Sustainable Production and Consumption 57 (2025) 292–305

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

A systems approach the Circular Economy: Policy recommendations to increase building components reuse☆

Lucia Corsini

University of Oxford, Department of Engineering Science, Parks Road, Oxford OX1 3PJ, United Kingdom of Great Britain and Northern Ireland

ARTICLE INFO

Editor: Prof. K Tsagarakis

Keywords:
Circular Economy
Reuse
Buildings
Policy

ABSTRACT

Building Components Reuse is a promising Circular Economy approach that can help to tackle the sector's rising waste production, energy consumption and material shortages. However, there remains limited widespread implementation of Building Components Reuse and policy makers still lack understanding about how related policies should be developed and implemented within the sector. To address this, the study uses the literature to develop a detailed Causal Loop Diagram that shows the interrelated factors enabling and constraining Building Components Reuse. Twelve leverage points and related policy recommendations are identified from the Causal Loop Diagram, which are then evaluated with policy and government stakeholders in the UK. The findings highlight the need for more robust standards and guidance on the design and quality assessment of building components for reuse, the enforcement of financial incentives and related reuse targets, and the development of technology-based solutions for the effective evaluation, recovery and traceability of building components. The study also finds that industry education and awareness, establishing consistent protocols for sustainability assessment of Building Components Reuse and public procurement strategies can increase the adoption of Building Components Reuse practices. Further collaboration between government and industry is recommended to establish their respective roles and responsibilities in developing Circular Economy policies and practices. Overall, it is likely that a range of policies and supporting mechanisms are needed to enable Building Components Reuse. Further research could address the development of Building Components Reuse policies in relation to other Circular Economy strategies such as adaptive reuse and recycling.

1. Introduction

The built environment is the largest consumer of raw materials and energy (Pomponi and Moncaster, 2017; European Circular Economy Stakeholder Platform, 2021). It is also responsible for the greatest waste, with less than a third of all construction and demolition waste being recovered and reused (Breene., 2016). In total, the construction industry represents more than a third of global emissions (United Nations Environment Programme, 2024). Shortages of natural resources and materials such as water and crushed aggregates are also putting pressure on the sector and increasing the price volatility of raw materials (Ioannidou et al., 2017). Embedding the Circular Economy (CE) in the built environment therefore offers a solution to mitigate these supply and resource challenges (Joensuu et al., 2020). The CE is an economic system in which resource input and waste, emission, and energy leakages are minimised by cycling, extending, intensifying, and dematerialising material and energy loops (Geissdoerfer et al., 2017). Prior research has shown that embedding a CE will make the sector more resilient to supply chain disruptions (O'Grady et al., 2021) and reduce global CO_2 emissions from buildings (Gallego-Schmid et al., 2020; European Circular Economy Stakeholder Platform, 2021). Gallego-Schmid et al. (2020) find that closing resource loops in buildings through reuse, remanufacture and recycling could reduce emissions by 30–50 % compared to landfill or incineration at end-of-life.

Reuse is highlighted as a particularly promising CE strategy in the built environment. According to the waste hierarchy introduced in the European Commission Waste Framework Directive 2008/98/EC (EU, 2008) and the Demolition Protocol (ICE, 2008), reuse offers the greatest potential to drive resource efficiency. Building Components Reuse (BCR) is defined as the process by which building components are salvaged from old buildings and prepared for reuse and reassembled into new buildings (Riuttala et al., 2024). BCR therefore incorporates both aspects of design with reused components and designing buildings for disassembly (reuse). BCR is expected to significantly reduce environmental

☆ This article is part of a Special issue entitled: 'Circular Economy 2024' published in Sustainable Production and Consumption.

E-mail address: Lucia.Corsini@eng.ox.ac.uk.

https://doi.org/10.1016/j.spc.2025.05.019
Received 25 November 2024; Received in revised form 15 May 2025; Accepted 25 May 2025
Available online 30 May 2025
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emissions and energy consumption as compared with other CE approaches such as recycling (Victar et al., 2024; Zhuang et al., 2023). For example, a study on structural steel found that transitioning from recycling to reuse would result in approximately 60 % energy and 35 % cost savings (Geyer et al., 2002). Similarly, Rakhshan et al. (2020) report that the reuse of reclaimed steel sections reduces environmental impact by 25 times compared with 60 % recycled content steel sections. Collectively, this represents a significant opportunity for decarbonising the construction industry. Passarelli and Mouton (2023) predict that even a conservative 50 % reuse scenario for metals and sawn wood in new buildings could reduce Global Warming Potential by 8 %.

Despite several contemporary examples, the literature emphasises that there is no widespread industry implementation of BCR (Munaro et al., 2020; Lynch, 2022). Giorgi et al. (2022) find that BCR of bricks is being used in public buildings in Denmark, and Kanyilmaz et al. (2023) document examples of structural steel reuse in UK, including Sloane Square House, which was constructed using fully reuse steel sections, leading to a 60 % reduction in carbon impact. However, these are isolated examples as only 20–30 % of construction materials are recycled or reused at end-of-life, with the remaining waste send to landfill (Adams et al., 2017). Of this, it is reported that reuse represents a small percentage (Mhatre et al., 2024). Ineffective policies and regulations are commonly identified as a key barrier to BCR (Hill et al., 2023; Hamida et al., 2023) and it is noted that current legislation focuses more on recycling than reuse (Giorgi et al., 2020). Although policy is widely recognised as a key mechanism for enabling the CE (Droege et al., 2023), the role of policy in enabling BCR is relatively understudied in the literature (Eissa and El-Adaway, 2024). Prior policy-perspectives on BCR are mainly focused on evaluating current policies and industry practices and less attention is paid to the development of policy recommendations or policy scenarios (Eissa and El-Adaway, 2024). With the notable exception of Eissa and El-Adaway (2024) who conduct a life-cycle analysis of CE policy scenarios and Giorgi et al. (2022) and Lynch (2022) who conduct an interview study of construction industry stakeholders that includes policy makers, the majority of studies are non-empirical and do not incorporate the perspectives of the policy makers themselves. This is a problem since these studies may overlook important contextual, political and institutional factors that influence the design and implementation of CE policies in practice.

This research aims to address this problem by identifying a set of policy recommendations to increase BCR which incorporates the perspectives of government and policy stakeholders in the UK. Hence this study addresses an understudied stakeholder perspective, which is critical to the CE transition. In order to do this, the study uses a systems approach which is urgently needed in the CE (Kravchenko et al., 2020) to consider underlying relationships and whole system behaviours (Iacovidou et al., 2021). This study therefore addresses key gaps in the existing literature by: (1) providing a systemic view of the interrelated factors that enable and constrain BCR; (2) offering policy recommendations to enable BCR that are evaluated by policy and government stakeholders; (3) demonstrating the capabilities of a systems approach to the Circular Economy, which is currently underrepresented in the field. The paper is structured as follows: Section 2 will outline the literature background to this study, including prior work on BCR and related policy studies. Section 3 explains the methods used in the study. Section 4 presents the Causal Loop Diagram in detail and the stakeholder evaluations of the twelve policy recommendations identified from the Causal Loop Diagrams. Section 5 discusses the findings and its limitations. Section 6 concludes the study and its contributions to knowledge, as well as highlighting areas for further research.

2. Literature review

Reuse has been relatively understudied as compared to recycling in the construction sector (Mhatre et al., 2024; Lynch, 2022). Until recently, the field has been criticised for being underdeveloped and mainly theoretical (Rahla et al., 2021). However, it is noted that there has been a notable growth in literature on BCR in the last five years, since Rakhshan et al. (2020) conducted the last literature study of BCR. Combinations of Scopus searches for BCR that used in this paper (see Section 3) show that 80 % of literature on BCR has been published since between 2020 (see Fig. 1), indicating that this is an area of growing academic interest. Table 1 provides a summary of the focus and methods of the current literature on BCR, where Fig. 2 shows the relationship between focus and methods used.

