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COMPARATIVE ANALYSIS ON INTERNATIONAL CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT POLICIES AND LAWS FOR POLICY MAKERS IN CHINA

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Abstract. In the current age of enhanced environmental awareness, transformation to sustainable management in the construction sector is needed. China currently produces the largest amount of construction and demolition (C&D) waste around the world, but the average recovery rate of the waste was only about 5% in 2017. In order to investigate problems in current C&D waste management in China, a cross-national comparative analysis is conducted among China and seven selected countries (Japan, South Korea, Germany, Italy, Austria, the Netherlands and the United Kingdom), to compare legal texts of national policies and laws which relate to C&D waste management and are currently being used. Through the comparison, problems in management of C&D waste in China are investigated. The problems could be concluded to: (a) inadequate guidance on recycling, (b) lack of market incentives in utilising recycled materials, (c) incomplete knowledge of stakeholders' responsibilities, (d) lack of penalty for other stakeholders, and (e) inefficient supervision system. By understanding these problems, this paper further provides recommendations to enhance the performance of C&D waste management in China.

Keywords: construction and demolition waste, waste management, comparative analysis, China.

Introduction

A large amount of construction activities has resulted in an increase of construction and demolition (C&D) waste. Large generation of C&D waste threatens the living environment, and accelerates the depletion of lands (Ma et al., 2020), which becomes a global issue and receives increasing attentions (Wang et al., 2021). In Europe, annual production of C&D waste is approximately 820 million tonnes (Gálvez-Martos et al., 2018), while the number is 191 million tonnes in United States (Duan et al., 2019). In China, there was a significant increase in generation of C&D waste, from 560 million tonnes in 2005 to 2.1 billion tonnes in 2018 (Wang et al., 2021). In current age of enhanced environmental awareness, transformation to sustainable management in the construction sector is needed. Compared to landfilling, recycling could achieve efficient use of resources (Balachandra et al., 2010), reduction of primary material utilization and avoidance of landfilling (European Commission, 2016).

A great collection of literatures has been performed to analyse the C&D waste management in developed countries of high recovery rates, including Japan (Amemiya, 2018; Sakai et al., 2011; Yolin, 2015), European countries (Gálvez-Martos et al., 2018; Iacoboaea et al., 2019; Menegaki & Damigos, 2018; Sakai et al., 2011; Tam & Lu, 2016), Singapore (Chew, 2010; Nitivattananon & Borongan, 2007), and South Korea (Sakai et al., 2011; Yang et al., 2015). In developing countries, urbanization has led to rapid growth in generation of C&D waste. Therefore, it is important for these countries to formulate management policies and avoid environmental degradation. China currently produces the largest amount of C&D waste around the world, but the recovery rate of the waste was

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only about 5% in 2017 (Huang et al., 2018). The C&D waste management in China is far from effective and still in a stage of infancy (Huang et al., 2018). Because of uneven development of C&D waste management around the world, there is possibility for China to learn from other high-performance countries, through comparing the current policies and formulating better waste management (Nugroho et al., 2015). Although few studies have conducted comparative analysis between C&D waste management of China and some countries (Aslam et al., 2020; Fang et al., 2017; Li et al., 2017; Liu et al., 2018; Wang et al., 2015), these researchers concentrated on the comparison between China and a single country. Researches which comprehensively review current policy documents related to C&D waste management and conduct comparisons in the scope of various countries are relatively insufficient.

The aims of this study are to review current national policy documents related to C&D waste management in China as well as documents from seven countries (i.e., Germany, Italy, the Netherlands, Austria, the United Kingdom, Japan, and Korea). Based on cross-national comparative, this paper will identify the problems in the promotion of recycling and provide recommendations to enhance C&D waste management in China. The results could help China and other developing countries learn experiences from other high-performance countries to formulate useful and proper management strategies.

1. Research methods

Figure 1 presents an overall view of the proposed processes. In stage 1, this paper firstly provides a unified definition of C&D waste, because the definition of C&D waste varies among regions (Menegaki & Damigos, 2018). Secondly, data of the generation amount of C&D waste and the recovery rate from 35 countries in 5 continents are collected and presented. Countries that generate >10 million tonnes of C&D waste (excluding soil) and have a recovery rate of >85% will be selected for further investigation. Seven countries, i.e., Germany, Italy, the Netherlands, Austria, the United Kingdom, Japan, and South Korea are selected.

In stage 2, document study is employed on the policy documents concerning C&D waste management

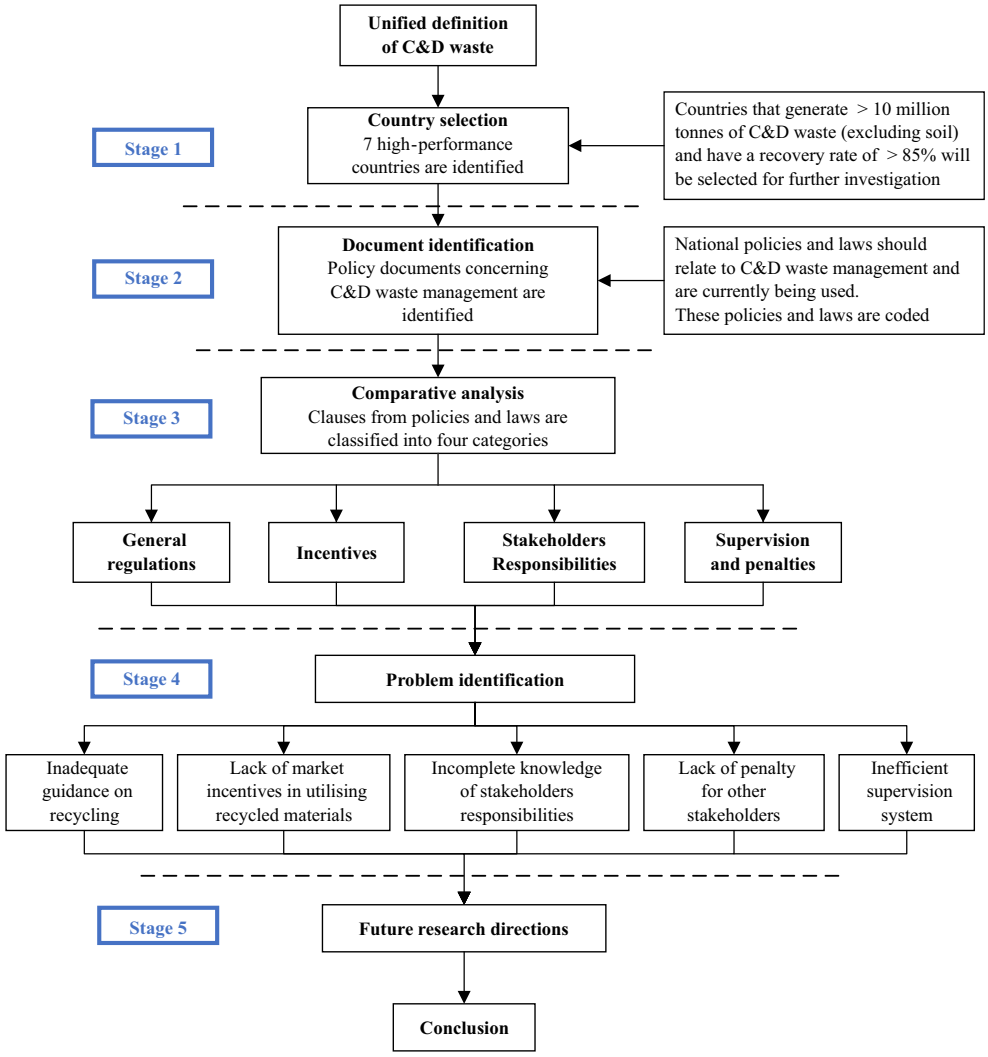

Figure 1. The research framework of this study

in China and seven selected countries. The last decades have witnessed an increase in the use of document study in journal and review articles (Bowen, 2009). Document study is featured as a systematic procedure for reviewing and assessing documents (Mackieson et al., 2018) and could present examples from various disciplines and provide valuable guidelines for researchers who focus on same topic. National policies and laws are selected based on two criteria: (1) they should relate to C&D waste management; and (2) they are currently being used and not repealed. These policies and laws are coded. Clauses collected from these policies and laws are classified into four categories: general regulations, incentives, stakeholders' responsibilities, and supervision and penalties, because these policy and laws centre on the four perspectives. Besides, Ma et al. (2020) focused on government incentives, local regulations, and supervision and penalties to identify the challenges in the current C&D waste management in China, which could be one fundamental reference for this study. Addition to the three categories mentioned in Ma et al. (2020), stakeholders' responsibility is one major focus of these policy documents and is critical in affecting construction and demolition waste (Yuan, 2017). Therefore, it is considered as a category. The codes of policies and laws which mentioned the specific clause are filled in the corresponding blanks.

In stage 3, a cross-national comparative analysis is carried out to compare legal texts. Cross-national comparative analysis was a frequently used method in previous literatures to put in perspective of current status and prevailing trend. Specifically, it was used to examine social care policies in seven European countries (Rostgaard, 2002), broadband strategies in Finland and Sweden (Eskelinen et al., 2008), tourism polices applied in Singapore and Hong Kong (Wong et al., 2008), regulations on renewable energy in Australia and China (Hua et al., 2016), open data strategies in five countries (Huijboom & Broek, 2011), and C&D waste management in China and United States (Aslam et al., 2020).

