C&D diversion in the past three years? A. Yes B. No
2. Based on your work needs, do you plan to be involved in projects related to recycling and reuse of C&D waste in the near future?
   A. Yes B. No C. Unsure
3. Your working location.____________
4. Your career field. A. Construction materials B. Construction Industry C. Engineering design or consulting D. Academics E. Others (Please specify).
5. What is the major way of disposing construction waste in the region where you work? A. Landfilling B. Recycling and reuse C. Others (Please specify).
6. According to your experience, what are the main applications of the construction and demolition waste recycling and reuse in your region? Multi choice. A. Wall materials (e.g. bricks and blocks) B. Recycled aggregate concrete C. Precast concrete members D. Roadbase E. Others (Please specify).

Perceptions on Recycling and Reuse of Construction and Demolition Waste

Please answer the benefits, difficulties and suggestions in construction waste recycling area. For the following questions, the choices are 1-6 (1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree 6. Not sure)

7. The benefit of construction and demolition waste recycling and reuse

- Saving space from landfills, reducing the demand for new waste landfills
- Saving natural materials
- Lowering project budget by using recycled materials
- Saving the transportation cost between construction site and landfills and saving the disposal cost
- Complying with the governmental policies of green building and environmental protection
- Enhancing the competitiveness and increasing business opportunities for AEC companies
- Motivating the entrepreneurships in the field of construction waste recycling and reuse
- Others, please explain ____

8. The difficulties of construction and demolition waste recycling and reuse

- High cost and labor-intensiveness in separating C&D wastes
- High cost for transportation between jobsites and waste diversion facilities
- Difficult to install and maintain recycling & reuse machines (e.g. crushers) on jobsites
- The cost for waste diversion is higher than traditional landfilling
- Increased maintenance and management cost spent in C&D waste diversion
- Difficult to establish a recycling plan for an individual project
- Increased work load such as recording and supervising C&D waste diversion related activities
- Causing changes in companies' existing management policy and working mechanisms
- Lack of participation and training of employees in C&D waste recycling and reuse
- Inferior quality of products containing recycled contents (e.g. strength reduction in recycled aggregate concrete)
- Limited applications for recycled products
- Lack of balance between demand and supply in the recycling and reuse market
- Lack of investment in the scientific research of C&D waste diversion
- Not enough AEC companies' support in developments of technology, resource, training and human resource in C&D waste recycling
- Lack of demand from the owner or investor side on C&D waste recycling and reuse
- Not enough construction waste recycle practitioners
- Lack of awareness and support for C&D waste recycling in the industry
- Lack of support from government
- Lack of supervision and regulations in C&D waste recycling and reuse
- Lack of industry standard in C&D waste recycling and reuse
- Others, please explain ____

For the following questions, the choices are 1-6 (1. Least important 2. Unimportant 3. Neutral 4. Important 5. Very important 6. Do not know)

9. Suggestions in construction and demolition waste recycling and reuse

- A comprehensive and accurate evaluation on the return on investment of C&D waste recycling and reuse
- Defining the categories of recyclable C&D wastes according to the application of the recycled product (e.g. red bricks, old concrete, mud and etc.)
- Enhancing C&D waste recycle technologies
- Including C&D waste recycling and reuse in the early project stages
- Enhancing trainings and management of C&D waste recycling within AEC companies
- Promoting training of C&D waste recycle in the industry
- Effective communication among clients, engineers, contractors and consultants on C&D waste recycling and reuse
- Mandatory requirement or financial incentives from governmental authorities for waste recycling on construction sites
- Increasing the tipping fee for landfilling C&D wastes
- Others, please explain ____