Of the total 129 articles reviewed on BCR, a significant number of articles have focused on modelling life cycle impacts and developing metrics and assessments ($n = 33$). For example, several authors develop reuse assessment frameworks (Bergmans et al., 2023; Gillott et al., 2023). Devènes et al. (2024) introduce a specific methodology for the reusability assessment of load bearing reinforced concrete components. Other studies, such as by Paglia (2023) and Passarelli and Mouton (2023) are dedicated to modelling the environmental impacts of component reuse using Life Cycle Assessments; or utilise Material Flow Analysis to forecast the availability of material and component stocks to meet demand (Meijer et al., 2024; Sumikura and Katsumi, 2022). A similarly significant number of articles ($n = 31$) have addressed technical design requirements to enable Design for Deconstruction/Design for Disassembly. For example, Estrella et al. (2024) presents the conceptual design of a new slab-and-column system called “Re:Slab”, which is optimised for disassembly and reassembly. Li et al. (2024) develop a solution for the rapid assembly and disassembly of Cross-Laminated Timber (CLT) modules, and Zhuang et al. (2023) develop a system for interlocking reusable modular components. A very small number of articles ($n = 6$) are focused on cultural or heritage studies of BCR such as Andrews (2023) who examines how the reuse of ancient tuff blocks in early medieval architecture in Rome was common in both papal and private structures.

Other studies look more broadly at the systemic barriers and enablers to Building Components Reuse ($n = 25$). Some of these studies are focused on a particular material or component. For example, Kanyilmaz et al. (2023) investigates the barriers to steel reuse, emphasising the importance of solutions enabled by digital technologies and Artificial Intelligence (AI). In an older study on structural steel reuse in the UK, Tingley et al. (2017) highlights the need for more effective databases on component availability for reuse as well as government leadership to stimulate demand and awareness. Zhu and Feng (2024) analyse the potential benefits of wood waste circulation, highlighting that reuse could lead to job creation and cultural and heritage conservation, however they find that policy and regulatory challenges are hampering uptake. Specifically, they find there is a lack of government support, standardised practices and tools for deconstruction, and regulations that encourage Design for Disassembly. The majority of these studies are literature based and only a handful of empirical studies ($n = 9$) that utilise stakeholder interviews, workshops and focus groups or surveys to examine barriers and enablers. Among these, Karaca et al. (2024) evaluates stakeholder perspectives on the costs and benefits of implementing CE material efficiency strategies in construction. The findings highlight that European stakeholders prioritise reuse and design for disassembly, whilst studied non-European countries focus on offsite production and material reuse optimisation. Anastasiades et al. (2024) conducted a survey of 629 stakeholders in the Netherlands to investigate the current implementation of Design for Disassembly and the reuse of construction components. They show that whilst ISO20887 advocates for the implementation of construction standards that support reuse, these standards still need further clarification and development.

There have been some recent efforts to also consider value capture and business models associated with BCR ($n = 5$). For example, Nußholz et al. (2020) analyses a Scandinavian case study of BCR of windows, wood cladding and concrete which shows successful BCR models must be price-competitive with linear alternatives, whilst providing significant reductions in environmental impact. Bestul and Gruis (2024)

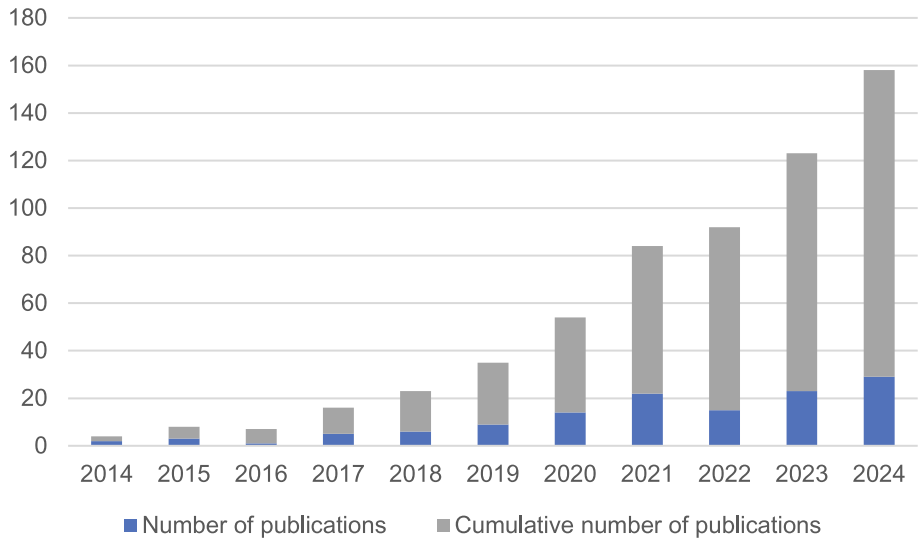


Fig. 1. Publications on Building Component Reuse between 2014 and 2024.

Table 1
Focus and methods used in literature on building components reuse.

Focus	n =	Methods	n =
Life cycle assessments, metrics, indicators	33	Literature	34
Technical design	31	Case study	28
Barriers and enablers	25	Life-Cycle Assessment	15
Infrastructure and tools	19	Experimental	14
Policy	10	Interview, focus group, workshops	9
Historical and cultural analysis	6	Computational	8
Value capture, business models	5	Survey	8
		Material Flow Analysis	5
		Archive Analysis	4
		Experimental and computational	4
N =	*129*	*N* =	*129*

propose several CE construction business model types, including three BCR related business models: (i) *reuse platforms* which can make searching for reused products easier and improve sustainability credentials; (ii) *material reseller* which can provide quality assurance and make salvaged component integration simple; and, (iii) *reuse consulting office* which improves competencies by providing technical consulting on BCR. Riuttala et al. (2024) conduct a multi-methods analysis to determine a value capture model for BCR, highlighting that legislation can generate new revenues for BCR by influencing the duration and steps required in the reuse process. They also identify the consistency of regulation as a key attribute of BCR business models, as it reduces stakeholders' perception of financial risks.

From a policy perspective, a limited number of studies ($n = 10$) focus explicitly on evaluating current policies and practices related to reuse in the built environment. For example, Fernandes and Ferrão (2023) conduct a critical analysis of EU frameworks, regulations, policies and incentives related to building refurbishment. Hjaltadóttir and Hild (2021) investigate how firms in the building industry in Luxembourg and Sweden, understand circular economy policies and develop circular practices. Similarly, Kummen et al. (2023) investigates the status of Building Components Reuse in the Nordic public sector, finding that the level of ambitions varies in the different projects and should be set by what materials are available. Giorgi et al. (2019) investigate industry attitudes towards building regeneration including their opinions on legislative obstacles towards reuse and recycling. Finally, Giorgi et al. (2020) find that ineffective policies are hampering the adoption of circular economy practices in Italy. Specifically, current waste frameworks incentivise higher quantity not higher quality recycling, and current legislation focuses more on recycling than reuse. In another comparative study of CE policies in the built environment in five European countries, Giorgi et al. (2022) conduct an interview study with a range of European stakeholders that both influence and are impacted by current circular economy policies in the building sector, including policy makers, banks, designers, suppliers and waste management companies. They note that current legislative frameworks focus more on recycling practices than on reuse or resource management. Additionally current circular economy strategies are diverse and fragmented and there is a need for greater coordinated action from bodies such as the European Commission.

Only a handful of articles explore future policy scenarios related to reuse. For example, Eissa and El-Adaway (2024) use stock and flow analysis to estimate the future embodied carbon emissions of US commercial building stocks for various circular economy policy scenarios, one of which promotes the use of secondary building components and materials. To facilitate circular economy policy development, Yu et al. (2022) suggest a five-stage policy development framework that includes stages of policy agenda setting, formulation, decision-making, implementation and evaluation. They identify a bi-directional policy-making mechanism which provides top-down translation of national and regional polies to local businesses, as well as bottom-up evaluation from industry to adjust and develop effective long-term policies. Similarly, Fuertes (2017) calls for more stringent policy to incentivise Building Components Reuse, however, falls short of providing details on specific policy recommendations. Overall, there is a need for further policy-perspective studies on BCR (Yu et al., 2022; Eissa and El-Adaway, 2024) since this area of literature is still relatively immature. In summary the main gaps in current policy literature on BCR are: (1) policy is regularly cited as a key barrier or enabler to BCR, however there is a limited number of policy-focused research; (2) among limited studies, research is focused on current policy evaluation as opposed to the development of future policy recommendations or scenarios; (3) policy-focused research is mainly non-empirical and only two studies include primary data from policy/government stakeholders. This study therefore contributes to a much-needed area of research which is increasingly being recognised as important for implementing BCR.