In stage 4, problems in the current management of C&D waste in China are identified. This paper provides recommendations to help formulate management policies. In stage 5, future research directions are discussed.

2. Key review findings

2.1. Definition of C&D waste

C&D waste is defined as waste generated from all types of construction, renovation and demolition activities (Yuan, 2017). It contains many types of materials, including excavated materials, non-hazardous waste, and hazardous materials (Table 1).

The scope of this study is limited to non-hazardous and hazardous C&D waste, excluding excavated materials. Although excavated soil accounts for a large portion of C&D waste and has potential for backfilling, it is not included in the calculation of the recovery rate for most countries. Further, it is not included in the definition of C&D waste in China. The Ministry of Housing and Urban-Rural Development of the People's Republic of China (1996) specifies that excavated soil is managed by a special environmental agency, and does not belong to the category of C&D waste.

2.2. Country selection

The C&D waste recovery rates have large variability (Table 2). Recovery rates of >95% were achieved by Denmark, Italy, the Netherlands, United Kingdom, Japan, South Korea, and Singapore. However, the estimation of C&D waste in China has uncertainty because of unavailability of systematic data collection (Akhtar & Sarmah, 2018).

In this study, countries that generate >10 million tonnes of C&D waste (excluding soil) and have a recovery rate of >85% are further investigated. Specifically, high recovery rate is no longer the only consideration. Countries with a high recovery rate but a small quantity of waste have limited research value, as a high recovery rate can be achieved more easily with a small volume of waste. Therefore, policies and laws of C&D waste management in Germany, Italy, the Netherlands, Austria, the United Kingdom, Japan, and Korea are examined in this study.

2.3. Overview of C&D waste management

2.3.1. C&D waste management in China

While some Chinese cities have achieved recovery rates higher than the national average, e.g., 20% for Shanghai and 16% for Shenzhen (Ghisellini et al., 2018), these rates are significantly lower than those in developed countries. In recent years, Chinese government directed considerable efforts towards encouraging waste reduction. Several C&D waste management-related documents have been issued by governing bodies. The existing Chinese policies and laws on C&D waste management are presented in Table 3. Specifically, Plan for Comprehensive Utilization of Solid Waste (National Development and Reform Commission, 2011), Green Building Plan (General Office of the State Council of the People's Republic of China, 2013), Circular Development Plan (National Development and Reform Commission, 2017), and Experimental Programs of

Table 1. Categories of C&D waste (Deloitte, 2016)

Excavated materials	Topsoil, sand, gravel
Non-hazardous waste	Building debris, concrete debris, track ballast, site waste, building demolition waste wood, packing, metals, road rubble
Hazardous waste	Asbestos and asbestos cement, contaminated oil

Table 2. Recovery rate of C&D waste

Countries	Total C&D waste (Million tonnes)	C&D waste exclude soil (Million tonnes)	Recovery rate (%)	References	Year of data
Europe					
Bulgaria	–	0.15	24%*	Eurostat (2019, 2021)	2018
Czech Republic	–	7.5	–		
Denmark	–	4.13	97%*		
Germany	–	86.4	93%*		
Estonia	–	1.21	95%*		
Ireland	–	0.7	100%*		
Spain	–	14.5	75%*		
France	–	69	73%*		
Italy	–	41.3	98%*		
Netherlands	–	21.2	100%*		
Austria	–	11.2	90%*		
Sweden	–	2.9	90%*		
Norway	–	2.4	63%*		
Finland	–	1.3	74%*		
The United Kingdom	–	68.7	98%*		
Asia					
Japan	–	74.4	97.2%	Ministry of Land Infrastructure Transport and Tourism (2018, 2020)	2018
China	–	2100	<5%	Huang et al. (2018); Wang et al. (2021)	2018
South Korea	68	66	97.2%	Somasundaram et al. (2015); Wu et al. (2020)	–
Thailand	–	–	7%	Kofoworola and Gheewala (2009)	2000
Vietnam	–	1.9	0%	Kien (2013)	–
Singapore	–	0.825	99%	National Environment Agency (2021)	2020
Malaysia	–	9.5	–	Esa et al. (2017)	–
India	–	17	<10%	Duan et al. (2019); Esa et al. (2017)	2015
Oceania					
Australia	–	19	55%	Hyder Consulting (2011)	2008
New Zealand	–	3.5–4.5	80%	Inglis (2007)	2007
Middle East					
Israel	7	4	–	Israel Ministry of Environmental Protection (2015)	–
Jordan	2.6	–	–	Alhyasat et al. (2014)	–
Saudi Arabia (Eastern Province)	0.143	–	–	Blaisi (2019)	2016
Africa					
Algeria	11	–	–	Youcef (2014)	2012
Libya	3.6	–	–	Ali et al. (2016)	–
Americas					
The United States	–	191	70%	Duan et al. (2019)	2015
Canada	–	4	–	Brantwood Consulting (2016)	2015
Chile	–	191	70%	Duan et al. (2019); Ossio and Castillo (2012)	2015

Note: * – Only non-hazardous waste is considered.

Construction Waste Management in Selected Provinces (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2018) aim to extend the scale of recycling, and promote the development of recycling technologies. Regarding the promotion of corresponding standards and regulations, developing an adequate regulatory system of waste recycling is one of the main problems (Ghisellini et al., 2018). However, landfilling and dumping are still considered as the first choice for contractors needing to dispose of waste in practice, owing to the low landfill fees (Huang et al., 2018).

Technical Specifications for the Application of Recycled Aggregate (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2011) indicates different applications of recycled aggregate, together with its performance requirements and inspection, transportation, and storage methods. Since 2010, Chinese standards GB/T 25177-2010, GB/T 25176-2010, and JGJ/T 240-2011 were released successively, filling the long-term technology gap of recycled concrete in China and regulating the production of recycled aggregate (Zhao et al., 2011). GB/T 25177-2010 and GB/T 25176-2010 present classifications for recycled coarse and fine aggregate, respectively. JGJ/T 240-2011 specifies the applications of recycled aggregate according to their classification.

2.3.2. C&D waste management in Japan

Japan is a crowded island nation with limited land area. The amount of C&D waste is increasing rapidly (Nitivattananon & Borongan, 2007), exacerbating the problem of landfill shortages. The depletion of natural resources obligates policymakers to be aware of the economic value of waste (Yolin, 2015).

Table 3. Existing policies and laws on C&D waste management in China

Ref.	Policies and laws	Year	References
C-1	National Guideline, Regulations for Construction Waste Management in Cities	1996	Ministry of Housing and Urban-Rural Development of the People's Republic of China (1996)
C-2	Notice on Promoting the Urban Sewage and Waste Treatment Industrialisation	2002	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2002)
C-3	Clean Production Act	2003	Standing Committee of the National People's Congress (2003)
C-4	Regulations on Urban Construction Waste Management	2005	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2005)
C-5	Circular Economy Promotion Law of the People's Republic of China	2008	Standing Committee of the National People's Congress (2008)
C-6	Financial Subsidy for Recycled and Energy-saving Building Materials	2008	Ministry of Finance of the People's Republic of China (2008)
C-7	Value-added Tax on Comprehensive Utilization of Resources and Other Products	2008	State Taxation Administration (2008)
C-8	Responsibility of the Construction Waste Recycling Department	2010	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2010)
C-9	Recycled Fine Aggregate for Concrete and Mortar (GB/T 25176-2010)	2010	General Administration of Quality Supervision Inspection and Quarantine of the People's Republic of China & Standardization Administration of the People's Republic of China (2010b)
C-10	Recycled Coarse Aggregate for Concrete (GB/T 25177-2010)	2010	General Administration of Quality Supervision Inspection and Quarantine of the People's Republic of China & Standardization Administration of the People's Republic of China (2010a)
C-11	Technical Specifications for the Application of Recycled Aggregate (JGJ/T 240-2011)	2011	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2011)
C-12	Guidance on the Comprehensive Utilization of Resources in the 12th Five-year Plan	2011	Ministry of Education of the People's Republic of China (2011)
C-13	Adjustment of Value-added Tax Policies	2011	State Taxation Administration (2011)
C-14	Plan for Comprehensive Utilization of Solid Waste	2011	National Development and Reform Commission (2011)
C-15	Green Building Plan	2013	General Office of the State Council of the People's Republic of China (2013)
C-16	Circular Economy Promotion Plan in 2015	2015	Ministry of Commerce of the People's Republic of China (2015)
C-17	Environmental Protection Tax Law	2016	State Taxation Administration (2016)
C-18	13th Five-year Plan for Construction in Cities	2017	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2017)
C-19	Circular Development Plan	2017	National Development and Reform Commission (2017)
C-20	Experimental Programs of Construction Waste Management in Selected Provinces	2018	Ministry of Housing and Urban-Rural Development of the People's Republic of China (2018)

In Japan, C&D waste is treated as a by-product from the construction site. It includes both municipal and industry waste (Tokyo Bureau of Environment, 2018). According to the Ministry of Land Infrastructure Transport and Tourism (2014), recyclable components of C&D waste (including concrete, asphalt, wood, and sludge) must be recycled. In recent years, Japanese government formulated several standards for different recycled products. Table 4 presents existing policies and laws on C&D waste management in Japan. A series of regulations and guidelines were enacted to deal with the application of recycled aggregate in concrete, including JIS A 5021 Recycled Aggregate for Concrete – Class H (Japanese Standards Association, 2011), JIS A 5022 Recycled Aggregate for Concrete – Class M (Japanese Standards Association, 2006), and JIS A 5023 Recycled Aggregate for Concrete – Class L (Japanese Standards Association, 2012). These standards are related to the classification of recycled concrete, along with its quality control and applications. Recycling plants have been developed across the country after the implementation of relevant policies (The Climate Group, 2014). The number of recycling facilities dealing with concrete debris and asphalt increased from 1790 in 2000 to 2531 in 2005 (Ministry of the Environment (Japan), 2008).

