Resources, Conservation & Recycling Advances 19 (2023) 200169

Contents lists available at ScienceDirect

Resources, Conservation & Recycling Advances

journal homepage: www.sciencedirect.com/journal/Resources-Conservation-and-Recycling-Advances

Systematic review on stakeholder collaboration for a circular built environment: Current research trends, gaps and future directions

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ARTICLE INFO

Keywords:
Circular economy
Sustainability
Construction
Built environment
Stakeholder collaboration

ABSTRACT

Construction is one of the most impactful sectors in the use of resources, while having a complex network of stakeholders. To drive towards sustainable development, implementing circular economy (CE) principles in construction projects by connecting stakeholders has become a priority. This research explores the current trends in CE-research in construction and identifies gaps for future directions in connecting stakeholders for CE. Hence, a systematic literature review (quantitative and qualitative) was undertaken. The quantitative analysis identified a gradual increase of CE research in construction. The qualitative content analysis revealed that there is a tendency to adapt various models/frameworks, actions for CE adaption, strategies for stakeholder collaboration, and, digital technologies to connect stakeholders for CE. Lack of promoting CE is a key challenge that needs to be addressed for efficient stakeholder collaboration. Blockchain, could be an enabler for effective stakeholder collaboration for CE in construction and will be the way forward.

1. Introduction

The traditional linear economy focuses on the 'take, make, dispose' production model. However, the traditional linear economic model is reaching its tipping point, limiting the supply of inputs for mankind that needs sustenance (Sariatli, 2017). According to Magazzino et al. (2021), the traditional economy is slowly shifting towards a circular economy (CE). CE assists in achieving a sustainable built environment by improving resource efficiency and effectiveness and reducing resource use and waste to lower the environmental impact (Jansen et al., 2020). Effective collaboration of key stakeholders is vital to achieve circularity and minimise negative sustainability impacts during the whole lifecycle of a construction project (Leising et al., 2018).

The construction industry has a significant impact on the environment. It produces around 10 billion tonnes of construction and demolition (C&D) waste each year and has a low waste recycling or reuse ratio (Leising et al., 2018; She et al., 2020). The CE concept is used in the construction sector to recycle C&D waste. However, there is still a need to incorporate CE during the design stage to promote the reuse of materials and resources throughout the whole lifecycle (Adams et al., 2017). Buildings should be designed to preserve their reusability and value until the end of life (Senaratne et al., 2021). KPMG (2020) stated that Australia has the potential to embrace circularity by producing 70% of buildings as energy-efficient buildings by 2028.

In a linear construction supply chain, stakeholders have already encountered challenges related to lack of information transparency, fragmented value chain and lack of agreement. These stakeholders, which included manufacturers, suppliers, subcontractors, contractors and so forth, have identified a considerable amount of rework and waste as the main consequence (Chen et al., 2020; Love et al., 2004). On the other hand, in a circular form of construction, these challenges are magnified because additional players (such as demolition contractors and recycling plants) add another layer of complexity to the supply chain network (Chen et al., 2022).

There is a growing body of CE research in construction. Most studies have mainly analysed the implementation of CE from a process perspective, focusing on materials and waste management (for example, Chen et al. 2022; Munaro et al. 2020). They have identified some stakeholders involved in a circular model in the built environment and even highlighted the importance of promoting stakeholders' collaboration. However, these studies have not fully explored stakeholders' collaboration in CE. Therefore, the following research question was

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https://doi.org/10.1016/j.rcradv.2023.200169

Available online 6 July 2023

identified and addressed in this paper: What are the current research trends and gaps related to stakeholder collaboration for CE? The following section explains the research methods adapted. The research findings are presented in Section 3. Finally, the conclusions of the study are offered with further research directions.

2. Research methodology

This study aimed to explore current research trends, gaps and future directions on stakeholder collaboration towards a circular built environment. To achieve this aim, a systematic literature review was carried out in two parts, a quantitative analysis using bibliometrics followed by a qualitative content analysis. Systematic literature reviews are commonly used in construction and can identify critical trends and gaps in literature by achieving the best evidence-based answers to a specific question (Belayutham et al., 2016; Ayodele et al., 2020). Data is synthesised and extracted from the literature after exhaustive planning, evaluation and identification of the available resources (Ayodele et al., 2020). Considering the available systematic literature review protocols, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were selected as the most suitable framework.