3. Methods

Several studies on CE emphasise the importance of a systems

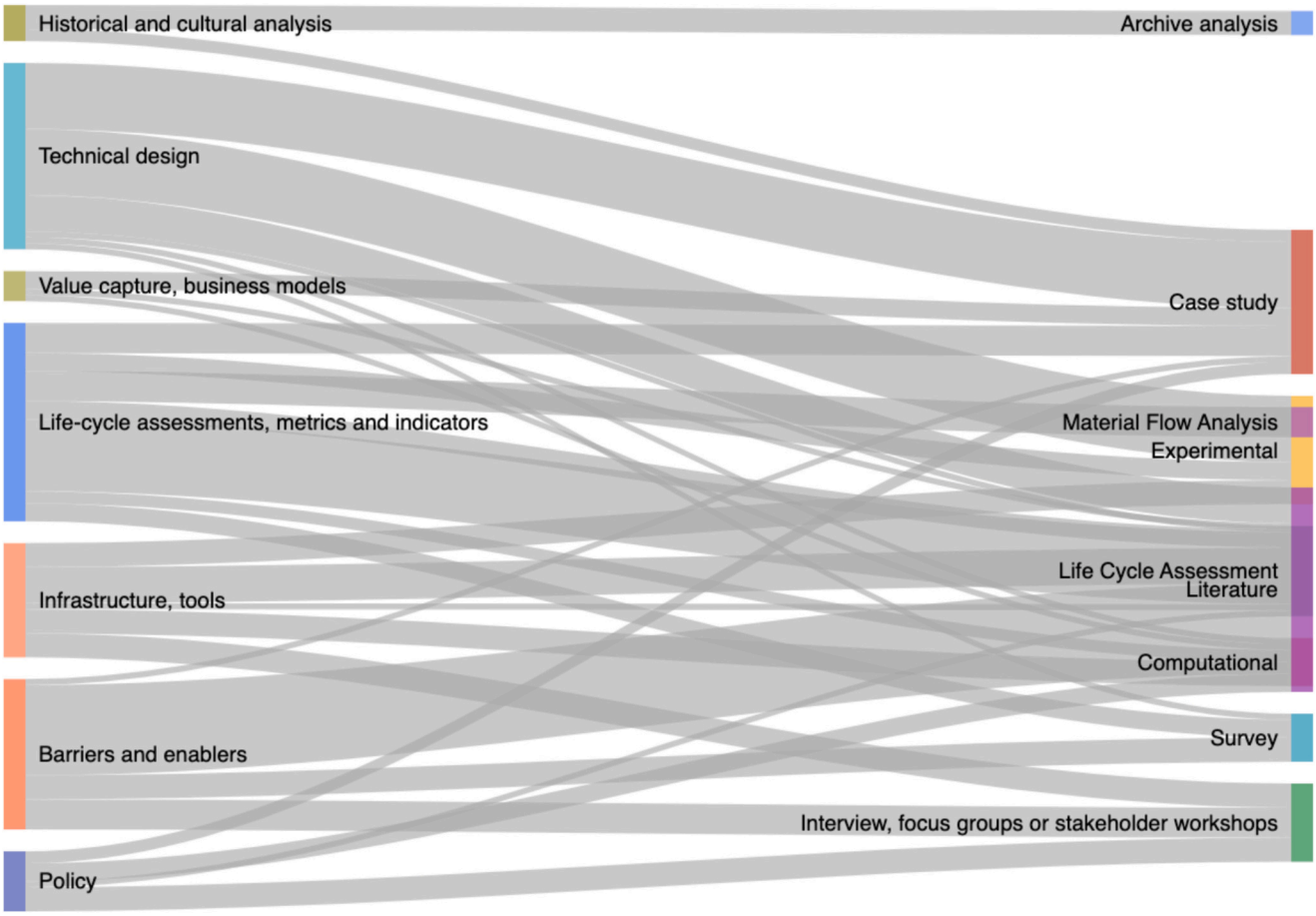


Fig. 2. Relationship between focus and methods used in the literature on Building Components Reuse.

approach (Kravchenko et al., 2020; Iacovidou et al., 2021). Unlike traditional analytical approaches which seek to break down complexity into parts, a systems approach is based on holism and aims to understand the relationships that hold these complex systems together (Sterman, 2000, p. 4). Whilst analytical approaches are useful for deriving operational variables, they have been also criticised for not paying enough attention to the interconnected relationships between different elements (Sayer, 2010). In this study Causal Loop Diagrams (CLDs) are selected as an established modelling convention in the field of Systems Dynamics, that represent feedback structures in a system including positive and negative behaviours (Sterman, 2000). CLDs are a well-established as a qualitative research approach for developing corresponding policy interventions by highlighting direct, indirect and induced policy outcomes across social, economic and environmental indicators (Bassi et al., 2021). Table 2 provides an overview of the types of effects in CLDs and their annotation conventions.

Table 2
Type of effects in Causal Loop Diagrams.

Type of effect	Description
Positive	A positive (+) arrow means that an increase in one variable causes an increase in another variable.
Negative	A negative (−) arrow means that an increase in the one variable causes a decrease in another variable.
Reinforcing loop	A reinforcing loop (R) is when an action continuously reinforces a condition leading to spiralling growth or decline.
Balancing loop	A balancing loop (B) is when a condition drives a corrective action that adjusts the original conditions. This leads to balancing, constraining or self-regulating processes.
Time delay	In some cases there is a time delay between a change in one variable causing a change in another variable. This is shown by two dashes on a Loop - ||

Several stages of analysis were conducted as part of the study (see Fig. 3). To begin with, the systems boundary was defined as including all activities related to Building Components Reuse during the construction, use and end-of-life lifecycle stages, as defined in ISO 21930:2017 - Building Components Lifecycle. This excludes other Circular Economy strategies such as reduction or recycling; other types of reuse such as adaptive reuse or building material reuse; and reuse in the broader Built Environment such as roads, bridges, transportation systems.

The author then searched for relevant literature using Scopus. The following searches were used to search titles, abstracts and keywords: “Building Components Reuse”; “component reuse” AND “build*” OR “built environment” OR “construction”; “material reuse” AND “build*” OR “built environment” OR “construction”; “material” AND “reuse” AND “built environment”; “material” AND “reuse” AND “built environment”; “Policy” AND “reuse” AND “build*” OR “built environment” OR “construction industry”; “Policy” AND “Circular Economy” AND “build*” OR “built environment” OR “construction industry”. Searches were limited to journal and review articles published in English between 2014 and 2024. This resulted in a total of 288 results. 24 duplicates were removed and then all the article titles were reviewed carefully to remove any articles which were irrelevant or did not meet the search criteria. For example, if the study focused on reduction or recycling in buildings; or focused on component reuse in electronics. 3 snowballed article was added to the search. All the available articles were downloaded, and article meta-data was exported from Scopus into Excel (see supplementary materials for full list of articles, meta-data and summary of key findings, focus and methods). This resulted in a total of 129 publications for review.

Next, all articles were then imported to MAXQDA, a popular mixed-

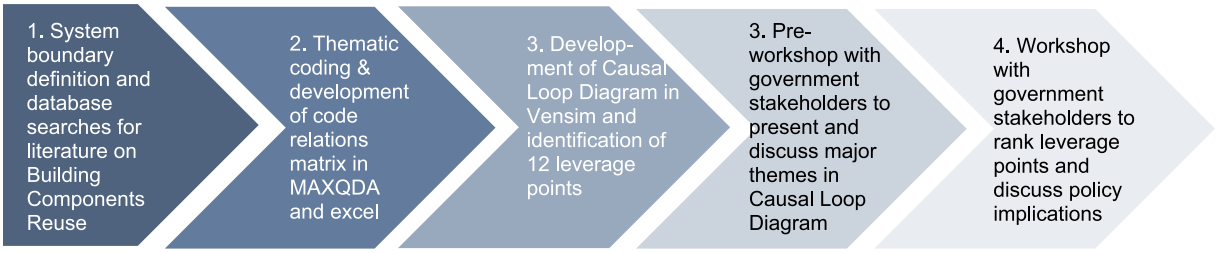


Fig. 3. Overview of study design.

methods data analysis software that enables text data to be manually read and assigned a thematic code based on interpretation that is used in several qualitative studies (e.g. Sannou et al., 2023; Herbes et al., 2024). For example, the extract "After the initial cleaning of the object, a capacity check and quality check must be conducted. The capacity check includes three parts: (1) visual inspection to spot any apparent structural deficiencies, (2) load test, and (3) materials data acquisition" (Nian et al., 2022) was labelled (coded) as "Testing, verification and certification". The review articles were organised in order of citation count (highest to lowest) and imported to MAXQDA for thematic analysis, following guidance by Saldaña (2009). This involved the author reading each article to identify barriers and enablers to BCR and manually highlighting and labelling relevant text in the software and labelling these highlighted text segments as codes. This process is manual, and no automated retrieval of text segments is used. The author then reviewed these codes to determine whether they were: (i) endogenous variables i.e. influenced by other variables within the system boundary or (ii) exogenous variables i.e. influenced by factors outside of the system boundary. For example, "recycling efficiency" has an impact on the rate of BCR, however changes to the recycling efficiency are defined outside of the model boundary.

