A systematic literature review on Circular Economy implementation in the construction industry: a policy-making perspective

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ABSTRACT

Implementing Circular Economy (CE) is a promising solution to tackle environmental challenges in the construction industry. On the way towards a circular built environment, governmental policy support is viewed as an important enabler. However, most existing policies are insufficient to address complex CE challenges and there are substantial knowledge gaps in understanding CE policy-making from a systemic perspective in the construction industry. This literature review investigates construction CE based on the five-stage policy cycle developed in the domain of public policy. Our main finding is that there is a lack of integrated policy-making frameworks to manage construction projects based on CE. The five-stage-policy model is not widely recognized by scientific communities or industrial practitioners to understand CE policy-making as a dynamic, interactive, and iterative cycle. Therefore, we propose an integrated CE policy-making cycle based on the explicit alignment between the state-of-the-art and the classical policy model. Furthermore, the lack of policy integration is considered as one of the critical research gaps and we propose a bi-directional policy-making mechanism to conceptualize the integrated processes of policy implementation and evaluation. The proposed frameworks address current knowledge gaps and serve as theoretical guidelines for public and private actors to understand more complex CE policy-making in the reality. Finally, we encourage interdisciplinary research to enhance in-depth investigation of the potential of CE in the construction industry. This literature review investigates construction CE based on the five-stage policy cycle by 1) exploring the synergistic effect of CE policy packages on the construction life cycle, and 2) creating a streamlined, transparent, and collaborative policy-making environment based on Information & Communication Technologies.

1. Introduction

Being responsible for around half of the physical asset creation in the society, the construction industry is the principal force for the urban dynamics and changes in the built environment (Winch, 2010). It is closely related to urban development and economic growth but the traditional linear production model of this industry is too wasteful to maintain (Adams et al., 2017). The main negative environmental impacts caused by construction and demolition activities include land deterioration, resource depletion, waste generation, and various forms of pollution to nature (Brown et al., 1996). Annually, the natural resources consumed by the construction industry are between 1.2 and 1.8 million tons in Europe (IWF, 2015). In terms of its wasteful outputs at a global level, the overall construction waste generation in 40 countries reached more than 3.0 billion tons annually until 2012 and this trend has been increasing constantly (Akhtar & Sarma, 2018). Therefore, innovative solutions are in great demand to address the environmental challenges witnessed in this industry.

Circular Economy (CE) is regarded as a promising solution to harmonize economic growth and environmental protection. Although CE is a contested concept with various implications in different domains (Korhonen et al., 2018), it is generally defined as a sustainable initiative that entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system (EMF, 2015). Essentially, CE seeks a paradigmatic shift from linear to circular practices and generates economic, environmental, and social value through designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (EMF, 2015). Regarding the core principles incorporated within CE, various R frameworks have been used by scholars and practitioners for decades ranging from 3R to 10R (Kirchherr et al., 2017) and a critical discussion of different Rs in a 10R framework is provided by Reike et al. (2018). Particularly, the 3R...
(Reduce-Reuse-Recycle) framework is recognized as the most fundamental and inclusive CE principle (Brennan et al., 2015; Ghisellini et al., 2016). It is at the core of CE promotion law 2009 in China (National People’s Congress, 2008) and also serves as the foundation of the Waste Framework Directive in the European Union (EU) with an added dimension of ‘Recover’ (European Commission, 2008a).

In practice, CE can also be operationalized through three product design and business model strategies. Two fundamental strategies are (1) slowing the loop through the design of long-life goods and product-life extension, the utilization period of the product is extended, and (2) closing the loop through recycling, the loop between post-use and production is closed, while the third focuses on (3) narrowing the loop using fewer resources per product (Bocken et al., 2016). The 3R framework contributes to the realization of these strategies as a guideline at different production levels (Kirchherr et al., 2017). Therefore, we consider the core principles of CE as the combination of the activity framework (Reduce-Reuse-Recycle) and the strategy framework (slowing, closing, and narrowing the loop) in this research.

In parallel, CE can also be seen as a useful approach to achieving local, national, and global sustainability (Rodriguez-Anton et al., 2019). As stated in the EU action plan for CE: “This action plan will be instrumental in reaching the Sustainable Development Goals (SDGs) by 2030, in particular, Goal 12 of ensuring sustainable consumption and production patterns.” (European European Commission, 2015). The relationships between CE and SDGs exist inherently in their policy definitions. Several studies investigated the extent to which CE practices are relevant for the implementation of SDGs and identified which SDGs have significant relationships with the concept of CE (Scheroder et al., 2019; Rodriguez-Anton et al., 2019). Since CE is closely related to sustainable development, it gains weight as a prominent part of the national policy agenda aiming to substitute the make-use-disposal paradigm across different industries (European Commission, 2011a).

Particularly, the construction industry attracts significant attention from the government because of its high resource intensity and waste pollution. However, the CE implementation in this industry is still hindered by various barriers and challenges (Adams et al., 2017; Ghisellini et al., 2018). Current literature recognizes that CE implementation in the built environment is an interlinked challenge that relates to both public and private stakeholders (Pomponi & Moncaster, 2017; Ruiz et al., 2020). Not only should the industrial actors strive for a circular future by revising their business models, behavioral patterns, and expectations from products, but also the government needs to actively provide regulatory guidance to align the strategic agendas of public authorities and industrial actors (Adams et al., 2017; Ghisellini et al., 2018; Schraven et al., 2019; Heurkens & Dabrowski, 2020). The regulatory guidance here covers a broad range of policies, regulations, ordinances, and initiatives introduced by local or national governments.

Legal enforcement is recognized as a focal driver towards CE transition because policies shape the top-down momentum to accelerate and scale up CE activities (Lieder & Rashid, 2016). However, there is limited understanding of CE policy-making given the unique characteristics of the construction industry. Whereas industrial actors wait for effective and tangible policy support, policymakers still puzzle on how exactly CE policies should be developed and implemented in this industry. The construction industry has its own culture and characteristics (Winch, 2010). First, most buildings are complex and one-off products built upon dynamic and interrelated material flows spanning huge differences in scales and lifecycles (Klomp & Le Maitre, 2017). Second, the construction value chain is fragmented and highly affected by inefficient collaborations with various stakeholders who share neither a common “language” (Adriaanse et al. 2010) nor a mutual vision (Vrijhoef 2011).

Since construction products are inherently different from other short-life products produced in a more streamlined environment, it is challenging to gravitate the construction industry towards CE via regular policy instruments. In fact, the current regulatory guideline has fallen short of providing clear rules for implementing CE goals and mismatches exist among official policies, regulatory frameworks, and industrial business practices on the way towards a circular built environment (Ghaffa et al., 2020; Heurkens & Dabrowski, 2020).

To tackle the CE policy-making challenge in this sector, we first need to understand the basic policy-making processes holistically. Public policies are government statements designed to achieve defined goals and present solutions to societal problems (Newton & Deth, 2005). To better conceptualize and evaluate diverse policy approaches, Harold Lasswell (1956) first raised the idea of modeling the policy process in terms of stages. During the 1960s and 1970s, the stage model served as a baseline to organize and systemize a growing body of literature and research with different variants of the stage typologies (Anderson, 1975; May & Wildavsky, 1978; Jenkins, 1978; Brewer & deLeon, 1983). Nowadays, the classic policy model has developed into the most widely applied policy-making cycle with five major stages, namely, (1) agenda-setting, (2) policy formulation, (3) policy decision-making, (4) policy implementation, and (5) policy evaluation. Although it is a simplified and ideal-type model of the policy-making processes, this model emphasizes the interconnections and feedback loops between different policy-making elements from a cyclical perspective (Fischer et al., 2007). Therefore, the policy cycle provides a useful heuristic for breaking the entire policy-making system into limited components to structure the realistic policy-making processes (Knill & Tosun, 2008).