PRISMA can be used to produce evidence-based outcomes with improved quality in the review and transparent literature selection process (Moher et al., 2009). According to Moher et al. (2015), PRISMA has a methodological and analytic approach that is clear and easy to understand. PRISMA has evolved through time to cover conceptual and practical advances within systematic reviews and as an answer to the lack of optimal reporting from a meta-analysis. The protocol is suitable for large academic literature databases, screening information and evaluating the eligibility of relevant literature (Shahruddin and Zairul, 2020). Several research studies related to construction/built environment, including Ayodele et al. (2020), Shahruddin and Zairul (2020), have used PRISMA to conduct their systematic literature review. The PRISMA framework developed for this study is presented in Fig. 1.

The main search string used to retrieve bibliometric data related to the research area of concern was: ("Circular economy" AND "stakeholders") AND ("construction" OR "built environment"). An initial search using Scopus and Web of Science databases was done for all fields and received 2012 documents. The number being too high made it difficult for a detailed analysis. Due to time and resource limitations, the search criteria were limited to 'Article title, Abstract, Keywords' and the date range '2011 to 2021′. This resulted in identifying 119 publications (after removing duplications) as of September 2021, which were included in the quantitative analysis carried out using bibliometric software, VOS Viewer and manual analysis.

From the 119 papers, inclusion and exclusion criteria were decided to identify the most relevant papers and conduct a qualitative content analysis. The product-related papers, non-construction related papers and papers that did not focus mainly on CE were excluded, while the management-related papers were included in this analysis. Accordingly, 54 papers out of 119 were shortlisted. The content analysis was used to review the paper's contents thoroughly in broader themes such as (1) models and frameworks in CE; (2) actions for CE adaption; (3) strategies for stakeholder collaboration for CE; and (4) the potential use of various digital technologies to improve CE. The research findings are presented under the two sections in 'Findings and Discussion' section.