"Supply of non-virgin materials" and "demand for non-virgin materials" were identified as key endogenous system elements and provided starting points for constructing the Causal Loop Diagrams. To examine the relationships between these and other factors, a MAXQDA code relations matrix was created in MAXQDA, which shows where there is a relationship between two codes i.e. where a coded segment of text is coded twice. For example: "there's a lack of guidance for reusing steel, particularly around design and testing requirements. This may partly explain the lack of industry awareness that steel reuse is a possible option" (Tingley et al., 2017) was coded as both "industry awareness" and "technical guidance/standards", and the code relations matrix shows a relationship between these two codes. This enabled the author to determine important variable relationships. This analysis was used to develop a separate template for documenting variable relationships in Excel. Table 3 provides an example which shows that the demand for non-virgin materials is positively influenced by reuse targets i.e. when reuse targets increase, the demand for non-virgin materials also increases. See supplementary materials for the full database of code relations.

Based on this analysis, variables (i.e. system elements) and causal loops (i.e. system relationships) were defined in an initial CLD using Vensim PLE software. During the analysis and interpretation stage, the CLD system elements and relationships were analysed thematically to reveal six main thematic areas in the model: (1) design and testing; (2) industry; (3) government; (4) recovery; (5) transport and storage; (6) data and infrastructure. These themes revealed key aspects of BCR. Following this, the CLD was analysed with respect to well-known systems archetypes (i.e. common patterns of systems behaviour (Braun, 2002), which led to the identification of twelve policy leverage points for influencing reuse in buildings. These leverage points were used to establish related policy recommendations to improve BCR practice.

This CLD was presented in a pre-workshop with civil servants from the UK Government Department for Levelling Up, Housing and Communities (DLUHC) in April 2024. The purpose of this pre-workshop was to explain the CLD to the participants and to explain how the policy leverage points had been identified. Following this a policy workshop was held, which focused on evaluating the CLD leverage points and related policy recommendations, which are presented in this paper. Five civil servants attended the workshop and were selected as representatives based on their experience in construction materials, circular economy and/or net zero policy (see Table 4). These civil servants were invited from DLUHC, the department which solely represented the buildings/built environment until end of 2024. Although some of the civil servants who participated in the workshop had <5 years' experience in their roles at DLUHC, it is noted that they previously held roles in other departments and were highly experienced in policy design and implementation.

In the workshop, each of the CLD leverage points was presented and evaluated as high, medium, low or very-low according to the perceived *impact* (i.e. potential impact on BCR), *desirability* (i.e. desire for government to take accountability) and *feasibility* (i.e. ability to implement). The discussion and evaluations aimed to reach consensus among all stakeholders. Scores of 3, 2, 1 and 0 were allocated for the respective high, medium, low or very-low ratings. Impact and desirability were weighted as 1 and feasibility was weighted as 0.5. An overall score was calculated for each recommendation by multiplying the individual scores and ratings. For example, a score of High impact, High desirability, and Medium Feasibility would result in an overall score of $3 \times 1 + 3 \times 1 + 2 \times 0.5 = 7$. The policy recommendations were then ranked based on their scores and categorised as either high, medium, low or very-low priorities. Scores of over 6/7.5 were ranked as high priority, scores of over 5/7.5 were ranked as medium priority, scores over 3/7.5 were ranked as low priority, and scores below 3 were ranked as very-low

Table 3
Example of template for documenting code relationships.

Endogenous variable	Influenced by	Direction	Sources	Illustrative quote
Demand for non-virgin materials	Reuse targets	+	Tingley et al. (2017) Gallego-Schmid et al. (2020)	"there could be a notice issued by the Local Authority Building Control requiring deconstruction and material salvage." Tingley et al. (2017)

Table 4
Overview of workshop participant role, area of focus and experience in construction/built environment.

Code	Area	Experience
C1	Policy Investigations (Circular Economy, Net Zero)	<5 years
C2	Construction materials	10–20 years
C3	Policy Investigations (Circular Economy, Net Zero)	<5 years
C4	Legislation (Building products)	<5 years
C5	Built Stewardship	5–10 years

priority. These evaluations were shared and validated by the stakeholders after the workshop. The final results are presented in Section 4.

4. Results

The results are presented in two parts. The first part presents the CLD in Fig. 4 which is coded thematically to improve readability. The variables and relationships in CLD in each thematic area are explained to reveal twelve policy leverage points and related recommendations. The second part presents the government/policy stakeholder evaluation and ranking of these recommendations based on their perceived impact, desirability and feasibility.

4.1. CLD variables and relationships

4.1.1. Design and testing loops

Reinforcing Loop 1 (R1) in the CLD shows that *technical guidance and design standards* are critical to increasing *industry capabilities* in designing with reused materials (Tingley et al., 2017), which in turn is expected to drive up *demand for BCR* (Benachio et al., 2020; Çimen, 2021; Hopkinson et al., 2019). Reinforcing Loop 2 (R2) also highlights that *design standards* will enable the appropriate *testing and verification* of materials and products for reuse (Gallego-Schmid et al., 2020; Tingley et al., 2017), and that this in turn will increase *safety and quality* (Byers et al., 2024; Cai and Waldmann, 2019; Hopkinson et al., 2019; Mayer, 2020; Nian et al., 2022) and reduce *stakeholder perception of risk* (Çimen, 2021), further enhancing the *demand for BCR*. The CLD also shows that *technical guidance and design standards* will increase the implementation of *Design for Disassembly* (*DfD*), hence *improving the technical ability to recover components* and boosting *supply of components for reuse* that is critical to BCR (see Loop 1 - L1). For example, Zhuang et al. (2023) identifies that improved guidance on topologically interlocking and modular component design is needed to ensure that components can be easily dismantled and reused. Hence the CLD clearly shows that, establishing robust CE design standards is critical to driving up both demand and supply of components for BCR.

⇒ Recommendation 1. Establish robust CE design standards that specify criteria for BCR.

4.1.2. Industry loops

Reinforcing Loop 3 (R3) shows that increased *industry education* and training is expected to increase *industry awareness* (Tingley et al., 2017; Victar et al., 2024), and in turn drive greater resource allocation to *industry education* and training. For example, Tingley et al. (2017) find that targeted steel reuse guidance and education for clients, structural