However, to the best of our knowledge, no study investigated construction CE implementation from an integrated policy cycle perspective. Little is known about the underlying mechanism of how policies reform construction and demolition practices towards CE through the policy cycle. The existing literature reviews of policy-making for sustainable construction mainly focused on conventional Construction & Demolition Waste (CDW) management without considering the broader landscape of CE (Lu & Tam, 2013; Zutshi & Creed, 2015; Umar et al., 2017; Ghisellini et al., 2018). Others emphasized the general CE policy-making at a national level (Sakai et al., 2011; Xia, 2016; Cui & Zhang, 2018; Milios, 2018), but left the peculiarities of construction products and markets in an interrelated set of policies unapprised. To this end, a comprehensive literature review on how public policy supports construction CE transition is missing. Exploring this topic helps (1) governmental actors to understand the vital processes of translating high-level policies into tangible industrial actions in order to accelerate and scale up CE implementation, and (2) industrial actors to recognize the entire policy cycle so that they can better position themselves within the interactions with the governmental actors. We argue that the five-stage policy cycle can serve as a valuable framework to conceptualize the CE policy-making processes in the built environment. Therefore, we conduct a systematic literature review on construction CE policy-making based on the five-stage policy cycle. Specifically, the research objectives are threefold:

- To make explicit alignment between the five-stage policy cycle and the state-of-the-art of CE policy-making in the construction sector;
- To propose an integrated CE policy-making framework as a guideline for public and private actors on how to implement CE in this sector;
- To identify the current challenges and limitations of CE policy-making for this sector and provide recommendations for future research directions.

The rest of the article is structured as follows: the next section presents the review methodology. In Section 3, we classify the state-of-the-art based on the policy cycle model and develop an integrated CE policy-making cycle. In Section 4, we identify research gaps and emerging topics, and propose future research directions. Finally, conclusions are provided in Section 5.

2. Methodology

A systematic literature review provides a comprehensive overview of
the existing scientific evidence concerning a specific research domain (Kitchenham & Charters, 2007). It helps to identify, evaluate, and interpret available studies regarding the topic of interest (Kitchenham & Charters, 2007), and guides new research directions based on the defined knowledge gaps (Tranfield, 2003). We conducted a systematic literature review in April 2021 by retrieving and analyzing the relevant academic papers from the Web of Science (WoS). WoS is regarded as one of the high-quality bibliometric data sources for academic research (Archambault et al., 2009). It was the only systematic publication source of evidence-driven decision support for funders and governments until 2004 when Scopus was introduced (Guerrero-Bote et al., 2021). There are no clear criteria for ranking these two databases but the fundamental difference in these two indexing bodies is: WoS (based on Eugene Garfield’s concepts) covers a selective set of most frequently used or cited journals, while Scopus (with broad coverage) is more similar to large disciplinary literature databases (López-Illéscas et al., 2008). To provide a replicable review process with the legitimacy and authority of the resultant evidence, the reviewing procedures proposed by Kitchenham & Brereton (2013) were applied.

For an extensive analysis of literature, the search scope should be properly defined. However, it is challenging to define the scope of this study because (1) CE is a new rising topic in the construction industry, and (2) CE covers extensive but scattered implications in diverse disciplinary fields. To overcome this challenge, the standard manual searching protocol was supported by additional citation analysis. This is a process to improve the comprehensiveness of the review by capturing any missing documentation based on the references of the selected papers, which is also known as the backward snowballing technique (Kitchenham & Charters, 2007). In summary, the overall workflow is graphically demonstrated in Fig. 1.

First, keyword combinations were developed based on the existing literature. CE is an essentially contested concept and numerous definitions were given by scholars from different fields (Geissdoerfer et al., 2017; Korhonen et al., 2018). The core of CE is generally perceived as a sustainable vision of realizing a circular or closed-loop structure of materials and energy consumption in the whole economic system, based on but not limited to the conventional waste management practices (Yuan et al., 2006; Geng & Doberstein, 2008). Therefore, the keywords

![Fig. 1. Methodology of systematic literature review](image-url)
encompassing the CE implementation were proposed as “Circular economy”, “Cradle to cradle”, “Closed-loop”, “Industrial ecology”, “Regenerative design”, “Green supply chain” and “Cleaner production” (EMF, 2015; Kirchherr et al., 2017). Besides, the CE implementation for the construction industry has a deep bond with CDW management (Adams et al., 2017; Ghisellini et al., 2018). Therefore, “Construction & demolition waste management” was added to the searching string to ensure a significant result. As for the policy, the following keywords were used, namely “Polic*”, “Government”, “Regulation*”, “Legal*”, “Subsid*” and “Tax*”. Finally, “Construction”, “Demolition” and “Built environment” were applied to remain the focus within the construction industry.

We collected peer-reviewed journal papers and conference proceedings published during 2010 – 2021. The year 2010 was selected as a starting point because (1) a growing interest of the scientific community in the CE implementation was witnessed in the construction industry over the past decade (Munaro et al., 2020; Hossain, et al., 2020), and (2) the concept of CE was consistently adopted by policymakers as a prominent part of national development strategy in the past decade through the Waste Framework Directive (2008/98/EC) (European Commission, 2008a), the “flagship” initiative for a resource-efficient Europe in 2011 (European Commission, 2011b), and the CE promotion Law launched in the Chinese national-level framework in 2009 (National People’s Congress, 2009). In the preliminary search, 521 out of 659 papers were filtered based on the inquiry strings with inclusion criteria of peer-reviewed articles and conference papers written in English between 2010 to 2021. Then, the first-round selection process was conducted to examine the literature relevance by screen-scanning titles and keywords, which resulted in 246 candidate papers.

The following inclusion criteria to further filter the articles were applied: 1) the documents contain the information about governmental policies proposed for CE implementation in the construction industry, 2) the studies that are associated with one or more policy-making processes covering agenda-setting, formulation, decision-making, implementation, and evaluation, and 3) the full-text of the document is available. The focus was placed on the studies that provide relevant information of policy-making processes and consider explicitly the core principles of CE. Otherwise, we considered that we could not retrieve sufficient evidence from the literature regarding how a particular policy can be formulated and carried out, and in which way it is associated with the concept of CE. Therefore, the following exclusion criteria were applied: 1) the studies only mention the importance of CE policy support as a suggestion without elaborating its role in the agenda-setting nor the potential of formulation, decision-making, and/or implementation, or 2) the studies only investigate down-cycle practices of sustainable CDW management with limited environmental or economic implications. This led to a shortlist of 40 papers. To further improve the completeness of the selected literature, a first-degree backward citation analysis was conducted. Another 9 articles meeting the inclusion criteria were added to the shortlist, which brought the final result of 49 papers (Appendix: Table 2. List of collected papers).

The selected papers were analyzed according to the Qualitative Text Analysis method proposed by Kuckartz (2014). We applied the following steps to conduct thematic text analysis: 1) highlight critical information of CE policy-making in the paper based on the keywords of policy-making processes, 2) develop main topical categories based on the five-stage policy cycle, 3) summarize the relevant statements and findings according to the categories, 4) analyze information and improve the categories iteratively, and 5) present the results. In particular, we identified the potential connections between the-state-of-the art and the five-stage policy cycle by mapping the main content of literature with each stage of the policy cycle. The intermediate mapping results can be found in supplementary materials. Based on the literature analysis, we conceptualized an integrated CE policy-making cycle in the construction industry and proposed future research directions.
3. Results

In this section, we first analyze the state-of-the-art of CE policymaking in the construction industry by understanding in which way it is aligned with the five-stage policy cycle. Then, we develop an integrated CE policy-making framework to outline the state-of-the-art based on the literature analysis.