Japan has directed considerable efforts toward the monitoring of illegal dumping. In the Construction Recycling Promotion Plan (2014), the on-site inspection for the recycling status was strengthened, promoting efficient recycling. Moreover, details shared by the construction by-product information exchange system force concerned parties to respond properly to waste management (Ministry of the Environment, 2019b).

2.3.3. C&D waste management in Germany

A set of European standards governs C&D waste management, binding all the member states in the EU (Sáez et al., 2011). The main policy driver for the management in Europe is Waste Framework Directive, which calls the member states to reuse or recycle 70% of their C&D waste by 2020 (Jeffrey, 2011). Although there are available technologies and waste management systems in market, the construction sector is completely driven by economic profits and relies heavily on standards (Gálvez-Martos et al., 2018).

Germany has one of the most advanced C&D waste management practices among the countries in Europe (Deloitte, 2015b). This country has been involved in conserving natural resources through recycling and other recovery operations for decades. Among the world's countries, Germany has one of the highest waste recovery rates (up to 93%) (Eurostat, 2019), while the number was 17% in 1994 (Merino et al., 2010). This remarkable increase was achieved via strict regulations regarding waste avoidance, recycling, and landfilling, to solve the problem of land shortages (Deloitte, 2015b). Only specific types of waste can be landfilled (German Federal Government, 2009). Additionally, all energy in the waste for landfilling must be exploited to the possible maximum extent (German Federal Government, 1994). In 2016, 195.5 million tonnes (87.7%) of C&D waste was recycled, and only 11% of the waste (24.6 million tonnes) ended up in landfill sites (Federal Statistical Office, 2019).

Germany gives top priority to avoiding waste generation. Waste avoidance is preferred over recycling, and recycling is preferable to landfilling. High landfill fees (US $112 to $190 per tonne in 2011) discourage waste disposal at landfill sites in Germany (Wonschik et al., 2014). Additionally, related parties are responsible for utilising recoverable waste or secondary raw materials in the production process. In Germany, quality marks are officially used to provide guidance for customers to verify the reliability of products and services. Only recycled products from C&D waste that satisfy performance-specific quality criteria and obtain adequate quality marks can be used in industry. The DIN 4226-100 standard was developed to regulate the use of recycled aggregate in concrete production (Pellegrino & Faleschini, 2016). This standard specifies four types of recycled aggregate that are allowed for recycling, and outlines the specific types used for concrete production (Pellegrino & Faleschini, 2016). The existing policies and laws on C&D waste management in Germany are presented in Table 5.

Table 4. Existing policies and laws on C&D waste management in Japan

Ref.	Policies and laws	Year	References
J-1	Waste Management and Public Cleansing Law	1970	Ministry of the Environment (1970)
J-2	Resource Utilization Promotion Act	1991	Ministry of the Environment (1991)
J-3	Construction Material Recycling Law	2000	Ministry of the Environment (2000b)
J-4	Basic Act on Promotion of Recycling Oriented Society	2000	Ministry of the Environment (2000a)
J-5	Proper Process on C&D Waste	2002	Ministry of Land Infrastructure Transport and Tourism (2002)
J-6	Recycled Aggregate for Concrete – Class M (JIS A 5022)	2006	Japanese Standards Association (2006)
J-7	Recycled Aggregate for Concrete – Class H (JIS A 5021)	2011	Japanese Standards Association (2011)
J-8	Recycled Aggregate for Concrete – Class L (JIS A 5023)	2012	Japanese Standards Association (2012)
J-9	Construction Recycling Promotion Plan	2014	Ministry of Land Infrastructure Transport and Tourism (2014)
J-10	Illegal Dumping in 2017	2017	Ministry of the Environment (2019b)
J-11	Governmental Funds for Waste Disposal	2019	Ministry of the Environment (2019a)

Table 5. Existing policies and laws on C&D waste management in Germany

Ref.	Policies and laws	Year	References
D-1	Act for Promoting Closed Substance Cycle Waste Management and Ensuing Environmentally Compatible Waste Disposal	1994	German Federal Government (1994)
D-2	Waste Catalogue Ordinance	2001	Federal Ministry of Justice (2011)
D-3	Aggregate for Concrete and Mortar (DIN 4226-100)	2002	German Institute for Standardisation (2002)
D-4	Ordinance Simplifying Landfill Law	2009	German Federal Government (2009)
D-5	Ordinance on the Management of Municipal Solid Waste and Certain C&D Waste	2017	Federal Ministry of Justice (2017)

2.3.4. C&D waste management in the Netherlands

The requirements in Waste Framework Directive were applied to the Netherlands, and this country has already surpassed this requirement, achieving 100% recovery of C&D waste in 2016 (Eurostat, 2019). This outstanding performance could be the result of strict regulations regarding landfills (BIO Intelligence Service, 2011). Landfilling is regarded as the least desirable approach for waste disposal in the Netherlands. A ban on landfilling is applied to all reusable, recyclable, and combustible waste (Ministry of Infrastructure and Water Management, 2019). Additionally, tax on landfill was reintroduced in 2014 (European Union, 2018). Companies and individuals must pay a waste tax when they receive waste. However, the waste tax is transferred to waste producers (Central Government of the Netherlands, 2019).

Environmental Protection Act (Ministry of Infrastructure and Water Management, 1979) is the basis for the regulation of C&D waste in the Netherlands. This act is in accordance with Waste Framework Directive. It introduces the order of preference in C&D waste management. Similar to Germany, the Netherlands priories waste avoidance. Table 6 indicates existing policies and laws on C&D waste management in the Netherlands. National Waste Plan 3 was released in 2017, with the aim of reusing as much waste as possible (European Union, 2018). Furthermore, the plan provides detailed definitions for different classes of waste and instructions for transportation and treatment. Moreover, the Netherlands enacts strict regulation on related stakeholders. Waste can only be processed by authorised companies. All demolition, transportation, recycling, and landfilling companies must register with the National and International Road Transport Organization to be included in the official list.

2.3.5. C&D waste management in Italy

Italy largely follows EU legislation. In Italy, as one of the most significant waste streams, approximately 41.3 million tonnes of C&D waste was generated in 2018 (Eurostat, 2021). The recovery rate in Italy has been steadily maintained since 2010, as it was 97% in 2010 and 98% in 2018 (Eurostat, 2019).

However, there is no waste management plan at the national level in Italy, as waste management plans and strategies are developed at the regional level (Deloitte, 2015c). Thus, various C&D waste management plans exist across different regions and provinces in Italy. With the scarcity of nationwide policies and related documents, Legal Decree No. 152/06 and subsequent amendments may be the only example of legislation that can be used for investigating the C&D waste management in Italy. Waste derived from C&D is classified as "special waste", because it constitutes a large volume of non-hazardous substances (98 vol.%) (Higher Institute for Environmental Protection and Research [ISPRA], 2016), which are treated in recycling facilities. Contaminants such as asbestos and other harmful substances, must be treated in a different manner.

Table 6. Existing policies and laws on C&D waste management in the Netherlands

Ref.	Policies and laws	Year	References
N-1	Environmental Protection Act	1979	Ministry of Infrastructure and Water Management (1979)
N-2	Aggregate for Concrete – Determination of the Chloride Content	1988	Royal Netherlands Standardization Institute (1988)
N-3	Aggregate for Concrete – Determination of Sulphate Content	1990	Royal Netherlands Standardization Institute (1990a)
N-4	Aggregate for Concrete – Determination of the Composition of Granular Debris	1990	Royal Netherlands Standardization Institute (1990b)
N-5	National Waste Plan 3 (LPA3)	2017	Ministry of Infrastructure and Water Management (2017)
N-6	Registration of Waste Transporters, Demolition Companies, Dealers, and Brokers	2019	Netherlands Enterprise Agency (2017)
N-7	Landfilling in the Netherlands	2019	Ministry of Infrastructure and Water Management (2019a)
N-8	Waste Tax	2019	Ministry of Infrastructure and Water Management (2019b)

Almost half of the hazardous waste generated in Italy is landfilled after proper treatment. The remaining portion is exported to other countries, such as Germany (Deloitte, 2015c).

In Italy, the quality criteria regulate the use of recycled aggregate in concrete production (Borghi et al., 2018). However, recycled aggregate is not competitive, owing to its poor quality and a lack of taxes on quarrying activities (Deloitte, 2015c). To increase the recovery rate, it is crucial to increase the demand for recycled aggregate and thus increase the utilisation of recycled aggregate. Green Public Procurement (Italian Ministry of Environment, 2005) was introduced. Building companies are required to use recycled materials in construction. Recycled products with the same characteristics as products from natural materials must account for >30% of the market for construction materials. Additionally, the price of recycled aggregate is strictly controlled. The price of recycled aggregate is available in the official recycling dictionary and is lower than that of virgin aggregate. Table 7 presents the existing policies and laws on C&D waste management in Italy.