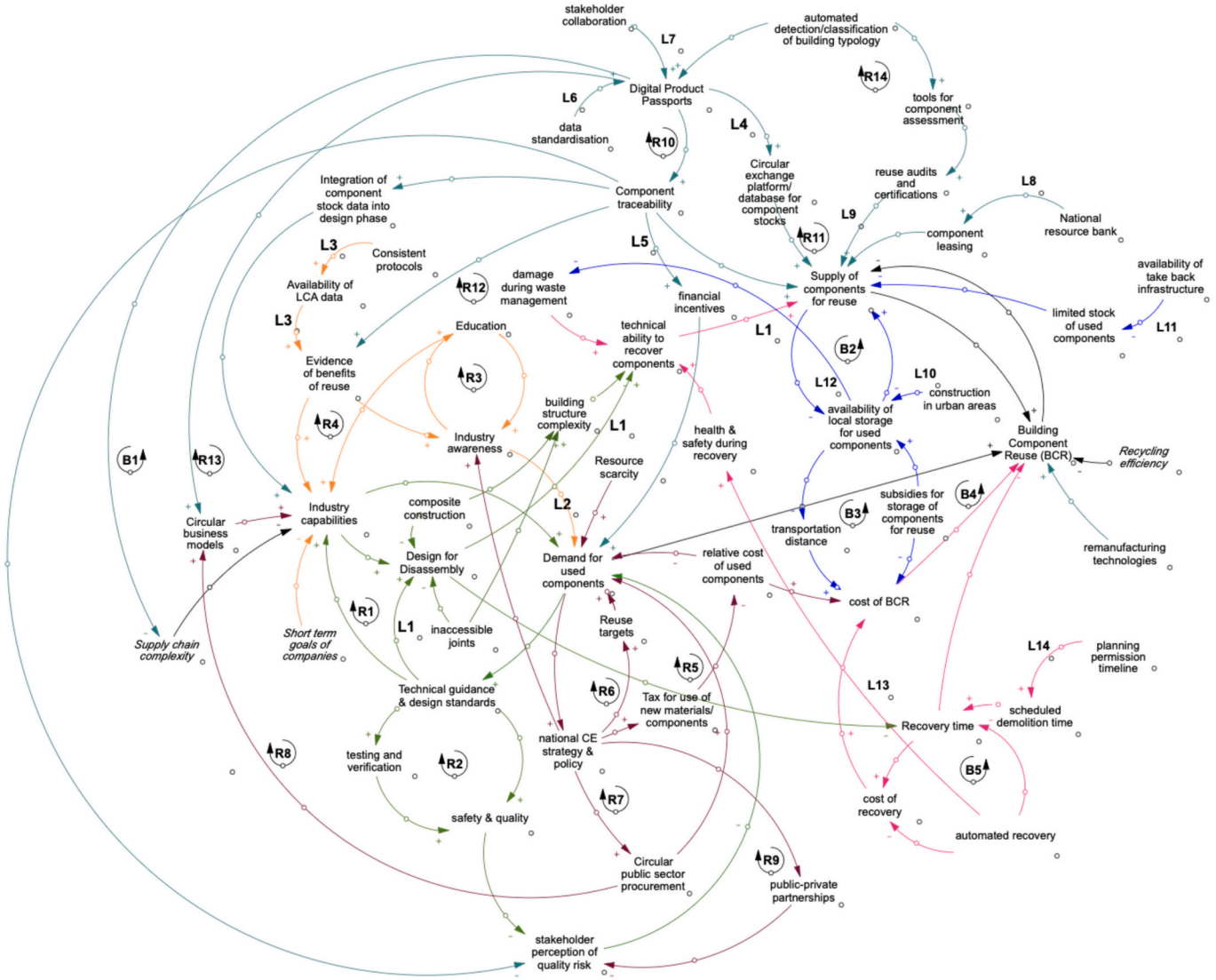


Fig. 4. Causal Loop Diagram of barriers and enablers to Building Components Reuse.

engineers, architects and contractors would help to improve industry awareness that steel reuse is possible, which is currently lacking. The CLD also shows that *industry awareness* will in turn drive greater *demand for BCR* (Çimen, 2021; Kanyilmaz et al., 2023) (see Loop 2 - L2). Azcárate-Aguerre et al. (2023) suggest that education and training is particularly important in the construction industry, as there is a deeply engrained culture and tendency towards short-term decision making and financial gain (Benachio et al., 2020; Tingley et al., 2017), which is not conductive to the adoption of CE practices as benefits to environment and society may be delayed (Çimen, 2021).

⇒ Recommendation 2. Allocate resources for industry education and training.

Loop 3 (L3) highlights that *evidence of the environmental benefits* of BCR is underpinned by the *availability of Life-Cycle Assessment* (*LCA*) *data* (Benachio et al., 2020), and that this LCA data requires the development of *consistent protocols* for evaluating the whole-life environmental impacts of BCR (Hartwell et al., 2021). Reinforcing Loop 4 (R4) shows that *improved evidence of the benefits of reuse* during the design stage is expected to increase *industry capabilities* when designing with secondary components (Hartwell et al., 2021), and simultaneously drive up *industry awareness* of CE options (Sanchez et al., 2019). In turn, both these factors are expected to drive up demand for BCR. As such, it is apparent that establishing consistent protocols for sustainability assessment (Recommendation 3) is an important leverage point for increasing demand for BCR.

⇒ Recommendation 3. Establish consistent protocols for sustainability assessment

4.1.3. Government loops

Reinforcing Loop 5 (R5) identifies that the *tax on use of new materials and components* would reduce the *relative cost of used components* (Benachio et al., 2020; Hill et al., 2023; Joensuu et al., 2020; Tingley et al., 2017), therefore reducing the relative cost of reuse and increasing *demand for BCR* (Derikvand and Fink, 2023; Mhatre et al., 2024; Nian et al., 2022; Victar et al., 2024). The literature underlines that both the actual and perceived cost of reuse is a major barrier to its uptake (Hopkinson et al., 2019). Byers et al. (2024) find that the greatest impediment to BCR is the perceived economic barrier, and similarly in an interview of quantity surveyors', Victar et al. (2024) find that cost is a major barrier to the adoption of CE practices, such as reuse. Increased cost may result from increased complexity associated dismantling (Derikvand and Fink, 2023; Hopkinson et al., 2019), storing or transporting materials and components (Zhuang et al., 2023).

⇒ Recommendation 4. Introduce a tax on use of new materials and components.

Reinforcing Loop 6 (R6) shows that *reuse targets* to mandate BCR will drive up overall *demand for BCR*. Hartwell et al. (2021) and Gallego-Schmid et al. (2020) put forward that legislating minimum targets for the use of reused or recycled products through the government or local planning authorities. Roberts et al. (2023) call for industry target values to be expanded beyond carbon emissions to include more holistic CE targets.

⇒ Recommendation 5. Set reuse targets to mandate BCR.

Reinforcing Loop 7 (R7) shows that *circular public procurement* will create a new market for BCR and increase *demand* (Çimen, 2021; Hill et al., 2023). It is expected that circular public procurement will incentivise the development of *circular business models* that in turn will enable industry capabilities in the circular economy that drive up demand for BCR (Reinforcing Loop 8 - R8). Hill et al. (2023) also suggest that government involvement in *public-private partnerships* will help to reduce *stakeholder perception of risk* that will in turn increase *demand* for non-virgin materials (Reinforcing Loop 9 - R9).

⇒ Recommendation 6. Establish a circular public procurement strategy and support for public
private partnerships.

4.1.4. Data and infrastructure loops

Reinforcing Loop 10 (R10) shows that implementation of *Digital Product Passports* (i.e. digital frameworks to record, store and disseminate material and component information) will improve *component traceability* which will in turn lead to better *integration of component stock data into the design phase*, therefore increasing *industry capabilities* and related *demand for BCR*, further incentivising the development of *Digital Product Passports*. The CLD also shows that *Digital Product Passports* can increase the supply of secondary components through the development of a *Circular Exchange platform*, enabled by component stock data (Sauter et al., 2018) (see Loop 4 - L4). Cai and Waldmann (2019) propose the concept of a (government facilitated) material and component bank which is established as an independent exchange service for accessing secondary raw materials for reuse or recycling. Reinforcing Loop 11 (R11) shows that such infrastructure is expected to directly increase the *supply of secondary components*, thus driving up *component reuse* (Çimen, 2021; Hopkinson et al., 2019; Nian et al., 2022).

Increased *component traceability* is also expected to improve *evidence of the benefits of reuse* (Reinforcing Loop 12 - R12). For example, Xing et al. (2020) claim that data on the maintenance, installation and disassembly methods, manufacture and material properties, as well as location of use, also serves as a critical parameter for assessing the environmental and economic implications associated with potential reuse. In turn, this is expected to further boost *industry awareness* and *demand for secondary components* (Benachio et al., 2020; Eberhardt et al., 2019; Hartwell et al., 2021). Additionally, Loop 5 (L5) shows that *component traceability* is critical to implementing *financial incentives* related to reuse. For example, traceability can confirm that reuse has taken place and a tax receipt could be issued automatically.

Reinforcing Loop 13 (R13) shows that *Digital Product Passports* are expected to support the development of novel *circular business models* (Azcárate-Aguerre et al., 2023; Benachio et al., 2020), which improve *industry capabilities*, thus driving *demand for BCR* and further incentivising the development of *Digital Product Passports*. Effective use of *Digital Product Passports* may help to reduce the perceived *supply chain complexity* in the built environment (Gordon et al., 2023), further improving *industry capability* to implement BCR (Balancing Loop 1). It is noted that both *data standardisation* and *stakeholder collaboration* are identified as important pre-requisites for the development of *Digital Product Passports* (see respectively, Loop 6 and Loop 7).

⇒ Recommendation 7. Develop robust and effective Digital Product Passports

Loop 8 (L8) in CLD shows that banks and public entities could form *national resource banks* to incentivise *material leasing*, thus increasing the *supply of secondary building components* (Çimen, 2021; Hopkinson et al., 2019; Nian et al., 2022). Resource banks are conceptualised as exchange hub that could enable buying and selling secondary raw materials or components and/or material and component leasing. In the latter, customers can rent a product for a set period and then opt to buy it outright or return it for reuse or recycling (Zhuang et al., 2023). The CLD shows that investment in such national resource banks could therefore increase BCR.