3.1. State-of-the-art

The literature analysis starts by mapping the main literature content with the different stages of the policy cycle in Table 1. The numbers allocated to each cell indicate the number of studies that fall under a certain category. Some studies match more than one category, therefore, every matched cell is counted. The definition of each policy-making process provided by Howlett & Ramesh (1995) is listed below:

- **Agenda-setting**: the initial stage where a problem/challenge that impacts the public is identified;
- **Policy formulation**: the stage that involves the development of policy options by narrowing the range of possible policy alternatives;
- **Policy decision-making**: the stage where government leaders decide on a particular course of action that ideally will best address the problem for the most members of the public;
- **Policy implementation**: the stage where governments put the chosen public policy option into effect;
- **Policy evaluation**: the stage where interested parties both within and without the government monitor the impact of the policy and determine if it is achieving the intended objectives.

Aligning the collected literature with the policy cycle based on the original definition of five stages is hindered given that (1) most studies are conducted without considering this cycle, (2) the review scope is confined within the scientific publications instead of focusing on the policy documents in different regions, and (3) the policy implementation generally requires a long-term perspective to become apparent. The literature provides limited “internal” information regarding how the governments make decisions, while scientific outputs come mostly in the form of “external” theoretical justifications supporting policy decision-making. In this regard, we tailor the definition of each policy stage in order to position the state-of-the-art in the five-stage policy cycle as follows:

- The vital role of CE in policy agenda-setting: the studies showing how environmental challenges of the built environment comes to the attention of governments and how CE policy proposals are developed;
- Alternatives in policy formulation: the studies researching various types of policy alternatives or recommendations that can be valuable to support CE transition in the built environment;
- Methodologies for policy decision-making: the studies developing predictive analysis methods in order to support policymakers when selecting and filtering a particular set of policies based on historical experience, and on the predictive assessment of their effects;
- Evidence collected from policy implementation: the studies showing how CE policies are carried out by the governments in different forms, and providing implementation evidence that is collected through policy execution plans indicating what policies take effect;
- Knowledge basis for policy evaluation: the studies developing scientific quantification methods as the knowledge basis for the monitoring and assessment of policy performance.

First, we observe that the vital role of policy support is well-recognized in CE transition at the stage of agenda-setting. Then,
multiple policy alternatives are provided to support CE implementation from different perspectives at the policy formulation stage. Starting from the third stage of policy decision-making, the literature category deviates from the original policy cycle to different extents. Instead of describing the actual decision-making process of how a policy alternative would be determined by policymakers as the final solution, the literature provides predictive analysis methods to facilitate such a process. In terms of policy implementation, policies that can potentially contribute to CE transition were conducted in various forms by public organizations at different levels. Although the collected studies do not show the entire policy cycle of CE policies due to the relative short-term implementation period, they indeed provide evidence indicating that most existing policies are insufficient to address complex CE challenges. Lastly, scholars propose novel approaches that can support policy evaluation by quantifying the environmental and economic impacts brought by CE activities in different scenarios. These studies can be regarded as the knowledge basis for policy evaluation though the corresponding interpretations are often derived from quantitative modeling results.

The proposed literature classification serves as a coherent baseline to understand the state-of-the-art of CE policy-making in the construction industry from a theoretical lens. Table 1 shows a diagonal mapping pattern between literature contents and policy cycle stages. On the one hand, the collected studies analyze CE policy-making in the construction sector from different perspectives. On the other hand, the pattern also indicates that there is a lack of comprehensive understanding of the CE policy-making cycle. Most studies only investigate CE policy-making from one particular perspective without considering the potential connections between different policy stages in a broader operational context of the entire policy cycle. In the following paragraphs, the main topics investigated by the collected studies are summarized.

3.1.1. The vital role of CE in policy agenda-setting

According to the literature, the CE challenges in the construction industry attracted the government’s attention from the stage of policy agenda-setting. A comparative study was conducted to analyze the policies for CDW management in China and the EU, and underscored the important role of punitive measures and preferential policies in sustainable CDW management (Hao et al., 2020). Mahpour (2018) prioritized the barriers to adapting CE in CDW management and pointed out that current policies and legal frameworks were inadequate to manage CDW in a circular way. Defined by Karhu & Linkola et al. (2019), efficient policy instruments and legislation support are imperative targets that must be adopted to realize CE. Meanwhile, the lack of effective regulatory frameworks to support CE transition is actually defined as a critical challenge associated with CE policy-making. Bilal et al. (2020) identified that a lack of environmental regulations and laws was driving the rest of the barriers to a CE in this industry. To understand the role of local governments in the CE transition, Bolger & Doyon (2019) conducted a comparative case study and explored the opportunities and barriers to applying CE principles through governmental strategic planning. Another study revealed that the lack of institutional collaboration and immature strategic policies for effective CDW recovery are the two major issues that hindered CE based on an assessment of CDW generation, regulation, and management policies (Blaisi, 2019).

To present a global overview of CE initiatives, policies, and regulations proposed in the construction industry, we developed Fig. 2 based on the collected information regarding CE policy agenda-setting. In this figure, the color of each location circle is loosely associated with the level of development of CE policies. In general, the deeper the color, the more traceable history of CE policies is observed. This result is limited to the information presented in the collected papers and may not capture all the policy details of each region. However, it shows that CE is globally gaining momentum as a prominent part of national development strategies. Particularly, the EU area has a higher density of CE policy initiatives compared to other areas. This could be the result of the fact that most EU member states adopted CE guidelines proposed by the European Commission and tailored CE strategies according to their own situations while other countries need to innovate CE with little cross-border collaboration. Although construction CE is implemented to different extents in different regions due to diverse social, political, and technical factors, each CE initiative generally contains the specific targets and timelines for achieving CE milestones spanning five to ten years.

However, it is rather unclear to what extent each country has implemented CE by only referring to the governmental agenda reports mentioned in the articles. The CDW recovery rates of EU member states increased in the past decade and 19 out of 30 counties (where data is available) have reached more than 90% (Eurostat, 2022). It is not completely clear to what extent the CE was implemented as this indicator is defined as follows: “the ratio of CDW which is prepared for re-use, recycled or subject to material recovery, including through backfilling operations, divided by the construction and demolition waste treated as defined in Regulation (EC) No. 2150/2002 on waste statistics” (Eurostat, 2022).

Backfilling operations do not efficiently help to maintain material value to the greatest extent, thus, they can only be regarded as a down-cycling indicator that does not stimulate high-quality CE implementation (Di Maria et al., 2018).

It remains a puzzle whether more CE proposals observed in policy agenda-setting actually lead to a higher level of CE implementation. What can at least be concluded here is that there could be a mismatch between policy agenda-setting and policy implementation. More information about policy implementation is provided in Section 3.1.4. Evidence collected from policy implementation. Still, this figure shows an increasing global awareness of CE implementation, and continuous pressure of implementing CE is allocated to the built environment by government bodies. Besides, non-EU countries have diverse national strategies for CE but the regulatory frameworks in the construction sector are mainly associated with CDW management at the End of Life (EoL) phase.

In summary, although the vital role of policy support in CE transition is recognized globally, there is a lack of effective policy frameworks to manage and supervise construction projects according to CE principles. The conventional CDW management policy has profound impacts on the modern CE policy in terms of establishing a regulatory foundation to deal with CDW by applying reusing and recycling principles (See supplementary materials for the analysis of keywords co-occurrence). Evolving from the previous CDW management policies, the recent CE policy initiatives shift the emphasis towards waste prevention strategies and cross-disciplinary collaborations, which indicates that policymakers and industrial actors aim to provide more efficient and advanced measures to achieve CE.