2.3.6. C&D waste management in Austria

The promotion of C&D waste recycling in Austria follows the characteristics of EU legislation. Austria has become one of the most advanced countries with regard to waste management (Deloitte, 2015a). There is a set of federal ordinances related to C&D waste, including regulations on recycled construction materials, waste traceability, and landfills (Table 8).

Waste Management Act (2002) is a legal basis for sustainable solid waste management, including management of C&D waste. It requires that a detailed waste management plan must be established or updated at least every six years. Additionally, Recycled Construction Materials Ordinance was enacted in 2015 and began to be enforced on 1 January 2016. This ordinance specifies separation duties, appropriate treatments for C&D waste, and limits the cost of secondary materials. Regarding recycled aggregate, analytical examinations and evaluations should be conducted by an external authorised specialist or group on samples of recycled materials. Only quality-assured recycled construction materials can be released into the market. However, there is a lack of financial incentives from the Austrian Government. Secondary building materials are unattractive to consumers, because of the low price of primary materials (Kleemann, 2010).

The intention of Austrian government is to maintain high waste management performance via legislation. C&D waste data from demolition and recycling companies have been directly transmitted to a central database since 2011 (Deloitte, 2015a). Under the Waste Management Act (Federal Ministry of Constitution Reforms Deregulation and Justice, 2002), contractors are obliged to keep records of types, quantities, and origins of waste, along with the waste codes. Moreover, demolition, transportation, and recycling companies must keep continuous electronic records. Landfill operators record detailed information, including the delivery dates, inspection results, and exact locations of waste at the landfill site. These records are kept for more than seven years and are accessible to the authorities.

Table 7. Existing policies and laws on C&D waste management in Italy

Ref.	Policies and laws	Year	References
T-1	Decree from the Ministry of Environment	2003	Italian Ministry of Environment (2003)
T-2	Green Public Procurement	2005	Italian Ministry of Environment (2005)
T-3	Legislative Decree (Legal Decree No. 152/06)	2006	Authority for the Supervision of Water Resources and Waste (2006)
T-4	Aggregate for Concrete	2013	Italian National Unification (2013)

Table 8. Existing policies and laws on C&D waste management in Austria

Ref.	Policies and laws	Year	References
A-1	Hazardous Waste Specification Ordinance	2000	Ministry of Sustainability and Tourism (2000)
A-2	Waste Management Act	2002	Federal Ministry of Constitution Reforms Deregulation and Justice (2002)
A-3	Waste List Ordinance	2003	Ministry of Sustainability and Tourism (2003)
A-4	Landfill Ordinance	2008	Ministry of Sustainability and Tourism (2008)
A-5	Waste Treatment Responsibilities	2009	Federal Ministry of Agriculture and Forestry (2009)
A-6	Austrian Ordinance for Tracking Waste	2012	Federal Ministry of Agriculture and Forestry (2012)
A-7	Dismantling of Buildings as Standard Method of Demolition	2014	Ministry of Sustainability and Tourism (2014)
A-8	Recycled Construction Materials Ordinance	2015	Federal Ministry of Constitution Reforms Deregulation and Justice (2015)
A-9	Recycled Aggregate for the Construction Industry	2015	Austrian Standards Institute (2015)

2.3.7. C&D waste management in the United Kingdom

The United Kingdom currently satisfies the requirement in Waste Framework Directive; and achieved a recovery rate of 91% in 2016 (Department for Environment Food and Rural Affairs, 2019). However, there is no specific legislation for C&D waste. Overarching waste legislation is enacted in the United Kingdom, which applies to C&D waste along with other types of waste. Moreover, the governing bodies in England, Wales, Scotland, and Northern Ireland have developed separate waste management plans, considering the current waste management status (Deloitte, 2016).

Table 9 presents the existing policies related to C&D waste management in the United Kingdom. Waste regulations in England and Wales, Northern Ireland, and Scotland specify requirements for waste management plans and prevention plans. England has already fulfilled the recycling target from EU legislation, achieving a 98% recovery rate in 2018 (Eurostat, 2019). Welsh and Scottish governments consider waste prevention in the construction sector as the most efficient approach and emphasise the use of recycled materials. In 2010, 3.5 million tonnes of C&D waste was generated in Northern Ireland, of which non-hazardous C&D waste accounted for 1.2 million tonnes (Department of Agriculture Environment and Rural Affairs, 2013). The number is far smaller than that in England.

Encouragement from governmental programs aims to maximise use of recycled aggregate in construction, such as by setting targets for the use of recycled content in construction products. A minimum of 10% of recycled content should be included in governmental construction projects in Northern Ireland (Department of Agriculture Environment and Rural Affairs, 2013). A uniform control process in production ensures sufficient waste recovery and greater use of recycled aggregate, with the aim of increasing market confidence in products manufactured using recycled waste (Civil Engineering Contractors Association, 2018). Additionally, investment from the government in the recycling sectors and an increase in the landfill tax in the United Kingdom have accelerated the transition to a more eco-friendly economy, owing to the reduced recovery costs (Deloitte, 2016).

2.3.8. C&D waste management in South Korea

To effectively address the waste issue, Korean government has shifted its focus to the minimisation of waste generation, through promoting the efficient use of natural resources and proper waste management (Ministry of Environment, 2003). Benign cooperation among three levels of governments is pivotal in C&D waste management. The Ministry of Environment (South Korea), special self-governing city governments, and municipalities are involved in devising and applying measures to facilitate eco-friendly disposal and recycling. Mayors/province governors and heads of cities direct researches on the status of C&D waste, including the distribution and treatment. Subsequently, the Ministry of Environment prepares a nationwide "master plan" based on the results of statistical data. To keep pace with the rapidly changing society, Ministry of Environment (South Korea) should review the feasibility of the master plan every five years and update the plan every ten years, in accordance with the Construction Waste Recycling Promotion Act (Ministry of Environment, 2003).

Table 9. Existing policies and laws on C&D waste management in the United Kingdom

Ref.		Policies and laws		Year	References
U-1	Waste Regulations	England	Waste (England and Wales) Regulations	2014	Department for Environment Food and Rural Affairs (2014)
		Wales			
		Northern Ireland	Waste (Northern Ireland) Regulations	2011	Department of the Environment (2011)
		Scotland	Waste (Scotland) Regulations	2011	Scottish Parliament (2011a)
U-2	Landfill Legislations	England	Environmental permitting (England and Wales) Regulations	2010	Department for Environment Food and Rural Affairs and Department of Energy and Climate Change (2010)
		Wales			
		Northern Ireland	Waste management licensing regulations (Northern Ireland)	2003	Department of Agriculture Environment and Rural Affairs (2003)
		Scotland	Waste management licensing (Scotland) regulations	2011	Scottish Parliament (2011b)
U-3	Waste management plan	England	Waste management plan for England	2013	Department for Environment Food and Rural Affairs (2013)
		Wales	Towards zero waste. One Wales: one planet	2010	Welsh Assembly Government (2010)
		Northern Ireland	Delivering Resource Efficiency	2013	Department of Agriculture Environment and Rural Affairs (2013)
		Scotland	Zero Waste Plan	2010	Scottish Government (2010)
U-4	European list of waste			2000	European Commission (2000)
U-5	Aggregate for concrete			2012	British Standards Institution (2012)

Table 10. Existing policies and laws on C&D waste management in South Korea

Ref.	Policies and laws	Year	References
K-1	Business Waste Reduction Program	1996	Ministry of Environment (1996)
K-2	Construction Waste Recycling Promotion Act	2003	Ministry of Environment (2003)
K-3	Waste Control Act	2008	Ministry of Environment (2008)
K-4	Act for the Promotion of Saving and Recycling of Resources	2010	Ministry of Environment (2010)
K-5	Recycled Aggregate for Concrete	2014	Korean Standards Association (2014)
K-5	Enforcement Regulations for the Promotion of Construction Waste Recycling Act	2018	Ministry of Environment (2018)

In South Korea, an electronic information sharing system is employed to manage C&D waste in a transparent and effective way. Information related to waste collection, transportation, recycling, and landfilling is recorded in the system automatically. This information is preserved for three years and can be verified and searched by authorised users. Additionally, state governments may grant local subsidies for all or part of the expenses for installing waste recycling facilities (Ministry of Environment, 2003, 2008). Ministry of Environment can provide technical guidance on installation if necessary. The existing policies and laws on C&D waste management in South Korea are presented in Table 10.

3. Comparative analysis

Cross-national comparative analysis was frequently used in previous literatures. It can concentrate on a specific research topic and is shown to be an effective method in generating meaningful policy implications (Ahn et al., 2021). Selected documents, including policies and laws enacted in China and seven countries, were comprehensively reviewed and coded. Clauses collected from these policies and laws are classified into four categories: (1) general regulations, (2) incentives, (3) stakeholders' responsibilities, and (4) supervision and penalties. These clauses are listed in Tables 11–14. The codes of policies and laws which mention the specific clause are filled in the corresponding blanks. A comparative analysis is conducted, based on the four tables. Comparative understandings of these policies and laws could indicate possible differences in C&D waste management in different countries and problems in waste management in China from a country-level perspective.