⇒ Recommendation 8. Support the development of a national resource bank

Additionally, Loop 9 (L9) shows that *reuse audits and certifications* will increase the *supply* of legitimate secondary building components that satisfy industry quality criteria. Tingley et al. (2017) suggests that

all buildings that register for demolition should be mandated to conduct a pre-demolition audit to determine available materials. Such reuse audits would be significantly enhanced by the development of new *tools for material and component assessment* and *automated detection and classification of building typologies,* as shown in Reinforcing Loop 14 (R14) (Mhatre et al., 2024; Victar et al., 2024). For example, Dai et al. (2024) propose a novel approach for estimating residential building material stock based on street view images and building foot print data. Similarly, Aldebei and Dombi (2021) advocate for the integration of new technologies such as building information modelling (BIM), geographic information systems (GIS) and artificial intelligence (AI) to *automate the collection of building data*. This *automated classification of building components* is also expected to increase the facilitation of Digital Product Passports (see Reinforcing Loop 14).

⇒ Recommendation 9. Develop standards for conducting reuse audits and issuing certifications

4.1.5. Transport and storage loops

The CLD shows that *construction in urban areas* presents a challenge for BCR since it reduces the availability of *local storage for secondary component* (see Loop 10). The availability of *local storage for secondary components* is identified as an important variable that can increase the *supply of components for reuse* (see Balancing Loop 2 – B2). The supply of secondary components itself is limited by the *availability of secondary materials* and the related *availability of take-back infrastructure* (see Loop 11 – L11).

Loop 12 (L12) also shows that *local storage* is also expected to reduce *damage to materials and components* by minimising risk of damage during transportation, thus improving the overall reuse yield (Mhatre et al., 2024). It is noted, however, that as the supply of secondary components increases there is likely to be a decrease in the *availability of local storage* (see Balancing Loop 3 – B3), which means that reuse materials will need to be *transported greater distances* (Hopkinson et al., 2019). This is expected to increase the overall *cost of component reuse* (Byers et al., 2024; Hamida et al., 2023) and will limit *component reuse* (see Balancing Loop 4 – B4). Under these circumstances, providing *subsidies for the storage of secondary materials* is identified as a key balancing variable which has the potential to increase the *availability of local storage* and reduce the overall *cost of component reuse* (see B3), therefore increasing *supply of secondary components* and overall *component reuse*.

⇒ Recommendation 10. Subsidies for storage of secondary raw materials

4.1.6. Recovery loops

The CLD shows that increases in *recovery time of components* are expected to reduce *component reuse*. Balancing Loop 5 (B5) shows that *automated recovery* is an important balancing variable that will reduce the associated labour *costs of building recovery* (Arora et al., 2020; Hopkinson et al., 2019) and *recovery time* (Cai and Waldmann, 2019; Lynch, 2022), reducing overall *cost of BCR*. *Automated recovery* is also expected to increase the *safety of component recovery*, hence improvement the *technical ability to recover materials* (Mhatre et al., 2024) and increasing the overall *supply of secondary components*, as shown in Loop 13 – L13.

⇒ Recommendation 11. Investment for the development of material recovery technologies

Finally, Loop 14 (L14) in the CLD indicates that adjustments to *planning permission timelines* for buildings may accommodate longer *scheduled demolition times*, which in turn increase the overall *time allocated for the recovery* of materials and components, thus increasing the reuse yield (Owojori et al., 2021).

⇒ Recommendation 12. Planning and building reform to mitigate against increased demolition times for material and component recovery

4.2. Stakeholder evaluation of policy recommendations

During the workshop each of the twelve policy recommendations was presented, discussed and scored (see Table 5). Fig. 5 shows the perceived impact, desirability and feasibility of each recommendation, and the classification of each recommendation as either high, medium, low or very low priorities. Based on these classifications, this section summarises the stakeholder evaluations of the policy recommendations.

4.2.1. High priority policy recommendations

The workshop identified that the most significant policy recommendations include the development of standards and fiscal incentives related to BCR. Firstly, stakeholders recognised that government could play a key role in setting and enforcing the development of robust Circular Economy design standards that specified criteria for reuse, and that these standards would be a pre-requisite for generating the industry confidence needed for widespread adoption of reuse. Related to this, standards for conducting reuse audits and issuing certifications were also identified as a priority, however there was disagreement about to the extent to which government should be involved in developing and enforcing reuse audit standards. Two of the five participants agreed that industry should lead on the development of such standards, whereas the remaining participants agreed that a government-driven initiative would improve process standardisation and resolve potential conflicts between industry practices.

Participants also demonstrated strong support for financial incentives. However, they expressed preference for a more nuanced and phased approach to implementing any taxes on virgin materials, for example using trading schemes to create an overall cap on use of virgin materials/components instead of a direct tax. It was also pointed out that industry levies and subsidies should be carefully balanced so that government did not seem to be actively profiting from BCR. Setting reuse targets to mandate BCR was recognised as another high-impact leverage point. To facilitate this, the stakeholders highlighted the importance of material and product traceability, as well as industry education to increase compliance with reuse targets and government enforcement of such targets.

4.2.2. Medium priority policy recommendations

The data reveals that investment in technology is perceived to be a medium priority for enabling BCR. Stakeholders recognised the significant potential impact that Digital Product Passports could have on improving traceability and increasing BCR. However, the implementation of such frameworks was considered to be technically challenging, particularly with respect to data standardisation. Whereas the literature suggests that the establishment of Digital Product Passports should be government-led, the stakeholders reported concerns that this would be technically outside of the scope of government and should be industry-led, albeit with some support from government in coordination. Investments in the development of material recovery technologies was recognised as being well aligned with the government's current funding strategy. However, there was some also some concern about whether elimination of more labour-intensive recovery processes could jeopardise potential job creation and it was suggested that further evidence was needed to justify this.

4.2.3. Low priority policy recommendations

The stakeholder evaluations ranked the establishment of consistent protocols for sustainability assessment as fairly desirable, however this recommendation was viewed as being less impactful as compared with

Table 5
Stakeholder Evaluations of Policy Recommendations.

Policy recommendation	Impact (×1)	Desirability (×1)	Feasibility (×0.5)	Score	Priority category	Illustrative quotes
1. Establish robust Circular Economy design standards that specify criteria for reuse	3	3	3	7.5	High	"If there are any concerns with building on the basis of using reused materials, that's going to be a huge blocker…if there were a set of design standards for non-virgin construction products this would radically increase confidence." (C1) "When I was asked about this topic my immediate thought was 'what about material specifications and standards?'" (C1).
2. Allocate resources for industry education and training	2	2	2	5	Medium	"Any investment in training will be secondary to the more hard levers… this should come later down the track… it's something that will come alongside something like targets or tax incentives to drive circular outcomes" (C1). "I interpret this about expanding or developing a market" (C2). "How do you get streamline training to make sure it's consistent… people need practical tools to be able to apply these principles" (C3).
3. Establish consistent protocols for sustainability assessment	1	2	1	3.5	Low	"I think auditing provides assurance to people who are active in the market who wants to do the good thing, to do the right thing" (C2), "Auditing [is important] both to prove that circular economy principles are effective … but it has to be in place in a broader framework… you can train people and tell people this is good, but without a bit more carrot and stick on either side, it doesn't necessarily get the outcomes you're after" (C1). "Data needs to be open and shared although this poses quite of lot of privacy and security issues" (C3).
4. Introduce a tax on the use of virgin materials	3	2	2	6	High	"There is already a lot of evidence that fiscal incentives work in waste management" (C3). "There would need to be a transition period to ensure that you've got access to the proper materials available… it loops back into knowing for certain that the products are safe to use from a reuse perspective. There would be a lot of things that you'd have to be quite certain on before you put higher sort of tax burdens on those products." (C5) "There is a reticence to do direct taxes" (C1)." You could put £50/tonne levy on new extracted aggregates, and counter that with £50/tonne subsidy per tonne on recycled or reused aggregates, so the levy measure is overall simple and cost neutral." (C2).
5. Set reuse targets to mandate component reuse	3	2	2	6	High	"It would be more powerful tool if inclusion of a proportion of reused products became a mandatory requirement, because then you would need an audited assurance trail for them for the material that you use" (C2). "it's just how you put it in place to make sure it's respected… how we would create those targets, and also how you would then track them consistently to make sure that people aren't using different ways of reaching those targets" (C4).
6. Establish a circular public procurement strategy and support for public-private partnerships	1	1	3	3.5	Low	"It's an easy lever, and it's always turned to as the thing to go for because we can control it, but the how effective it is, is another question." (C1) "Auditing [is important] both to prove that circular economy principles are effective … but it has to be in place in a broader framework… you can train people and tell people this is good, but without a bit more carrot and stick on either side, it doesn't necessarily get the outcomes you're after" (C1). "Data needs to be open and shared although this poses quite of lot of privacy and security issues" (C3).
7. Develop robust and effective Material Product Passports	3	2	1	5.5	Medium	"The largest obstacle is trying to create a database that is consistent" (C3) "This probably going to be something that bigger companies are going to have the capacity to do as opposed to smaller companies" (C3). "I'm not sure how much government would want to be involved." (C3); "You could think about it being government led potentially, but there's many complications with that. I think the question is how far do we get involved with industry… if we don't at all you're potentially having lots of different databases" (C4).
8. Support the development of a national resource bank	1	1	1	2.5	Very Low	"This would be a significant intervention for the state… If it's economically viable, then a company will provide this function and government shouldn't have to do it." (C1); "If we're shaping the market, this proposal should not be necessary" (C2)."