3.1.2. Alternatives in policy formulation

The literature provides various alternatives to support policy formulation. Gálvez-Martos et al. (2018) synthesized core CE principles and linked best practices for CDW management across the construction value chain to support policy-making. The practical cases of CDW policies and management in China were analyzed based on 3R principles of CE and various policy strategies were provided (Huang et al., 2018). (Campbell-Johnston et al. (2019) showed that public procurement, zoning laws, capacity building, and knowledge exchange can be applied to the construction sector to support CE. Similarly, Ghaffar et al. (2020) indicated that the legislation proposed by the government regulating the reuse and recycling thresholds for new project procurement can substantially improve construction circularity. Heurkens & Dabrowski (2020) identified and classified barriers to CE transition and provided recommendations to tackle the multi-disciplinary CE challenges, including enhancing regional spatial-economic coordination policies among different governmental levels and key actors.

Apart from general CE policy strategies, the economic policy interventions were discussed in detail as an effective CE measurement.
Nussholz et al. (2019) suggested that public policies can help companies to remove CE barriers by incorporating higher recovery goals and incentivizing the recovery market. Rodriguez et al. (2015) pointed out that the role of government support is mainly confined to regulating CDW recycling by establishing legislative frameworks with insufficient economic penalties or incentives involved. Moreover, the policies that provide long-term and reliable financial support should be promoted in compliance with CE principles to incentivize stakeholders who are innovating for CE (Gorecki et al., 2019; Ghaffar et al., 2020).

The reusing and recycling processes require careful management to ensure the quality of recovered CDW. Quaranta et al. (2010) presented a step-wise schema was presented for the safe recycling management of CDW containing hazardous or toxic substances as the first step to proposing proper EoL norms. Next, Rodriguez-Robles et al. (2014) presented reuse options and recommendations for concrete manufacturing for recycled aggregates by conducting physic-mechanical tests to validate the reusability of concrete waste according to Spanish standards. Behera et al. (2014) analyzed important features of recycled concrete aggregates as an alternative input for concrete production and summarized several suggestions to improve mechanical and durability performance, which can potentially contribute to the formulation of quality standards. Duan et al. (2016) urged the development of the proper CDW management policies with a priority of proposing a classification system to filter out harmful materials for more extensive processing.

In summary, five types of CE policy interventions were identified in the literature: (1) subsidizing policies for sustainable CDW management practices, such as innovating waste recycling technologies and purchasing recycling equipment, (2) taxing policies for unsustainable CDW management practices, such as charging waste dumping and raising taxes for virgin resource consumption, (3) operational guidance and regulations for sustainable CDW management, for instance, regulatory frameworks for on-site waste sorting and EoL waste management, (4) technical assessment schemas and standards for secondary materials, for example, the concentration standards for recycled concrete aggregates containing hazardous substances, to realize a non-toxic and circular material value chain, and (5) waste prevention and minimization suggestions were provided to cut down waste generation, such as circular design strategies and green procurement criteria.

3.1.3. Methodologies for policy decision-making

In the stage of policy decision-making, the decision is made to select the policy which is subsequently implemented in practice. The literature provides predictive analysis methods that can potentially facilitate policymakers with policy decision-making. Many studies conducted quantitative simulation analysis to estimate the potential policy effects. Yan (2015) developed a system dynamic simulation model to evaluate the dynamics of project-based competition for sustainable construction market development under different project awarding systems. Yuan et al. (2012) applied a similar method to simulate the effects of management strategies on CDW reduction while Calvo et al. (2014) used it to evaluate the impacts of economic incentives and tax penalties on the behavior changing of firms in the CDW recycling system. Besides, an optimization model was developed to assess the economic, technical, and environmental performance of a CDW supply chain under potential policy interventions (Hiete et al., 2011). Moreover, a stochastic simulation model was developed to optimize economic benefits to provide more incentive for material recycling with uncertain waste qualities under different environmental regulations (Trochü, et al., 2020).

The dynamic evolutionary game model was applied to investigate the effect of the government’s reward-penalty mechanism on the decision-making process of production and recycling actors in the CDW supply chain (Long, et al., 2020). A similar approach was applied to analyze the symbiotic evolution between construction and recycling actors in the situation with or without government incentives (Ma & Zhang, 2020). Su et al. (2020) developed an evolutionary game model to analyze the change of high-level strategies for governments, contractors, and recyclers in the sustainable CDW market. Besides, a mixed-integer nonlinear programming model was developed to optimize the economic performance of a CDW closed-loop supply chain under carbon policy scenarios (Shi et al., 2020). Some studies also considered the dynamic interactions among actors. A model integrated regional material flow modeling with stakeholders, policy measures, their impacts, and mutual interactions, to provide a predictive assessment of potential policy effects (Volk et al., 2019). In addition, an iterative algorithmic method with fuzzy random variables was proposed to balance the requirements of public and private stakeholders in the construction industry (Zhang et al., 2017). Furthermore, agent-based simulation was applied to explore how the change of attitudes and the dynamic interaction among actors can influence CDW management with the government agent playing a leading role by conducting policies, laws, and regulations (Ding et al., 2016). Finally, a qualitative framework was developed to facilitate local government with the selection of appropriate CDW policy instruments (Li et al., 2020a).

In summary, simulation models were developed to understand the potential effects of economic policy interventions through scenario analysis considering stakeholder behaviors or dynamic market situations. Under different policy scenarios, most models revealed policy effects on the dynamic interactions of heterogeneous stakeholders, and others predictively quantified future material flows. These studies provided predictive indications for alternative policy options and can potentially support policy decision-making. However, existing models are not comparable due to different system boundaries, assumptions, and data sources, and often focus on one particular material with limited stakeholders (Calvo et al., 2014; Su et al., 2020). More practical data is needed to validate how the simulated policies would take effect and diffuse through different organizational levels in the long term (Yan et al., 2015; Volk et al., 2019).

3.1.4. Evidence collected from policy implementation

In this section, we summarize the evidence collected from policy implementation to understand what policy instruments take effect and what challenges are identified through the implementation process. First, Bao & Lu (2020) pointed out that strong governmental interventions combing penalties and subsidies is an important factor contributing to successful CE implementation in China. Ma et al. (2020) identified several challenges for sustainable CDW management after investigating recycling plants in China, namely, unstable sources of CDW for recycling & reusing, absence of subsidies for sustainable business activities, and insufficient attention paid to design for waste minimization. Besides, Yeheyis et al. (2013) provided an overview of legislative regulations and codes implemented for sustainable CDW management in Canada and revealed the lack of enforcement mechanisms related to 3R regulations. Another study by Arm et al. (2017) investigated waste recovery targets implemented in Nordic countries and indicated factors such as the unclear definition of waste and lack of data standardization as the reasons why recovery target was not proposed properly in the EU Waste Framework Directive.

The Construction Waste Disposal Charging Scheme (CWDSC) implemented by the Hong Kong government in 2005 was one of the policies that attracted long-term investigations. Several studies examined the effectiveness of this scheme together with other CDW policies on the way towards a circular built environment. Lu & Tam (2013) proposed two lessons derived from Hong Kong’s experience in implementing CWDSC policies, namely, forming interventions system and launching educational campaigns for sustainable development to increase the awareness of citizens about sustainable policies. Besides, local feedback indicated improving environmental performance as the least important project requirement for construction projects in Hong Kong, and the lack of effective waste management methods incorporating 3R principles as the major barrier encountered by actors (Tam et al., 2012). Poon et al. (2013) explored the perceptions of construction practitioners towards CWDCS after three years of implementation and found that the
policy only led to less than 5% CDW reduction, and the costs of CWDCS were not high enough to raise industrial awareness about sustainable CDW management.

Apart from the academic literature, we also noticed the CE momentum generated by the recent development of EU policies in the form of Green Public Procurement (GPP). Specifically, GPP is defined as "A process whereby public authorities seek to procure goods, services, and works with a reduced environmental impact throughout their life cycle when compared to those with the same primary function that would otherwise be procured" (European Commission, 2008a). Alhola et al. (2019) identified four areas where circular procurement can potentially occur in the construction sector through case studies, namely, the procurement of better-quality products in circular terms, the procurement of new circular products, the use of business concepts that support the CE, and investments in circular ecosystems. Also, the European Commission promoted GPP through the use of life cycle assessment, circular economy principles, and sustainable innovation approaches in Europe since 2010. By setting "greener" criteria and requirements for the extension of product life spans and efficiency of material consumption, successful case studies were observed with valuable lessons learned (European Commission, 2021). For instance, practices with a circular building in Brussels showed that the evaluation approach of circularity and sustainability must be integrated into the holistic design of a project and not regarded as a stand-alone criterion (Government of Flanders, 2021).