3.1. Comparisons on general regulations

Table 11 presents a comparison of the general regulations. Clauses R-1 to R-23 are summarised from the contents of national policies and laws in China and the seven selected countries. 5 of the 23 clauses are included in polices and laws in China, i.e., priority to reduce waste generation (R-1), centralized landfilling (R-17), development of recycling technology (R-19), enactment of experimental programs in leading cities (R-20), and cooperation with capitals (R-21).

It is generally agreed that "3R" principle (reduce, reuse and recycle) is the basis of C&D waste management (Huang et al., 2018). The hierarchy of C&D waste management is applied to all the countries, as waste avoidance is considered as the highest priority (R-1). A great collection of measures to reduce production of waste have been carried out. In Japan, import of C&D waste from other countries is restricted (R-9), to slow the increase in waste quantity. Meanwhile, in all the seven selected countries, separate collection and different treatments for different classes of C&D waste are emphasised (R-6). According to Table 11, Japan, South Korea, Germany, Austria, the Netherlands, and the United Kingdom have established integrated classification systems for C&D waste (R-5). For instance, Japan divided C&D waste into three big categories: reusable, recyclable and non-recyclable waste (Gao, 2008). In addition, C&D waste has been further classified into 20 small classes (Nakajima, 2014). However, classification of C&D waste is not uniformly defined in China (R-5).

Japan, South Korea, Germany, the Netherlands, and Austria have adopted mandatory recycling (R-12). Mandatory recycling has specifically targeted recyclables, such as concrete, wood, and asphalts, to make waste disposal compatible with public interests (R-15). To reduce the dependence on landfilling, only specific types of (non-hazardous) waste can be deposited at landfill sites (R-13). The energy potential of waste that is transported to landfills should be exploited to the maximum extent in South Korea, Germany, the Netherlands, the United Kingdom, and Italy (R-16). In Germany, Ordinance Simplifying Landfill Law (German Federal Government, 2009) defines landfill sites of Class 0, I, II, III, and IV for different codes of waste (R-14). Similar to Germany, governing bodies in Austria and the United Kingdom define the types of landfills (R-14). Mixing one class of waste with another substance or class of waste is strictly prohibited in Germany, the Netherlands, Austria and Italy (R-8). In contrast to the mandatory recycling of recyclables (R-12) and strict control of landfilling in selected countries, C&D waste produced in China is transported to storage centres to be landfilled together (R-17), as recycling and other treatments are unavailable (Ma et al., 2020).

3.2. Incentives

Table 12 presents a comparison of incentives among China and the seven selected countries. Value-added tax (VAT) deductions (I-2), and BOT right (I-5) were released in China. BOT (build-operate-transfer) is a financing mechanism, where private sector is given responsibility to

Table 11. Comparison on general regulations

Ref.	General regulations	China	Japan	South Korea	Germany	Netherlands	Austria	United Kingdom	Italy
R-1	Priority to reduce waste generation	C-5, C-15, C-18	J-1, J-2	K-1, K-2, K-3, K-4	D-1	N-1	A-2	U-1	T-3
R-2	Tax on generation of C&D waste		J-2	K-3		N-8			
R-3	Higher waste tax for waste exported					N-8			
R-4	Mandatory waste management		J-2, J-4	K-1, K-2, K-4	D-1, D-5	N-1, N-5	A-2		
R-5	Detailed types of C&D waste		J-9	K-4, K-6	D-1, D-2, D-5	N-1, N-5	A-3	U-4	
R-6	Separate collection		J-9	K-4, K-6	D-1, D-2, D-5	N-1, N-5	A-8	U-1	T-3
R-7	Quality inspection on waste						A-4, A-7		
R-8	Mixing ban on hazardous waste				D-5	N-1	A-2, A-8		T-3
R-9	Restricted waste imports		J-1						
R-10	Development of recycling-oriented economic system		J-2			N-1	A-8	U-1	
R-11	Development of closed substance cycle				D-1				
R-12	Mandatory recycling of the recyclables		J-2	K-4	D-5	N-1, N-5	A-7		T-3
R-13	Only specific types of waste can be landfilled				D-4	N-7	A-2, A-4		T-3
R-14	Detailed classification of landfill sites				D-4		A-4	U-2	
R-15	Waste disposal should be compatible with the public interest			K-2, K-4	D-1	N-1	A-2, A-4		T-3
R-16	Energy in the waste for landfilling should be exploited to the possible maximum extent			K-4	D-1	N-7		U-2	T-3
R-17	Centralized landfill	C-15							
R-18	Maintenance of waste recycling facilities		J-9						
R-19	Development of recycling technology	C-14	J-1						
R-20	Experiments in selected provinces and cities	C-16, C-19, C-20							
R-21	Cooperation between government and capitals	C-18							
R-22	National self-care (Duty of care for waste)		J-1		D-1	N-1		U-1	
R-23	Quality assurance for recycled building materials						A-8		

finance, build, operate until the project is transferred back to public sector (Shen, 2007; Song et al., 2017). Enterprises who obtained BOT contracts can conduct operations within the scope of the franchise rights, including investing, implementing projects, and collecting waste transportation tariffs. Currently, innovative procurement models, including BOT, have been applied to multiple pilot C&D waste recycling projects in China, which could ensure sufficient finance, quality and timeliness of service and a long-term relationship (Bao et al., 2019). Additionally, funds for recycled material producers (I-3), subsidy for use of recycled materials (I-4), reduced prices for electricity (I-6) and land use (I-10) are employed as incentives in China. In recent years, incentive policies related to C&D waste management have been enacted in multiple Chinese cities (Ma et al., 2020). For instance, recycling company could get 1 CNY (or US $0.14) back from government for every piece of recycled brick produced (Bao & Lu, 2020).

Table 12. Comparison on incentives

Ref.	Incentives	China	Japan	South Korea	Germany	Netherlands	Austria	United Kingdom	Italy
I-1	Awards for distinctive performance in clean production	C-3		K-1					
I-2	VAT deductions for recycling operators	C-6, C-17							
I-3	Funds for recycled-material producers	C-2, C-6		K-3					
I-4	Subsidy for use of recycled materials		J-11						
I-5	BOT right or recycling businesses	C-2							
I-6	Lower price of electric power	C-2							
I-7	Funds for starting new recycling business		J-11	K-2				U-3	
I-8	Funds for research		J-11						
I-9	Concessional loans for recycling businesses		J-11						
I-10	Less expensive land use	C-2							
I-11	Recycled products should account for a certain percentage of the market share								T-2
I-12	Price control on recycled aggregate			K-3					
I-13	Price list for recycled building materials								T-2
I-14	Encouraging use of recycled products	C-5, C-12	J-2	K-2	D-1				
I-15	Obligatory use ratio for recycled building materials			K-2, K-4					
I-16	Instructions on applications of recycled aggregate	C-9, C-10, C-11	J-6, J-7, J-8	K-5	D-3	N-2, N-3, N-4	A-9	U-5	T-4

Although Chinese government has provided information and standards regarding the use of recycled aggregate (I-16) and encourage the use of recycled products (I-14), there is a lack of market incentives in utilising recycled materials. Some countries issued policies to promote the use of recycled products. It is obligatory for contractors to use recycled aggregate that satisfy the quality standards for construction works in South Korea (I-15). In Italy, recycled materials and products should account for >30% of the market share of the given type of products (I-11).

3.3. Stakeholders' responsibilities

The responsibilities on different levels of government are specified in C-1 and C-8 (S-1, S-5, S-7 and S-10). Similar to other selected countries, Chinese central government makes important decisions on behalf of the country and has the responsibility of drafting national waste management plans with the highest priority (S-1). Technical assistance from central governments to lower governments is provided in Japan, Germany, and Italy (S-2), to effectively turn waste into resources and ensure safe operations. The central government in Germany incorporated recycling into the culture and defined a standard recycling process for waste facilities (S-3). Publicly notified assessments of the capability of recyclers to perform services are conducted by the central government in South Korea (S-4), to help contractors select qualified companies. Municipalities in Japan and South Korea promote voluntary efforts from business to reduce waste (S-8), extend the lifetime of buildings, and use recycled building materials.

In the seven selected countries, responsibilities of related stakeholders, including contractors, material suppliers, demolition and recycling companies, landfill operators, have been defined. In European countries, polluter pay principle guides the C&D waste management, which requires producers cooperate with other stakeholders and consider possible environmental impacts and risks during activities (Sáez et al., 2011). However, the responsibilities of stakeholders involved in C&D waste recycling activities in China are not well-defined (Table 13). Although contractors' responsibilities to formulate plans for waste disposal and to manage waste for whole lifecycle (S-17) are specified (S-15), the responsibilities of other parties, such as ordering parties, demolition, transportation, recycling, and landfilling companies, are not specified in China (Table 13).

3.4. Supervision and penalties

Table 14 presents a comparison of supervision and penalties. China conducts nationwide inspections targeting fly-tipping (P-1). However, the penalties faced by related stakeholders who fail to fulfil their responsibilities are not presented in the Chinese regulations at national level (P-2). In China, illegal behaviours frequently occur during the disposal process of C&D waste, because related stakeholders are driven by profits and neglect environmental damages (You et al., 2020). Strict penalty mechanism could guarantee obedience of relevant stakeholders.