(*continued on next page*)

Table 5 (*continued*)

Policy recommendation	Impact (×1)	Desirability (×1)	Feasibility (×0.5)	Score	Priority category	Illustrative quotes
9. Develop standards for conducting reuse audits and issuing certifications	3	2	3	6.5	High	My first thought is that if something goes wrong, like a safety issue, who's responsible for that?" (C3). "There needs to be a mechanism to verify that C16 or C24 certified timber still has structural integrity years later" (C5), "We want industry to lead and to own the risk they create. They should lead on developing the mechanisms for assurance, particularly when innovative products are used… Government's role is perhaps to coordinate and convene, but it's for industry to lead on developing these standards" (C1), "Government has for a long time placed an emphasis on industry-led audit and certification. But in the back of my mind, there's an old saying: 'who polices as a policeman?' An industry-led auditing and certifications team could work but how does society know that it's any good?'" (C2). "If industry were to create something, how are we going to get everyone on the same page? How are we going to make sure all of the measures are consistent?" (C3).
10. Subsidies for local storage and reverse logistics	1	1	2	3	Very Low	"This is an obstacle but it's not going to unlock the whole system" (C3) "We need to have a better idea of whether these products are likely to be reused or not [before we invest]" (C4)." If it is viable, then people will build extra storage." (C1).
11. Investment for development of material recovery technologies	2	2	3	5.5	Medium	"I can imagine this sort of tech accessing a net zero innovation grant fund of sorts… particularly if there's an AI element, which is currently aligned with government's funding strategy" (C1).
12. Planning and building reform to mitigate against increased demolition times for material and component recovery	1	1	2	3	Very Low	"Recovery of materials from a demonstration site is part of the normal project planning process that a developer would plan for, and they are recovering a material that has economic value" (C2) "If they're recovering something that has economic value to them, they are incentivized to do that properly. If we start subsidising or changing the regulatory framework that allows them to cut corners, then are we actually delivering the benefits of the policy?" (C1).

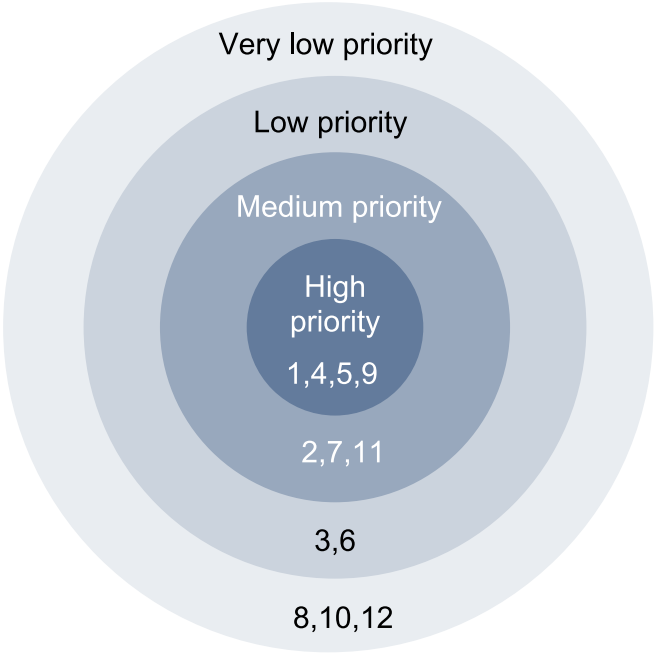


Fig. 5. Priority categorisation of the policy recommendations.

other levers. There were also some concerns around the feasibility of implementing sustainability assessment protocols, particularly with respect to data privacy and security. The establishment of a circular public procurement strategy and support for public-private partnerships was viewed as a low priority by the stakeholders. The impact of circular public procurement was considered by the stakeholders to be limited, since the vast majority construction in the UK is in the Private sector. This feedback is in some ways promising as it suggests appetite for more far-reaching BCR infinitives that go beyond the public sector.

4.2.4. *Very low priority recommendations*

Despite strong support in the literature for local storage to minimise reverse logistics challenges, government stakeholders largely rejected the idea of subsidies for the storage of secondary materials and components. It was assessed that the impact of such a policy would be minimal, and concerns were raised regarding the cost-effectiveness of such policy. Stakeholders agreed that if there was value in local storage, then industry should be able to fund such capacities. Similarly, there was no support for the development of a national resource bank among the stakeholders. Government stakeholders indicated that this would pose significant feasibility challenges and exceed the scope of government responsibilities. Finally, stakeholders did not agree with the recommendation for planning and building reform to accommodate increased demolition times for material and component recovery. The workshop participants emphasised that such amendments to planning and building reform were unnecessary since there should already be an established process for value capture embedded in the BCR process.

5. Discussion

The need for greater policy support for BCR is widely reported on in the literature (More and Dorpalen, 2023; Abadi and Moore, 2022; Huuhka et al., 2015; Hradil et al., 2014). Whilst some material/component specific BCR standards already exist, for example SIS-CEN/TS 1090-201:2024 which provides guidelines for reuse of structural steel in Sweden (SIS, 2024), and NS3682 which specifies standards for hollow core slabs in Norway (Standards Norway, 2022), the workshop

data confirms that the development of more comprehensive and universally applicable standards for BCR is a key priority to cover all material types. These standards should build on ISO Standard 59000:2024 Circular economy — Measuring and assessing circularity performance (ISO, 2024a) and ISO Standard 20887: 2020 which focuses on design for disassembly and adaptability (ISO, 2020a, 2020b). Whilst the latter sets out a mandate for BCR by encouraging modular construction, easy separation of materials and reversible connections, it fails to provide a detailed reuse assessment criteria and clear methodology for designing buildings for deconstruction (Anastasiades et al., 2024). Similarly, Derikvand and Fink's (2023) study on design for deconstruction for timber-concrete composite floors finds that current guidance under ISO Standard 20887:2020 lacks specific details regarding expected performance levels, and Eberhardt et al. (2019) observe that whilst ISO Standard 14044 standard fail to explain how reuse and related material changes should be implemented. Whilst this study confirms there is an urgent need for a standardised framework for evaluating the durability and safety compliance of secondary components, it is important to acknowledge that several initiatives are already underway. For example, national efforts in Sweden and Denmark are progressing towards standards for precast concrete element reuse, that includes criteria for estimating load-bearing capacity to ensure safety and quality of BCR (Swedish Institute for Standards, n.d.; Danish Technological Institute, n.d.). Future work should expand on these efforts and be translated into standard and legislative requirements for a broad range of materials/components. The stakeholders viewed the lack of standardised methodology for measuring the environmental impacts of BCR as relatively less important. This contrasts with views in the literature that strongly criticise existing policy for its failure to provide sufficient guidance on measuring circularity and monitoring CE adoption in the design of existing building stock (Fernandes and Ferrão, 2023).