In summary, experiences of CE policy implementation were rather limited because it generally takes time and continuing policy enforcement to reveal the long-term effect of CE policies. On the one hand, most studies identified challenges and enablers of CE policy implementation and found that existing policies mostly cover waste-centric regulations dealing with the generated waste. They could be insufficient to address complex CE challenges because ‘prevention’ is prioritized as the most favored option in the waste hierarchy pyramid based on CE principles (European Commission, 2008a). On the other hand, valuable lessons were learned from GPP practices through European case studies because modern circular policies are mostly at their incipient stages except for circular procurement practices which immediately take effect when the new project is initiated. Notably, the experience and evidence were limited to specific construction projects because every project was unique regarding its life-cycle complex and material composition.

3.1.5. Knowledge basis for policy evaluation

To realize CE in the construction industry, evaluating policy measures can be challenging because (1) there is a lack of standardization and tools to evaluate policy performance on construction projects (Filho et al., 2020), and (2) policy-making often involves multicriteria trade-offs on environmental, economic, and social aspects (Fischer et al., 2007). Therefore, solid scientific evidence should be provided to ensure comprehensive and informative policy evaluation. Economic viability analysis of the CDW recycling plant was conducted and showed that CDW recycling practices can be profitable even without government policy intervention and the methodology can potentially support the evaluation of economic policy instruments (Coelho & De Brito, 2013). To promote CE, Di Maria et al. (2018) combined Life Cycle Assessment (LCA) with Life Cycle Costing (LCC) to evaluate alternative CDW End-of-Life scenarios in Belgium and highlighted environmental and economic enablers in CDW management. Similarly, Liu et al. (2020) analyzed the environmental and economic drivers of recycling CDW under three waste disposal scenarios in China and evaluated low-carbon policies. Ram et al. (2020) quantified the environmental impacts of recycling CDW debris to support sustainable CDW management. Verhagen et al. (2021) provided an empirical method to quantify CDW that can be re-promoted as secondary materials, which supported the decision-making of new CDW policies. Other studies developed various quantification methods to estimate CDW flows and stocks under different policy scenarios to provide an informative representation of recoverable material flows, which can be taken as a predictive knowledge basis for policy evaluation (Ortlepp et al., 2016; Stephan & Athanasiadis, 2018; Arora et al., 2020).

Based on the assessment from various aspects, environmental indicators were proposed as a managerial tool for the public sector to link the statistical results with policy evaluation. A literature review of environmental impact indicators for adaptive reuse of cultural heritage buildings from a CE perspective was conducted and it encouraged the improvement of the CE indicator system (Foster & Kreinin, 2020). Paschoal Filho et al. (2020) proposed a list of environmental indicators for CDW management practices assessment to verify the
adhesion of practical routines to environmental laws, technical standards, and green building certification systems recommendations. Furthermore, exploratory data analytics and data envelopment analysis were proposed to evaluate the performance of CDW management policies, which addressed the limitations of the poor quality of metrics, data, and parametric indicators (Taboada et al., 2020).

To summarize, LCA and LCC results showed that the combination of environmental and economic analysis can improve the understanding of the CE problem to be analyzed, which can potentially support policy evaluation though time factors may introduce uncertainties to the results (Di Maria et al., 2018; Liu et al., 2020). It is also consistent with the analysis of keywords co-occurrence (See supplementary materials). This finding echoes the suggestions raised by Ghisellini et al. (2018b) that stronger integration of economic and environmental evaluation instruments should be realized to support sustainable policy-making, in order to overcome regulatory, know-how, and business barriers to a CE. Also, the quantitative estimation of CDW flows can be regarded as a knowledge basis for policy evaluation though more reliable databases of material flows are required (Ottepp et al., 2016; Stephan & Athanassiadou, 2018). The CE indicators proposed from different perspectives enhanced the evaluation of policy effects and created room for continuous adjustment and improvement of policy objectives and interventions. However, the literature provides limited information on how exactly the evaluation would lead to the re-conceptualization of the existing policies based on the combination of quantitative modeling results and qualitative evidence observed from actual policy implementation.

3.2. Integrated CE policy-making cycle

According to the literature discussed above, we develop a stage-wise overview of construction CE policy-making in Fig. 3. It summarizes the state-of-the-art in a stage-wise manner, shows the potential interconnections among different policy-making processes, and reveals the iterative nature of policy-making. As mentioned in the previous section, most information and evidence related to CE policy implementation in the built environment are limited to agenda-setting and policy formulation. Although there is adequate policy implementation evidence regarding CDW management, those policies are mostly restricted to reusing and recycling practices by economic stimulus and failed to achieve a systematic CE transition considering the complex CE landscape. Currently, the three major functions of CE policies formulated in the construction industry are identified based on the literature: (1) providing long-term reliable financial support to motivate circular behaviors and nourish circular business collaborations, (2) applying economic instruments to coordinate the secondary market by regulating the supply and demand dynamics of secondary materials, and (3) proposing assessment standards to ensure qualities of recovered materials. The CE policies aiming at waste reduction/minimization remain at the formulation stage where various theoretical options are proposed with little evidence outside the lessons learned from GPP. In short, CE policy-making for the construction sector is currently at an incipient stage.

Fig. 3 also shows that Information and Communication Technologies (ICT) play a vital role in policy decision-making and evaluation. At these two stages, various ICT solutions are applied to facilitate complex policy-making tasks. For instance, the scenario analysis based on simulation techniques creates opportunities to test hypothetical solutions under future scenarios. By building, testing, and evaluating such a simulation model, predictive knowledge can be obtained regarding actual implementation to a certain extent (Yuan et al., 2012; Calvo et al., 2014). Besides, LCA and other mathematical quantification methods present a comprehensive evaluation of the policy effect on the material and monetary flows (Di Maria et al., 2018; Liu et al., 2020). The mainstream research on applying ICT to support policy-making found in the literature is policy scenario simulation. With the development of simulation techniques, policymakers can carry out complex scenario analyses of potential policy options based on improved computational capacity and flexibility. Through the robust quantitative policy analysis, critical factors that influence policy implementation can be identified and underlying connections of different factors are revealed, which substantially support policy evaluation. The predictive policy assessment is particularly important because of the dynamic and extensive life spans of construction projects.

From a technological perspective, the continued development and adoption of ICT are vital to capturing local feedback and integrating policy-making processes. As pointed out by Pardo et al. (2011), new ICT solutions can make the public sector more accessible, not only through the provision of information or public services online but also as a result of developed communication systems and advanced interoperability among different organizations. However, the ICT applications (mainly simulation models) reviewed in the literature rarely guide the integration and optimization of entire policy-making processes with multi-stakeholder communication functions. On the one hand, most models have limited system boundaries (Calvo et al., 2014; Su et al., 2020) and the practical data is limited on how the simulated policies would take effect and diffuse in the long term (Yan et al., 2015; Volk et al., 2019). On the other hand, the literature provides insufficient information about how to organize and structure the combination of quantitative modeling results with qualitative stakeholder feedback as the input that may lead to the re-conceptualization of the existing policy. Therefore, we argue that the integrated CE policy-making cycle is not yet realized in the construction industry. More interdisciplinary research is required to streamline the top-down policy translation and bottom-up policy evaluation based on more diverse ICT solutions.