Table 13. Comparison on stakeholders' responsibility

Stakeholders' responsibilities		Ref.	China	Japan	South Korea	Germany	Netherlands	Austria	United Kingdom	Italy
Central government/ Federal government/ Ministry	Provide national guidance on waste management	S-1	C-1, C-8	J-1, J-3	K-2, K-3	D-1	N-1	A-2		T-3
	Promote related technology	S-2		J-1		D-1				T-3
	Define requirements for waste facilities	S-3				D-1				
	Assess capability of recyclers to perform services	S-4			K-2					
Prefectural government/ States/Provinces	Proper waste management in administrative area	S-5	C-1	J-1, J-3, J-5	K-2, K-3	D-1	N-1		U-1, U-3	T-3
	Provide technical advice to municipalities	S-6		J-1, J-3						
Municipalities	Take actions for proper management	S-7	C-1, C-8	J-1, J-3, J-4		D-1				T-3
	Promote voluntary activities	S-8		J-1	K-1					
	Organize a council for promoting waste reduction	S-9		J-1						
	Follow national policies	S-10	C-1	J-3, J-4		D-1				T-3
Ordering parties	Investigate surroundings	S-11		J-5						
	Plan for sorted demolition and other operations	S-12		J-3, J-5						
	Require contractors to use recycled aggregate	S-13			K-2					
Main contractors/ waste producer/ waste holders	Reduce waste from design	S-14		J-1, J-3, J-4, J-5,	K-3	D-1, D-4, D-5,		A-2, A-6, A-8	U-1	T-3
	Make and submit waste disposal plan	S-15	C-1, C-4, C-15	J-3, J-5	K-2, K-3		N-1			
	Use recoverable or recycled building materials	S-16			K-2	D-1				
	Manage waste for whole lifecycle	S-17	C-15	J-3	K-2, K-3	D-1, D-4	N-1	A-2, A-8	U-1	T-3
	Deliver waste to authorised disposal companies	S-18			K-3	D-1	N-6	A-2		T-3
	Separate collection	S-19		J-3	K-4, K-6	D-1, D-2, D-5	N-1, N-5	A-8	U-1	T-3
	Report information of waste	S-20		J-1	K-2	D-1, D-5	N-1	A-2, A-6		
Sub-contractors	Follow instructions of main contractors	S-21		J-5						
Demolition companies	Registered	S-22		J-3			N-1, N-6		U-1	
	Proper demolition work	S-23		J-3, J-5	K-2, K-3	D-1, D-5		A-6, A-8		
	Records on waste	S-24			K-2	D-1		A-2,		

End of Table 13

Stakeholders' responsibilities		Ref.	China	Japan	South Korea	Germany	Netherlands	Austria	United Kingdom	Italy
Recycling companies	Registered	S-25		J-1, J-5	K-2, K-3		N-1, N-6	A-6, A-8	U-1, U-2	
	Cooperate with municipalities	S-26		J-1						
	Proper, safe, and high-quality recycling	S-27			K-2, K-3	D-5				
	Visual inspections and assessments of waste	S-28						A-8		
	Keep records regarding waste	S-29			K-2	D-1	N-1	A-2	U-1	T-3
	Conduct researches and improve facilities	S-30			K-2					
Landfill operators	Acceptance inspection of waste	S-31				D-4		A-4		T-3
	Organise landfill sites	S-32				D-4				
	Keep records regarding waste	S-33				D-4	N-7	A-2		
Suppliers of materials	Products designed for reducing waste	S-34		J-2, J-4		D-1				T-3
	Use recycled products	S-35				D-1				T-3
Consumers	Proper maintenance	S-36				D-1				
Transportation companies	Registered	S-37			K-2		N-1, N-6		U-1	
	Record data on waste	S-38			K-3	D-1	N-1, N-6	A-2, A-6	U-1	T-3
	Comply with local regulations	S-39							U-1	T-3

Table 14. Comparison on supervision and penalty

Ref.	Supervisory and penalty	China	Japan	South Korea	Germany	Netherlands	Austria	United Kingdom	Italy
P-1	Penalty for illegal dumping	C-4	J-1	K-2	D-1				
P-2	Penalty for other violations		J-1	K-2	D-1				
P-3	Regular data collection for recycling status		J-9			N-1			
P-4	Enhanced monitoring and on-site inspection		J-9, J-10						
P-5	Information exchange system		J-9, J-10	K-2					T-3
P-6	Special supervision for contractors that produce large amounts of waste				D-1				
P-7	Related parties provide information and keep a record book			K-2, K-3	D-1	N-1	A-2, A-6, A-8	U-1	T-3

Additionally, governmental supervision (P-3, P-4, P-7) and information exchange system (P-5) are unavailable in China. It is found to be difficult to trace the waste and estimate the total volume of C&D waste in China (Akhtar & Sarmah, 2018; Lu et al., 2017). In contrast to situations in China, in South Korea, Germany, the Netherlands, Austria, the United Kingdom and Italy, all the related parties, including contractors, demolition, transportation, and recycling companies and landfill sites, are required to keep a record book and submit their records to governing bodies for inspection (P-7). Regular data collection (P-3), on-site inspection (P-4), and information exchange system (P-5) are developed, allowing related stakeholders to properly manage disposal according to the waste profile.

4. Discussions

4.1. Problems in the current C&D waste management in China

China has spent some efforts to develop C&D waste management. However, it needs further improvement. China could consider strategies in selected countries and pursue

Table 15. Problems and recommendations of the current C&D waste management in China

Problems	Related clauses	Recommendations
Inadequate guidance on recycling	R-4–R-9, R-12–R-16 (Table 11)	1. China should define classification of C&D waste and following treatments of each class; 2. China should issue a landfill ban; and 3. China should take measures to reduce waste generation.
Lack of market incentives in utilising recycled materials	I-11, I-12, I-13, I-15 (Table 12)	1. China could expand financial incentives; 2. Chinese government could provide funds for related researches; 3. China could promote the mandatory use of building materials recycled from C&D waste; and 4. Chinese governments could consider recycled products as prior choice in governmental projects.
Incomplete knowledge of stakeholders' responsibilities	S-11–S-39 (Table 13)	1. China should expand stakeholders' responsibilities.
Lack of penalty for other stakeholders	P-2 (Table 14)	1. China should fill gaps in the law, and outlines rules for violations by relevant stakeholders.
Inefficient supervision system	P-3–P-7 (Table 14)	1. China should conduct precise estimation on annual generation and flows of the waste; 2. China could establish a waste tracing system, through collecting records, and conducting on-site inspection; and 3. China could develop a data sharing platform which could be accessible to all the related stakeholders.

proper C&D waste management. Table 15 summarizes problems in the current C&D waste management in China and specifies corresponding recommendations. However, not all the strategies would be suitable to be applied to China, because of regional variation. Evaluation on advantages and disadvantages should be adopted through actual practices.

4.2. Inadequate guidance on recycling

In China, there is a lack of an intermediate link between waste generation and the use of recycled materials in the recycling chain, since related contents are missing in national guidance (Table 11). This is consistent with Lu and Yuan (2010) and Yuan (2017). Most current policies in China are not operable and not detailed enough to guide efficient C&D waste management (Lu & Yuan, 2010). Specifically, one reason for the limited recycling capability could be a lack of proper guidelines on how to classify C&D waste (Huang et al., 2018). Integrated classification systems for C&D waste have been established in Japan, South Korea, Germany, Austria, the Netherlands, and the United Kingdom (Table 11). For example, Japan issued legislation to stimulate recycling, and identified approximately 20 classes of C&D waste (Nakajima, 2014). The recycling rates for each class of waste were calculated separately (Nakajima, 2014). Without a standard classification, the subsequent treatments of different class of waste are difficult to be specified in China. Additionally, the lack of a standard classification could lead to unorganised waste separation and collection (Zhao et al., 2010). The quantity and quality of recyclable materials can be maximised via separate collection of waste (Calabrò, 2009), increasing the efficiency of recycling (Wang et al., 2010). In contrast to natural aggregate, recycled aggregate cannot be produced and immediately used before their properties are carefully tested. Therefore, separate collection of selected class of waste with certain features is essential for producing high-quality recycled aggregate (Torgal, 2013). Currently, most waste is mixed in China, and recyclers must direct considerable efforts and financial resources toward manual and machine separation (Huang et al., 2018).

During the last few decades, fly-tipping of C&D waste was prevalent. In recent ten years, landfilling starts to become a convenient and dominant solution to handle the waste (Duan et al., 2015). In 2014, approximately 84% (29.4 million tonnes) of C&D waste generated in Shenzhen ends up in landfills (Duan & Li, 2016). A landfill ban for recyclable components and unsorted waste could help to deal with the waste sustainably and desirably (Ulubeyli et al., 2017). In Germany, the Netherlands, Austria and Italy, only specific class of waste can be landfilled, and recyclable components should be recycled (Table 11). In the Netherlands and Germany, a strict control of landfilling prevents disposal of recyclable components, which have promoted a better waste management (Sáez et al., 2011). In 2002, German government issued a ban on landfilling, to encourage reuse and recycle of C&D waste (Agamuthu, 2008). The Netherlands has a high landfill charge for approximately 83 €/t (US $97) (Sáez et al., 2011).