The workshop data also strongly agrees with the literature that technology is a critical leverage point for BCR. The literature highlighted a range of technology applications with respects to BCR, including: integration of BIM for lifecycle management and traceability (Cai and Waldmann, 2019); 3D scanning for assessment and inspection of components (Gordon et al., 2023; Byers et al., 2024); blockchain for management of component ownership across the life-cycle (Shojaei et al., 2021); and, robotics and automation for non-destructive disassembly of buildings (Arora et al., 2020; Hopkinson et al., 2019). Among these technology applications, the workshop data highlighted that improving the traceability of components was a key concern for enabling BCR. In part, this may be influenced by upcoming EU legislation on Digital Product Passports which highlights construction industry as one of the first four sectors to adopt requirements (European Commission, 2022). It is noted that the Product Circularity Data Sheet in ISO Standard 59040:2025 supports transparency (ISO, 2025a, 2025b), however these standards do not provide practical guidance how to integrate digital tracking systems such as Building Information Modelling (BIM) or Digital Product Passports that are needed to enable real-time traceability. Successful implementation will likely depend on complementary frameworks or technical guidelines that support better alignment between data standards and digital tools. The government stakeholders recognised the challenges of developing these systems for complex, multi-component buildings, and echoed calls for greater data standardisation to underpin these systems (Gordon et al., 2023). The workshop data also confirmed the role of economic incentives as a 'hard lever' to steer the construction industry towards CE. Whilst economic incentives are one of the most mentioned drivers for industry adoption of BCR in the literature (Hill et al., 2023), it is also noted by some authors that the implementation of such policies, without the development of supporting infrastructure, will lead to poor uptake of CE practices. For example, Giorgi et al. (2022) find that although legislative frameworks are moving towards the elimination of landfilling through increased taxes, an organised system of traceable material and component flows is not established, leading to a policy-practice action gap. The literature also encourages careful development of economic incentives and targets to avoid sustainability rebound effects. For example, Huuhka et al. (2015) points out that current targets under the Waste Framework Directive (EU, 2008, p.10) place a strong emphasis on the recycling of heavy mineral materials because of the 70 %-by-weight utilization target for construction and demolition waste. It is therefore critical that the implementation of any reuse targets is carefully considered to avoid unintended negative sustainability impacts. In France this is addressed through the implementation of RE2020 which promotes the reduction of embodied carbon in new buildings and encourages but does not mandate BCR (Ministère de la Transition Écologique, 2021).

Whereas improving industry education and awareness and sustainability assessment of BCR are frequently mentioned in the literature (Byers et al., 2024; Karaca et al., 2024), the workshop data shows that this policy recommendation is less of a strong lever and should be implemented to complement already discussed high priority policies. The findings also show that reforms to the planning system, local subsidies for storage of building components and the development of a national resource bank are not viewed as desirable policy recommendations. This is perhaps explained by the fact that although ISO 59010: 2024 focuses on transitioning business models, it does not provide adequate guidance on handling reverse logistics, storage and redistribution of components (ISO, 2024b). It is worth pointing out that these initiatives have been implemented successfully in other countries, for example Opalis is a regional platform in Belgium, France and the Netherlands that operates a marketplace and database for reusable components (Opalis, n.d.). Challenges related to transportation, cost and contamination of components remain unaddressed (Bergsagel and Heisel, 2023) and the findings show that these considerations are undervalued by government and policy makers. More broadly the findings point out that the role and responsibilities of government and industry need further clarification. Whereas the literature tends to place a significant emphasis on the role of government in leading solutions within a relatively fragmented ecosystem (Hjaltadóttir and Hild, 2021), the workshop data reveals the expectation that many of these solutions should be industry-led and that government is better suited in a coordinating role.

The latter view could however be justified, considering the gap between policy and practice on BCR that is observed by several authors. For example, Kummen et al.'s (2024) study of a Finnish municipality finds that although there are strict governmental requirements for dismantling and sorting materials and components, Finland lacks any standardised data register or digital platform, highlighting that regulation has not effectively incentivized implementation. Giorgi et al. (2022) also report similar findings and also find that in Denmark the reuse of building elements in industry practice is advancing ahead of legislative framework, which shows that policy is not the sole driver of industry adoption of BCR. Huuhka et al. (2015) also find in their analysis of Finnish precast concrete panels that standardisation of components was already embedded within the culture of the building industry even though this was not mandated in policy. To this extent, Yu et al. (2022) puts forward that there could be a mismatch between policy agenda-setting and policy implementation, and a balance of government and industry responsibility is needed to reconcile this mismatch. Their proposed policy-making cycling encourages participatory alignment between different stakeholders through an iterative process of developing integrated CE policy.

Overall, it is likely that a range of policies and supporting mechanisms are needed to enable BCR. The workshop revealed that even the policy recommendations that are ranked as medium or low priority are still considered to be important supporting policies, alongside the enforcement of appropriate design and quality certification standards, financial incentives and implementation of technology solutions. Similarly, the literature echoes these views that a range of policies and mechanisms are needed (Benachio et al., 2020). Eissa and El-Adaway (2024) advocate for a comprehensive CE policy that combines various

aspects of the building lifecycle. Whilst this study has focused exclusively on BCR, it is noted that there is some perceived tension between reuse and recycling policies (Çimen, 2021) and that industry still defaults to recycling over reuse. For example, Huuhka et al. (2015) found that although survey respondents from industry were asked to distinguish between reuse from recycling, almost none of them did so. A more recent study by Giorgi et al. (2022) also find that recycling takes preference over reuse. Interestingly, Eissa and El-Adaway's (2024) modelling of various CE scenarios for US building stock found that landfill diversion scenarios, including BCR, had the least cumulative emissions reduction compared with other policies focused on unit size reduction and carbon intensity reduction. Hence, it is recommended that the combination of multiple CE strategies emerges is the impactful approach for reducing waste and decarbonising the building sector.

This study has some limitations which must be taken into account. Firstly, this study considers BCR in general and does not focus on a specific type of building component e.g. building facades or material e.g. steel, concrete, timber. It is noted in the literature that different materials may have particular reuse barriers (Yang et al., 2020), and this may have been overlooked in this study. We suggest that follow up studies could examine BCR for components or materials. Secondly, this study has focused exclusively on BCR and does not consider component reuse in the built environment more broadly (e.g. roads, bridges) which means that some insights may have been missed. Other studies may wish to expand the system boundary in the study to examine a broader set of drivers and enablers to BCR, and also further examine the relationship between reuse and other CE strategies such as recycling. Thirdly, this study has focused on developing this model with the perspective of government and policy makers in the UK. A limited number of stakeholders (5) participated in evaluating the policy recommendations set out in this study and there is the possibility that their views could be biased based on their role or experience. Whilst other studies have used a similar number of participants in CLD formulation and evaluation (e.g. Mohamad-Ali et al., 2024), we recommend that further studies are replicated, including with stakeholders in other policy contexts e.g. EU, US and China where there are significant advances being made on CE policy. Finally, it should be noted that any model is only a "provisional representations of reality" (Corsini and Moultrie, 2022) which is "useful for guiding further study, but are not susceptible to proof" (Oreskes et al., 1994). All systems models are inherently subjective and we encourage other researchers to develop and edit our CLD, and indeed to update it as the CE policy landscape evolves. Further research should also be taken to evaluate the policy recommendations from the perspectives of other stakeholders not included in this study (e.g. with industry or citizens), and elaborate on how the policy recommendations identified in this study could be practically implemented. As the field matures, we also call for greater evaluation of CE policies in practice.

6. Conclusion

Resource scarcity and pressure to decarbonise the construction industry has driven the creation of policy on the CE around the world. Reuse is a particularly promising CE strategy, as it is offers the potential to significantly reduce energy use and carbon emissions. Despite this, reuse is not being widely embedded within building design and there remains limited understanding about how policy makers can incentivise BCR. Hence, this study sought to identify key policy recommendations to increase BCR. Applying a systems dynamics approach, this study conducted a detailed literature review to develop a CLD to model the factors enabling and constraining BCR, and the relationships between these factors. The CLD was analysed to identify key leverage pointed and related policy recommendations which were evaluated by policy/government stakeholders in the UK and ranked according to their perceived impact, desirability and feasibility.

Overall, this research has made several contributions to knowledge. It has improved our understanding of the interrelated factors that enable and constrain BCR. It adds to the existing literature on Circular Economy by demonstrating the capabilities of a systems approach to studying phenomenon which is urgently needed in the sector. Moreover, it identifies and evaluates twelve policy recommendations that could increase BCR in the UK. It highlights the need for more robust standards and guidance on the design and quality assessment of building components for reuse, the enforcement of financial incentives and related reuse targets, and the development of technology-based solutions for the effective evaluation, recovery and traceability of building components. It also finds that industry education and awareness, establishing consistent protocols for sustainability assessment of BCR and public procurement strategies can increase adoption of BCR. The findings highlight the policy-practice action gap and raise questions as to whether BCR initiatives should be industry or government-led. Further collaboration between government and industry is recommended to establish their respective roles and responsibilities in the development of CE policies and practices. Overall, it is likely that a range of policies and supporting mechanisms are needed to enable BCR. Further research could address the development of policies on BCR in relation to other reuse strategies such as adaptive reuse and other CE strategies such as recycling.

CRediT authorship contribution statement

Lucia Corsini: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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.

Acknowledgements

The author was supported by the UK Universities Climate Network to undertake a secondment to UK Government Department of Levelling Up, Housing and Communities between February–May 2024 during which they collected the data for this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2025.05.019.

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