One principal disadvantage of Fig. 3 is that it may oversimplify the policy-making processes. It should not be misinterpreted as suggesting that all the policy-making processes are executed in a systematic linear fashion because this is not the case in the reality where more complexities are underlined. This also reflects another critical challenge of current CE policy-making: linearization assumptions and simplifications were often applied to guide the complex decision-making and ensure the model tractability, which overlooked the iterative and complex nature of the policy-making. Therefore, studies failed to tailor policy measures for regions with different economic, technological, and social conditions. Limited research evidence was collected from the literature regarding how proposed policies would take effect and diffuse on a realistic scale with dynamic and real-time performance feedback. In other words, the interconnections between top-down policy implementation and bottom-up policy evaluation are not always explicitly shown in the literature.

4. Discussion

In this section, we discuss and evaluate the results of the systematic literature review from three perspectives. First, we identify research gaps and emerging topics. Second, we propose a conceptual framework of a bi-directional policy-making mechanism to exemplify the way how a policy cycle would function through different organizational levels. Third, recommendations for future research are provided.

4.1. Research gaps & emerging topics

There is a significant research gap in understanding how policies can support CE transition in the built environment. Most studies investigate policy strategies based on traditional construction supply chain structures without fully integrating CE principles. Therefore, they are insufficient to present a comprehensive overview of how CE concepts are implemented through policy-making. The global landscape of implementing CE for the construction industry is currently waste-centric, based on conventional CDW recycling policies. Some policies failed to improve construction resource efficiency to the desired extent, let alone
to create added value and reach a wider socio-economic goal of CE (Arm et al., 2017; Bolger & Doyon, 2019; Hao et al., 2020).

We observed a lack of policy-making knowledge concerning the complex nature of CE from the perspective of the entire construction value chain. To this end, a research topic is emerging in terms of achieving a higher level of policy integration to enable more efficient resource recovery in the construction sector (Milios, 2018; Nussholz et al., 2019). Generally, policy integration refers to the management of cross-cutting issues in policy-making that goes beyond the boundaries of existing policy fields, which do not correspond to the institutional responsibilities of individual departments (Meijers & Stead, 2004). The basic requirements for integrated policy-making are comprehensiveness (recognizing a broader scope of policy consequences in terms of time, space, actors, and issues), aggregation (a minimal extent to which policy alternatives are evaluated from an overall perspective), and consistency (a minimal extent to which policy penetrates all policy stages at different organizational levels) (Underdal, 1980). To better settle the concept of policy integration in this review context, we refine and discuss it from two specific perspectives as follows: (1) the process-wise policy integration answering the question of how different stages of policy-making can be integrated to perform the policy cycle efficiently, and (2) the content-wise policy integration answering the question of how different types of policy instruments can be integrated to create synergistic CE policy effects.

Although the issues related to policy coordination, policy integration, and policy harmonization are of increasing importance in the field of CE policy-making (Dalhammar et al., 2021), they receive scant attention in the built environment. On the one hand, most studies analyze general enablers and barriers to CE implementation and identify the vital role of policy support in CE transition with various policy alternatives. However, the literature provides limited indications about how these proposed policy alternatives can be implemented through the policy cycle. The lack of process-wise policy integration relates to significant disconnections between policy formulation and policy implementation. On the other hand, various decision support methodologies are proposed in the form of simulation models to support policy decision-making. However, these models are relatively limited to analyzing economic interventions for CDW management individually without revealing the synergistic effect with other types of policies (Calvo et al., 2014; Volk et al., 2019; Shi et al., 2020). Therefore, there is also a lack of content-wise policy integration that incorporates different circular principles into an interlocking policy system addressing CE challenges along the entire construction life-cycle.

Developing an integrated policy system is challenging because there are various involved organizations and unconnected CE initiatives at different levels (Heurkens & Dabrowski, 2020). Cross-disciplinary coordination is required to ensure policy coherence across different levels of government (Bolger & Doyon, 2019). To address the issue of lack of policy integration, both content-wise, and process-wise integration need to be realized by coordinating complementary policy instruments to support CE transition considering their consistency, coherency, and synergistic effects at different organizational levels (Lu & Lam, 2013; Milios, 2018). In parallel, we also need to carefully consider the interactions and trade-offs of policies during the policy integration to limit potential conflicts (Dalhammar et al., 2021).

Furthermore, little research delves into the dynamic policy-making mechanism by systematically connecting policy implementation with evaluation as an iterative and holistic cycle. Implementing policies is only viewed as an external driver towards CE from a top-down perspective without absorbing local policy feedback as a whole. CE policy-making as a dynamic adaptive process is not recognized in the construction industry. Policy evaluation is vital to an effective policy-making cycle as it brings local knowledge and experiences of enacted policies and helps to reconceptualize the new round of agenda-setting (Lasswell, 1951). Some studies critically pointed out the shortcomings of proposed visions and implemented policies. For instance, Arm et al. (2017) questioned the ambiguous definitions of waste and waste recovery proposed in the CE target and provided more appropriate suggestions showing the necessity of capturing the feedback of local actors in policy-making processes.

Finally, a clear research trend is witnessed in innovating predictive methods to quantify CDW flows as well as associated environmental impacts in terms of both solid waste pollution and air emissions. The construction industry is known to be responsible not only for significant resource consumption but also for greenhouse gas emissions, which emphasizes the need for comprehensive policy efforts to reduce the overall resource burden together with pollutant emissions (UNEP, 2018). The topics of developing predictive assessment methods to quantify the environmental, economic, and social impacts brought by CE policies are emerging.

4.2. Bi-directional CE policy-making mechanism

To illustrate the iterative nature of the policy cycle and provide a guideline for policy process integration, it would be helpful to picture the dynamic interactions between policy processes at different organizational levels. In this section, we propose a conceptual framework of a bi-directional policy-making mechanism to exemplify the way how a policy cycle would function through different organizational levels.

First, we argue that CE policy-making is a set of interactive and iterative processes that will only be accomplished with the active participation of both public and private actors. Here, the entire process consists of two major parts, namely, policy translation and policy evaluation. Policy translation refers to the process through which the policy meaning is translated and diffused from one actor to another at different levels till it takes effect on the target stakeholders. It can be regarded as a hybrid process covering policy decision-making and implementation. One critical challenge during this process is that the authentic meaning of the original policy would fade after a long travel through different organizational levels and ambiguity of the policy may increase. This is also known as a recent metaphor of “travel of ideas” proposed by Mukhtarov (2014) indicating that policy coherence and stability are difficult to ensure as the policy travels.

The translation of CE policies is not exceptional. Bolger & Doyon (2019) underlined that the leadership at a national level and policy coherence across levels of government are crucial elements to implementing CE. In the literature, ambitious recovery rates of CDW are determined as national policy visions by governments, and diverse CE action plans are developed at a high managerial level. However, little information is available on how exactly these high-level visions would be realized by local industrial actors. Furthermore, some of these recovery targets are proposed inappropriately, for instance, the definition of some waste recovery actions can be interpreted differently and leads to confusing situations where the recovery contributions of certain actors are not taken into account (Arm et al., 2017).

On the other hand, policy evaluation is critical to forming a virtuous policy-making cycle. A newly proposed policy is never perfect because the information and knowledge are limited at the formulation stage. To improve the policy, governments can learn from success, as well as from failures and unexpected outcomes (Bolger & Doyon, 2019). Besides, there might be a considerable time gap between the policy formulation and implementation (Calvo et al., 2014). During this gap, the implementation environment can change especially considering the extensive life span and multi-stakeholders involved in a construction project. Therefore, the adaptive adjustment of public policies is essential to keep the policy up to date.