Regulatory environment is important to promote recycling of C&D waste (Bao & Lu, 2020). A national standard and legislation on C&D waste should be released to establish an integrated recycling chain, requiring additional details on the classification of C&D waste. Following the guidance, different classes of waste could be correctly separated and then transported to proper treatment facilities. Furthermore, based on a robust knowledge of classification, subsequent regulations, such as separate

collection, a ban on mixing waste, mandatory recycling, acceptance criteria on waste to recycling and landfilling plants and classification of landfill sites could be enacted.

Minimisation of waste can address the issue of large volumes of waste and encourage waste reduction. China should find a better solution for waste reduction. China has regarded waste reduction as an objective in C-5, C-12 and C15 (Table 11). Waste reduction measures in each stage of construction projects, including transportation plan of building materials, management plan of construction site and storage of materials, should be considered to retain the production and reduce overall C&D waste (Liu et al., 2020). In China, application of prefabricated technology in construction industry is emphasised in the long-run national development plan (Gao & Tian, 2020). Since 1999, national policies have been issued successively to promote prefabricated construction (Chang et al., 2018; Gao & Tian, 2020). However, the immaturity of the prefabrication market has resulted in lagged adoption of prefabricated technology in construction industry (Zhu et al., 2018). With regard to waste reduction, other measures from selected countries can be considered. Japan strives to reduce the waste generation through selection of proper materials and techniques, as well as efficient demolition. Authorities in South Korea encourage businesses to reduce waste generation voluntarily by considering environmental impacts throughout the processes of design, manufacturing, distribution, consumption, and disposal.

4.3. Lack of market incentives in utilising recycled materials

Provision of economic incentives is regarded as an effective measure to stimulate recycling (Ajayi & Oyedele, 2017; Armstrong, 2012; Wu et al., 2017), because it can compensate costs incurred from C&D waste disposal, improve companies' financial feasibility and increase their willingness for participation (Wang et al., 2021). Ding et al. (2015) demonstrated that tax deduction for developers or contractors who use the building materials recycled from C&D waste could increase the participation of related stakeholders. Except VAT deductions for recycling companies and subsidy for contractors, other forms of financial incentives (BOT right, funds for recycled material producers, reduced prices for electricity and land use for recycling business) are initiated in China (Table 12). Currently, multiple municipal governments in China formulated incentive policies to stimulate active engagement of recycling companies (Ma et al., 2020). Furthermore, China can expand incentive policies and apply regulations that have been used by other selected countries, such as concessional loans and funding for new recycling businesses, for purchasing facilities, employee training and welfare.

However, absence of market incentives in using recycled materials is a critical issue. There are differences between the properties of recycled-aggregate concrete and those of natural-aggregate concrete, because the properties of recycled aggregate are largely dependent on the source (Yehia et al., 2015). The use of recycled aggregate in China has been limited to road construction and the production of non-structural-grade concrete (Senaratne et al., 2017). Researches on widening the application of recycled aggregate in structural use could be conducted. Lu and Yuan (2010) identified research and development as a critical factor in implementation of C&D waste, and government should cooperate closely with local universities and research institutes to develop related technologies. There is limited interest in the replacement of natural resources with recycled aggregate in the Chinese recycling market, because of the unstable properties of recycled aggregate (Duan et al., 2019). Therefore, an important step in the establishment of a recycling program is to nurture a market for recycled products (Jin et al., 2017). Some selected countries forced contractors to use building materials recycled from C&D waste (Table 12). For instance, it is obligatory for contractors to use recycled aggregate that satisfy the quality standards for construction works in South Korea. Chinese government could move beyond voluntary use of recycled products and impose obligatory recycling content in building materials. In addition, the government could play a leading role as a customer, as recycled materials could be used in governmental programs and construction in fundamental facilities.

4.4. Incomplete knowledge of stakeholders' responsibilities

C&D waste management is sophisticated and involves several stakeholders each playing a role in optimising the management. Along with increasing environmental concerns from publics, more responsibilities of C&D waste disposal are laid on the shoulders of relevant stakeholders (Li et al., 2020). The influence of stakeholders on the success of C&D waste management is critical (Oppong et al., 2017; Yuan, 2017). For all the countries, a national plan forms the basis of legislation. Provinces are responsible for translating these basic policies into regional contexts, and municipalities take actions for proper waste management that are compatible with these regulations (Table 13). As current policies are too general to provide operable guidance, some local governments implemented C&D waste management in their administrative areas (Lu & Yuan, 2010). Therefore, the practices of C&D waste management vary across the regions (Huang et al., 2018). As described in Table 13, different levels of government have participated in C&D waste management. Yuan (2017) stated that the efficient arrangement of their management activities had not been achieved, because responsibilities on different government departments were not properly determined. However, whether a culture of efficient cooperation among departments has been achieved calls for additional robust researches.

In line with previous literatures (Lu & Yuan, 2010), the responsibilities of stakeholders involved in C&D waste recycling activities in China are ambiguous and not well-defined (Table 13 and Figure 2). Only contractors are re-

quired to formulate plans for waste disposal and should be responsible for the whole life of the waste, but recycling is not mandatory and landfilling is preferable for its low costs. In addition, the responsibilities of other parties, such as demolition, transportation, recycling, and landfill companies, are not specified. In China, construction waste reduction and environment protection received little attention from industry stakeholders (Yuan, 2013). Seldom would contractors pay attention to the destination of C&D waste, after it exits a construction site (Lu & Yuan, 2010). All the related stakeholders should be considered in the recycling chain. China can expand the responsibilities of different stakeholders based on the experience of the selected countries. Flowcharts of the waste processing among related stakeholders and their responsibilities in Japan are presented in Figure 3. Japan has concerned all the related stakeholders in the recycling chain, including central government, provincial government, municipali-

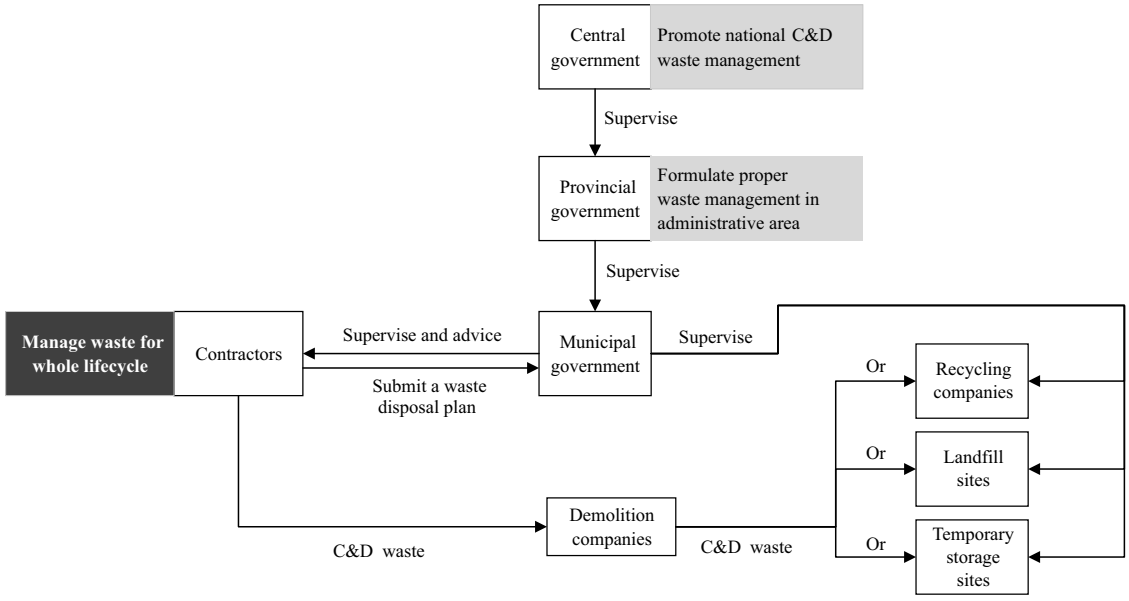

Figure 2. Responsibilities of related stakeholders in China (based on Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2010; Ma et al., 2020)