However, evaluating the performance of a policy is not a trivial task. An inherent policy-making problem of CDW management at a national level is the compilation of reliable statistics to inform and monitor the extent policies (Gálvez-Martos et al., 2018). Many relevant studies underscored the important role of a compatible database in evaluating circular material flows (Ortlepp et al., 2016; Stephan & Athanassiadis, 2017).
2018), however, there is a lack of policy monitoring systems supported by accurate and reliable databases. Moreover, policy evaluation always involves not only bureaucrats and policymakers within the government, but also non-governmental members of policy subsystems. The standardization of feedback information becomes a problem because the CE yardsticks applied by different actors may vary and most of them are not designed to be integrated. In other words, there is a lack of consistent and comprehensive evaluation indicators for CE policy performance at different organizational levels (Paschoalin et al., 2020; Taboada et al., 2020). Therefore, a transparent, collaborative, and streamlined environment where actors can communicate and evaluate policy performance is in great demand.

To further clarify the interrelationships between policy translation and evaluation, we develop a bi-directional CE policy-making mechanism in Fig. 4. It articulates the synergetic process in which policy translation and evaluation are linked as a coherent approach to achieving effective CE policy-making at macro-, meso-, and micro-levels. This journey of policy translation is summarized as the process starting from national policy visions, through regional policy guidelines, and resulting in tangible business actions. All these elements construct a complex multi-level environment where policies are implemented from the national government to local target actors in a top-down manner. By contrast, policy monitoring and evaluation often occur in a bottom-up manner by which the feedback from local actors is raised, then the feedback is organized and captured through regional supply chain evaluation by policymakers at the top level. Eventually, some may lead to the reconceptualization of the initial problem and policy adjustments to different extents.

This mechanism adds value to the integrated CE policy-making cycle from an inter-organizational perspective and reveals the critical steps that policy translation and evaluation take towards effective and efficient CE policy-making. For the first time, we propose this bi-directional mechanism for CE policy-making in the construction industry in order to raise the attention to the need of implementing CE policies by considering policy translation and evaluation as an integrated approach. As suggested by many scholars (Milios, 2018; Nussholz et al., 2019; Campbell-Johnston et al., 2019; Heurkens & Dabrowski, 2020), multi-level policy integration is in demand to gravitate construction value chains towards CE by enabling greater material and energy reduction and supporting circular business innovation. Thus, introducing such a bi-directional mechanism can be viewed as a stepping stone towards advanced multi-level CE policy integration in the built environment.

4.3. Future research directions

In this section, two future research directions are proposed: (1) develop CE policy packages to accelerate CE implementation from different aspects, and (2) apply ICT-based solutions to create a streamlined, transparent, and collaborative policy-making environment.

4.3.1. CE policy package

The development of a CE policy package is the first step to formulate integrated CE policy systems. Such a policy package comprises a combination of diverse policy instruments to address CE challenges on technical, economic, and social aspects. The literature review showed that policymakers aim to provide more efficient policy options to covert the extant waste-centric policy system to an integrated design-out-of-waste policy system. Therefore, the policies supporting CDW prevention and minimization can be prioritized according to the hierarchy of circular principles. However, it should not be misunderstood that the CE transition will be achieved solely relying on waste minimization. Although it is prioritized, all circular principles should be integrated and absorbed as a whole into the policy-making system because different circular mechanisms have advantages at different project life-cycle phases. For instance, waste prevention strategies are more likely to take effect at the designing phase while most untreated CDW has to be recycled or backfilled at the EoL phase. Thus, it is imperative to admit that there is no one-fits-all recipe for CE. The circular strategy of a construction project should be carefully designed to follow the pattern of material consumption of each construction and demolition phase. More research is encouraged to investigate the policy interrelationships within a CE policy package by linking demolition projects with newly initiated projects in a closed-loop value chain.

Next, new market-based policy instruments need to be proposed to foster the secondary material market. The key to closing the
construction material loop is re-directing qualified secondary materials into the construction material market. The subsidy policy instrument would enable long-term and reliable economic support for circular business model innovation, especially for the mediators who are actively connecting demolition projects and construction projects, such as CDW recycling factories and demolition companies. The secondary materials can never be competitive in the market if recovery costs are high and material quality is not ensured. To this end, economic policy interventions can not only help to regulate the price of secondary materials in the forms of subsidy allocation and tax reduction but also stimulate circular technology innovation to improve the quality of secondary materials.

However, it can be against the original purpose of implementing CE if the economic support is provided only based on the economic and environmental contributions brought by the circular activities without considering the original production model. In fact, extra manufacturing processes are often required to produce a circular product and the extra environmental and economic impacts, such as energy impact, brought by circular activities may partially or fully offset the circular benefits. This is known as “Circular Economy Rebound” (Zink & Geyer, 2017). Similarly, the “Circular Premium” introduced by D’Adamo & Lupi (2021) is a terminology that measures the price difference between circular and normal products. These two concepts can potentially be integrated with LCA methods to set a comparative baseline between primary and circular production systems. In such a way, conscious policy decisions can be made regarding whether it is more beneficial to subsidize certain secondary materials or promote a new choice of virgin materials based on a comprehensive overview of the production system. Therefore, we recommend that policymakers can take these concepts into account when proposing economic policy interventions in order to determine the extent to which the recycled materials need to be incentivized and promote the products that can efficiently generate meaningful CE value.

On the other hand, policies help to create demand for secondary materials. More policies in other forms, such as GPP, social communication, regular training, and education programs, should be diffused to raise public awareness and acceptance of CE (Lu & Tam, 2013; Ding et al., 2016; Alhola et al., 2019; Bao & Lu et al., 2020). To increase the demand for reused/recycled materials, we also suggest providing adaptive quality assessment schemas for secondary materials. The functionality and quality of reused/recycled materials are difficult to assess because they are not what the current quality standards are designed for (Rodriguez et al., 2014; Heurkens & Dabrowski, 2020). The on-site material audit can help to analyze material value to customize the evaluation processes for specific cases. For instance, a demolition contractor can optimize deconstruction processes and ensure waste purity and quality based on material inspection if the client recognizes CE as project requirements and allocate more time and benefits to the EoL phase.

In summary, we suggest proposing CE policies in a package form to shift the waste-centric policy paradigm towards the design-out-of-waste one, and regulate supply-demand dynamics of secondary materials by considering the synergistic effect created by a combination of diverse policy instruments. The ultimate goal of developing CE policy packages is to generate meaningful CE value based on a comprehensive understanding of the circular cost-benefit mechanism in a construction life-cycle.

4.3.2. ICT-based policy-making

ICT-based solutions attract increasing attention in the public sector because these solutions enhance business-making performance and streamline organizational activities with less time and costs by reducing principal-agent problems and transactions costs (Cordella, 2009). The innovation of ICT fuels digital government transformation by creating a streamlined, transparent, and collaborative environment for actors at multiple levels, and supports continuous evaluation linked to the traceability of actions (Cordella & Bonina, 2012). The wide adoption of ICT in the public sector has followed technical and strategic solutions based on the private sector experiences to improve efficiency and productivity of government performance, including policy-making. Although the momentum of adopting ICT solutions in the public sector is growing, the actual ICT implementation is problematic and subject to frequent failures (Cordella & Bonina, 2012; Gil-Garcia and Flores-Zúñiga, 2020). There are complex future challenges in experimenting with ICT-based solutions and models for collaborative governance and participatory policy modeling, and socio-economic impact assessment (Miszura et al., 2012). To foster the adoption of ICT, the knowledge-sharing between public and private sectors is critical.

Considerable research efforts have been made to enhance ICT adoption in the construction sector, such as the Big Data Analytic technology (Bilal et al., 2016; Li et al., 2020b), Internet of Things (Zhong et al., 2017; Arka et al., 2020), and Geographical Information Systems (Mastrucci et al., 2017; Arciniegas et al., 2019). The reviewed papers stressed the importance of incorporating GIS to analyze uncertainties and dynamics of CDW flows under different policy scenarios in future research (Hiete et al., 2011; Ding et al., 2016; Volk et al., 2019). However, it is not clear how exactly ICT would contribute to CE policy-making processes in the construction sector. Although the literature presents various mathematical methods that can support the predictive quantification of CDW, their potential functionalities are not explicitly demonstrated concerning CE policy evaluation. Therefore, innovating ICT-based solutions to streamline and integrate complex processes of CE policy-making is an indispensable future research direction in the construction industry.

Besides, some studies provided predictive indications of policy decision-making based on scenario analysis. From a methodological point of view, they mostly adopted local sensitivity analysis to investigate the response of the output around one point of interest in the model input space. Typically, the local sensitivity analysis is conducted by varying one model input at a time while the remaining model inputs remain as the baseline value (Saltelli et al., 1999). However, it is insufficient to explicitly show the interconnections among different inputs and outputs by applying this type of one-factor-at-a-time analysis when a larger exploration of the model input space is sought based on a range of uncertainties (Saltelli et al., 2007). As the level of complex interconnections between inputs and outputs increases, one may not anticipate model behaviors, thus, failing to interpret why the model achieves the right outcomes for the right reasons (Beven & Cloke, 2012). By contrast, Global Sensitivity Analysis (GSA) contributes to exploring the entire space of input factors and identifies the inputs to obtain additional insights into the inter-relationships among inputs and outputs (Saltelli et al., 2007; Anderson et al., 2014). It provides a holistic overview on the influence of inputs-outputs as opposed to a local scenario view of partial derivatives as in local sensitivity analysis. Some applied it to translate risks into policy actions based on robust LCA studies and showed that GSA is fundamental to guarantee a complete understanding of 1) the internal structure of the simulation model, 2) the importance of uncertain model inputs, 3) and the interactions among them (Czuczuch et al., 2016). Therefore, we consider GSA as a valuable method in future research that can potentially support the investigation of the complex cause-effect mechanism of CE policy packages revealing the underlying conflicts and trade-offs.

On the way towards ICT-based CE policy-making, there are three general challenges. First, we need to be aware of a principal difference
between public and private sectors before applying ICT based on the experiences learned from private sectors, namely, public sectors aim to achieve social value by balancing interests among various sides through policy-making while private sectors often only aim for individual monetary benefits (Cordella & Bonina, 2012). Therefore, the solution should be provided by considering the special value proposition for public sectors. Second, ICT techniques are not yet integrated to a sufficient level to fully support complex policy-making tasks (Demestichas & Daskalakis, 2020). The lack of interoperability, data accessibility, and information standardization hampers the integration of ICT. More research is required to fill the technological gaps and provide a robust technical background where coherent and intelligent decision support can be realized in the policy-making domain. Third, there is a lack of data management support (Yan et al., 2015; Volk et al., 2019). Although information-sharing contributes to developing effective governmental strategies, most private actors are reluctant to share business-related information because it can be abused and hazard business competitiveness. More interdisciplinary research is required to create a transparent and trustful information-sharing environment and enable cross-fertilization to bridge the gaps between various stakeholders (Misuraca et al., 2012).

5. Conclusions

Through a systematic literature review, this study has investigated the CE implementation in the construction industry from a policy-making perspective. In particular, we made an explorative attempt to align the state-of-the-art with the classic five-stage policy cycle and provided an integrated CE policy-making framework. However, it is found that little “internal” information is provided regarding how the governments make policy decisions in practice while scientific contributions mostly come in the form of “external” theoretical justifications supporting policy decision-making. Therefore, we refined the definition of each policy cycle stage and proposed a literature category based on (1) The vital role of CE in policy agenda-setting, (2) Alternatives in policy formulation, (3) Methodologies for policy decision-making, (4) Evidence collected from policy implementation, and (5) Knowledge basis for policy evaluation. The proposed classification system can be regarded as a coherent baseline to understand the state-of-the-art of CE policy-making in the construction industry from a theoretical lens.

Based on a global overview of CE initiatives, we found that the vital role of policy support in CE transition is well-recognized globally. Most CE policies are country-based with specific policy characteristics and we summarized the major forms and functions of current CE policies proposed for the built environment. The results also showed that ICT-based solutions play a vital role in policy decision-making and evaluation by providing predictive insights into policy effects. However, there is still a lack of an effective regulatory system to implement CE initiatives in practice. Most studies only investigated CE policy-making from one particular perspective without considering the potential connections between different policy stages in a broader operational context of the entire policy cycle. To this end, we identified the focal research gap regarding insufficient policy integration from two perspectives, namely, process-wise and content-wise policy integration. To provide a guideline for policy process integration and deepen the understanding of the iterative nature of the policy cycle, a conceptual framework of a bidirectional policy-making mechanism was proposed. This mechanism exemplifies the functioning of a policy cycle through different organizational levels and raises the attention to the need of implementing CE policies by integrating policy translation and evaluation as a holistic cycle.

Furthermore, we suggested developing CE policy packages to shift the waste-centric policy paradigm towards the design-out-of-waste one and regulate supply-demand dynamics of secondary materials by considering the synergistic effect generated by a combination of diverse policy instruments. This suggestion could effectively address the challenge of insufficient content-wise policy integration. Finally, the adoption of ICT-based solutions can be valuable to create a streamlined, transparent, and collaborative environment for process-wise policy integration. We encourage more interdisciplinary research to explore this topic and address identified challenges based on the combination of quantitative modeling results and qualitative evidence observed from actual policy implementation.

In conclusion, we provided a structured approach to conducting CE policy-making research based on the policy cycle. This review underlines the importance of understanding CE policy-making as an integrated and dynamic cycle with intertwined connections among different policy-making stages. Scientifically, it addresses the research gap of insufficient understanding of CE policy-making processes in the construction industry and sheds light on future research directions. Practically, the results serve as a theoretical guideline for policymakers and industrial practitioners to understand the more complex nature of CE policy-making in practice.

The review focused on the interdisciplinary research nexus of Circular Economy, Construction Management, and Public Policy. The nexus complexity, together with the nature of the literature review, led to limitations for the research. Our literature research was limited to the WoS digital literature database. Although we conducted a first-degree backward citation analysis, some relevant scientific materials may still be missing from our shortlist due to the searching limitation. For instance, the method of Strength, Weakness, Opportunity, and Threat (SWOT) analysis can be valuable to provide policy alternatives for CDW management (Yuan, 2013) while Hossain et al. (2018) applied LCA to develop a social sustainability assessment method for recycled construction materials including an impact category of support from the public sector. Second, ICT techniques are not yet integrated to a sufficient level to fully support complex policy-making processes in the construction industry and shed light on future research directions. Practically, the results serve as a theoretical guideline for policymakers and industrial practitioners to understand the more complex nature of CE policy-making in practice.

Declaration of Competing Interest

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

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.resconrec.2022.106359.
Appendix

Table 2
List of collected papers

<table>
<thead>
<tr>
<th>No.</th>
<th>Reference</th>
<th>Region</th>
<th>Summary</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>(Hao et al., 2020)</td>
<td>China &amp; EU</td>
<td>Policy comparison between China and EU</td>
</tr>
<tr>
<td>2</td>
<td>(Mahpour, 2018)</td>
<td>Iran</td>
<td>Barriers to adopting CE for CDW management</td>
</tr>
<tr>
<td>3</td>
<td>(Bilasi, 2019)</td>
<td>Saudi Arabia</td>
<td>Roadmap for sustainable CDW management</td>
</tr>
<tr>
<td>4</td>
<td>(Bolger &amp; Doyon, 2019)</td>
<td>Australia &amp; Sweden</td>
<td>Explore local government strategies to support CE implementation</td>
</tr>
<tr>
<td>5</td>
<td>(Bilai et al., 2020)</td>
<td>N/S</td>
<td>Enables and barriers to CE implementation in the built environment</td>
</tr>
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Notes: N/S – Not Specified; EU – European Union; HK – Hong Kong

References