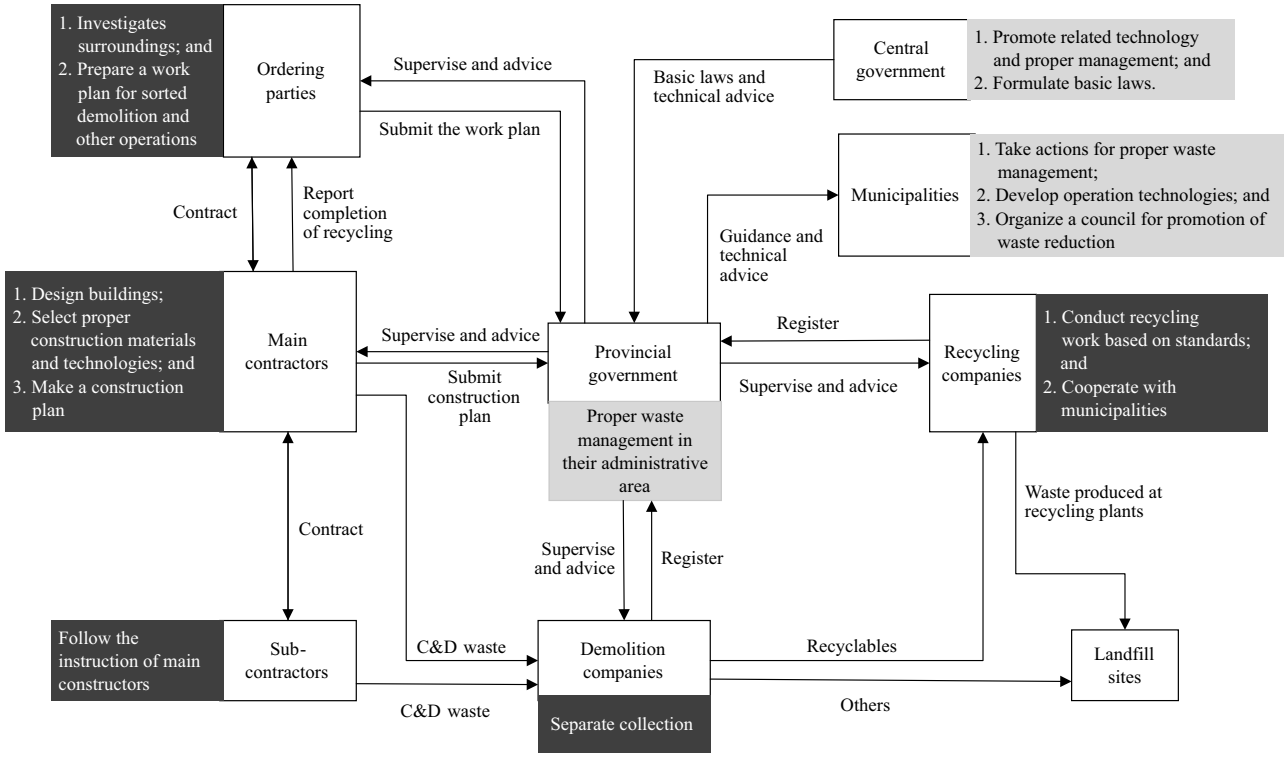

Figure 3. Responsibilities of related stakeholders in Japan (based on Ministry of the Environment, 2000b)

ties, ordering parties, main and sub-contractors, demolition and recycling companies, and landfill sites. Responsibilities of different stakeholders are well-defined. For instance, provincial government should formulate proper waste management and supervise relevant stakeholders to ensure their obedience. Demolition companies should conduct on-site sorting and deliver different classes of waste to their lawful disposal sites. Additionally, in South Korea, ordering parties can require contractors to use recycled building materials. Specifically, in Japan, South Korea, Germany, Austria, the United Kingdom, and Italy, legal regulations require contractors to consider the efficiency of demolition of materials and select appropriate technology when designing building. The primary duties of sub-contractors are to comply with the instructions of main contractors and undertake construction in a safe and eco-friendly manner. In Italy and Germany, the concept of product responsibility was introduced. This means that suppliers of building materials should use recycled building materials or recoverable waste and consider waste generation during production as well as subsequent use and recycling. Consumers are encouraged to protect, maintain, and extend the lifespan of buildings in Germany.

4.5. Lack of penalty for other stakeholders

There is a lack of penalty on other related stakeholders in recycling chain in national documents of China (Table 14). Appropriate use of penalties could be used to reinforce the obedience of related stakeholders and trigger an efficient recycling chain. In addition, combination of penalty and incentive mechanism is shown to be effective in reducing illegal dumping (Du et al., 2020). Governmental intervention is necessary to prevent occurrence of illegal behaviours. Japan, South Korea and Germany outline rules for violations by relevant stakeholders. For instance, the Waste Management and Public Cleansing Law (Ministry of the Environment, 1970) in Japan has been continuously updated over the past 40 years. Recycling enterprises that undertake recycling as a business without approval from the provincial government are subject to fines of up to 100,000 yen (or US $927). China can fill gaps in the law with standard clauses and terms.

4.6. Inefficient supervision system

Supervision is useful for evaluating the work performance (Nasution, 2017). It is important to ensure the enforcement of punishment mechanism and guarantee obedience of relevant stakeholders (Liu et al., 2019a, 2019b). Waste monitoring, tracing, and reporting are critical parts to ensure that waste disposal is compatible with public interests. Information of C&D waste production is a significant prerequisite to formulate an efficient waste management (Li et al., 2013). Currently, it is difficult to estimate the volume of C&D waste in China because of the unavailability of systematic data collection (Akhtar & Sarmah, 2018; Duan et al., 2015; Li et al., 2013; Lu et al., 2017). The availability of records for C&D waste makes it possible to estimate the annual waste production and prevent companies from conducting unlawful activities. China should collect validated records and enhance on-site inspection to calculate total volumes of C&D waste and trace the movement of waste. In order to better improve management efficiency, an electrical platform for data sharing could be developed. Contractors, collectors, recyclers, operators of landfill sites could login the system and record the waste dynamically. The platform could be accessible to all the related stakeholders.

5. Future research directions

A great collection of previous studies carried out investigations on critical challenges in C&D waste management in China. Despite the variety among different regions, the inefficient waste management practices in China can be attributed to limited recycling businesses and facilities (Akhtar & Sarmah, 2018), low landfill costs (Huang et al., 2018), uncontrolled dumping (Yuan, 2017), and an underdeveloped market for recycled products (Jin et al., 2017; Zhao et al., 2010). Increasing literatures addressed the problem of small-scale commercialization of recycled building materials, with special focus on the on-going improvement of product performance (Levy & Helene, 2004; Pernicova & Dobias, 2016; Tam et al., 2007; Yehia et al., 2015). Two problems identified in this article, i.e., inadequate guidance on recycling and incomplete knowledge of stakeholders' responsibilities, were not emphasized in previous studies. However, operable management strategies are solid foundations to implement recycling in practice. Guidelines on how to classify C&D waste could inform related stakeholders with standard process of following treatments and contribute to organized waste handling. As recycling of C&D waste is not mandatory and landfilling is preferable in China, role of other waste processors (such as recyclers) and their responsibilities are not considered in waste management. All levels should make efforts to manage waste or it could be difficult to achieve recycling goal. Future research efforts could be spent on these two problems.

In addition, this study only considers polices and laws at country level, while municipal regulations are not included. Although execution of national policies and laws are not detailed enough for operation in practice, few cities in China have started to recycle C&D waste, and restricted landfilling, including Shanghai, Shenzhen and Xuchang. As majority of Chinese cities heavily rely on landfilling, central government still needs to consume a large amount of time and efforts to promote recycling of C&D waste in cities. Besides, the comparison was focusing on the policies and laws, but not on how they are being executed in practice, for limited resources.

This study reviewed and compared national policy documents related to C&D waste management in China and seven selected countries, to help China learn experiences from other high-performance countries and improve the performance of C&D waste management. However,

not all the recommendations would be suitable to be applied in China, because of different waste quantity. Evaluation on advantages and disadvantages should be adopted through actual practices. According to Table 2, quantity of C&D waste reached 2100 million tonnes in 2018 in China, while the number is significantly lower in seven selected countries (86.4 million tonnes in Germany, 74.4 million tonnes in Japan, 68.7 million tonnes in United Kingdom, 66 million tonnes in South Korea, 41.3 million tonnes in Italy, 21.2 million tonnes in Netherlands, and 11.2 million tonnes in Austria). Large generated volume of C&D waste inevitably brings challenges in management. In addition, C&D waste management could be impacted by multiple factors, such as population, urbanization and economy (Aslam et al., 2020). There might exist some management deficiencies in construction sector, as China is a developing economy (Aslam et al., 2020). Therefore, the effectiveness of these recommendations in practice remains uncertain. Their practices could be evaluated in future studies.

Conclusions

China is the biggest generator of C&D waste. In the current age of enhanced environmental awareness, transformation to sustainable management in the construction sector is needed. Because of uneven development of C&D waste management around the world, there is possibility for China to learn from other high-performance countries. However, researches which compare documents related to C&D waste management among different countries are relatively insufficient, although case studies have been performed on specific countries.

This paper compared existing policies and laws concerning C&D waste management in China and seven selected countries with high performance in C&D waste management, i.e., Japan, South Korea, Germany, the United Kingdom, Austria, Italy and the Netherlands. It investigated current problems in Chinese C&D waste management, which could be concluded to: (a) inadequate guidance on recycling, (b) lack of market incentives in utilising recycled materials, (c) incomplete knowledge of stakeholders' responsibilities, (d) lack of penalty for other stakeholders, and (e) inefficient supervision system.

Large generation of C&D waste has become a global issue and receives increasing attentions from government and researchers. This study shows understanding of current problems in C&D waste management and could further help China and other developing countries who have similar problems to develop proper management policies, based on the experiences from other high-performance countries. Recommendations for improvement of C&D waste management in China were proposed. Since the contexts of the different countries differs from Chinese context, recommendations need to be assessed when formulating suitable C&D waste management. Excepting carrying out comparative analysis, this study also collected data about the amount and recovery rates of C&D waste in approximately 30 countries, and simultaneously listed existing policies and laws in different countries. For academia, this paper investigated each policy document in detail and presented a comprehensive overview of current C&D waste management in China and other high-performance countries, which could be a fundamental reference and provide solid background for researchers who are interested in related fields. In addition, promotion of C&D waste management requires governmental intervention (Bao & Lu, 2020). Findings of this study could be utilized by policy makers not only in China but also in other developing countries or regions to improve their related policies and therefore enhance the performance of C&D waste management.

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