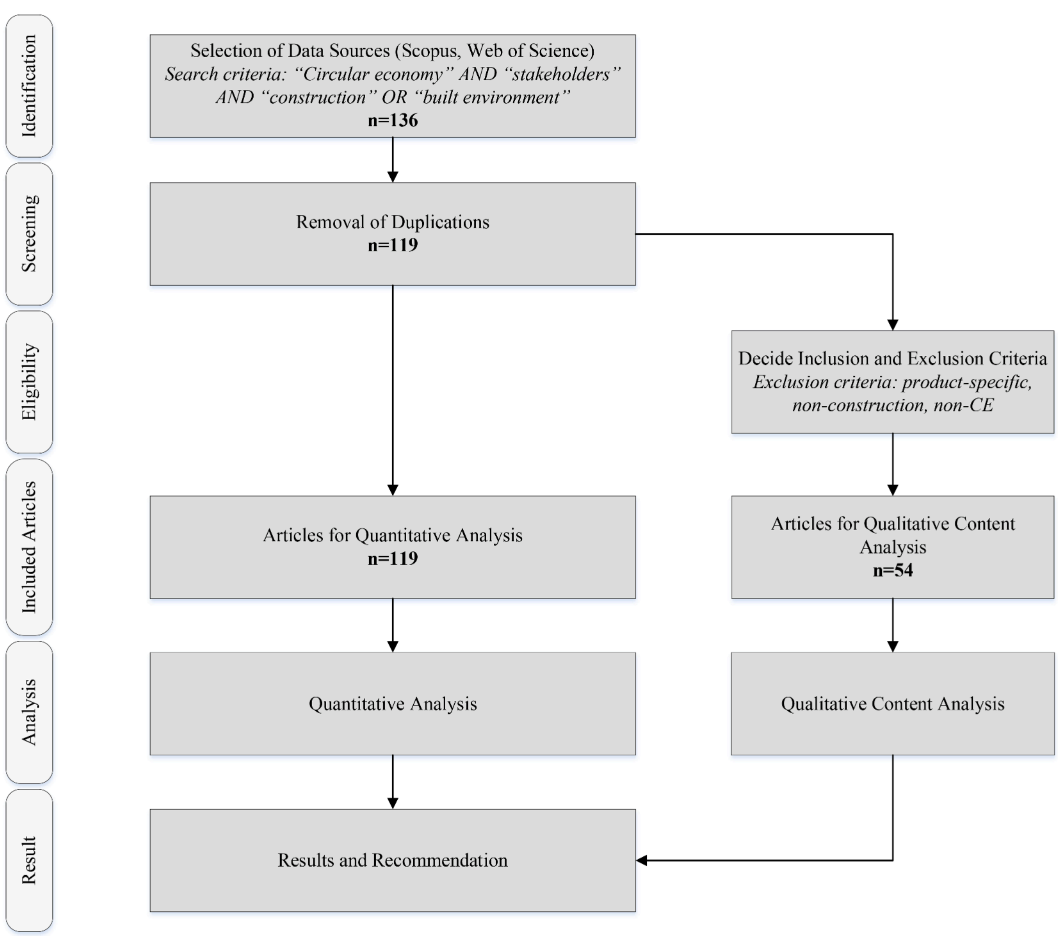

Fig. 1. PRISMA protocol for the systematic review process.

3. Findings and discussion

3.1. Bibliometric analysis through quantitative systematic literature review

3.1.1. Mapping of research areas/keywords and countries

VOS Viewer was used to develop the bibliometric network for the keywords used in the research area focused on this study. A cleaning process was carried out to remove duplicates (some singular and plural terms were repeated), and the final output is displayed in Fig. 2.

The most popular keywords found in the selected research articles have been presented in Fig. 2. The size of the nodes indicates the usage of keywords, while the links represent the co-relation between keywords. The biggest node represents 'circular economy', indicating that it is the most commonly used keyword in the selected data set. Keywords such as construction industry, sustainable development, recycling, built environment and waste management have been considered as the next level in popularity and demand. One of the key areas discussed in this paper, 'stakeholder', falls in the next level emphasising its importance to be explored. A bibliometric analysis was carried out on stakeholder involvement for CE in construction/built environment. The legend demonstrates the timeline of published keywords. The current trend towards research on circular economy, stakeholders, sustainability and so forth can be clearly seen in Fig. 2. A timeline was generated to demonstrate the current dominant research areas related to stakeholders and CE in construction, as demonstrated in Fig. 3.

According to Fig. 3, concepts related to circular economy and stakeholders have been researched in very recent years. Especially construction and demolition waste, reuse, economic conditions, waste management, and sustainable development, amongst others, have been focused in the recent past. Before that, focus has been more towards sustainable construction and economy in general. This indicates more tendency towards these research trends, emphasising why this study was carried out to explore the current research trends and gaps on stakeholder collaboration towards CE.

A bibliometric network to demonstrate countries that have worked on this research area was produced using VOS Viewer, as shown in Fig. 4.

Fig. 4 indicates that the UK, followed by Italy, has conducted most research. Countries such as the Netherlands, US, Spain, France and Australia are not far behind. However, out of all publications related to this area, only one conference paper published by Senaratne et al. (2021) has discussed the importance of stakeholder collaboration in adapting CE principles for sustainable construction. There is a clear gap in the investigated research that indicates the importance of exploring this research area.

3.1.2. Annual trend of publications and prominent publishers

The annual publications in the selected research area were analysed to observe its trends, as illustrated in Fig. 5.

Fig. 5 demonstrates the annual publications on CE. The orange line indicates the publications on CE in construction/built environment, while the blue line indicates the publications related to stakeholders for CE in construction/built environment. According to Fig. 5, the graph on CE shows an exponential increase after 2016 displaying the tendency towards research in this area. Though we considered publications after 2011, publications related to 'stakeholders for CE' commenced only after 2014. In 2014, one journal publication was done, followed by a gradual increase every year, with a peak of 41 publications in 2020 and 34 in 2021 (as of September). Within the last 3 years, the focus in this research area has increased massively, emphasising the importance of research in stakeholder collaboration in CE.

The prominent research publishers in the forms of journal articles (91 in total) or conference manuscripts (28 in total) have been presented in Table 1.

It is observed that sustainability focused journals that are beyond construction discipline are the key contributors in CE-related construction research. The above quantitative analysis of systematic literature review assisted in offering a holistic picture of current CE research in construction to achieve the aim partially. A content analysis was carried out next to achieve the aim fully, as discussed next.

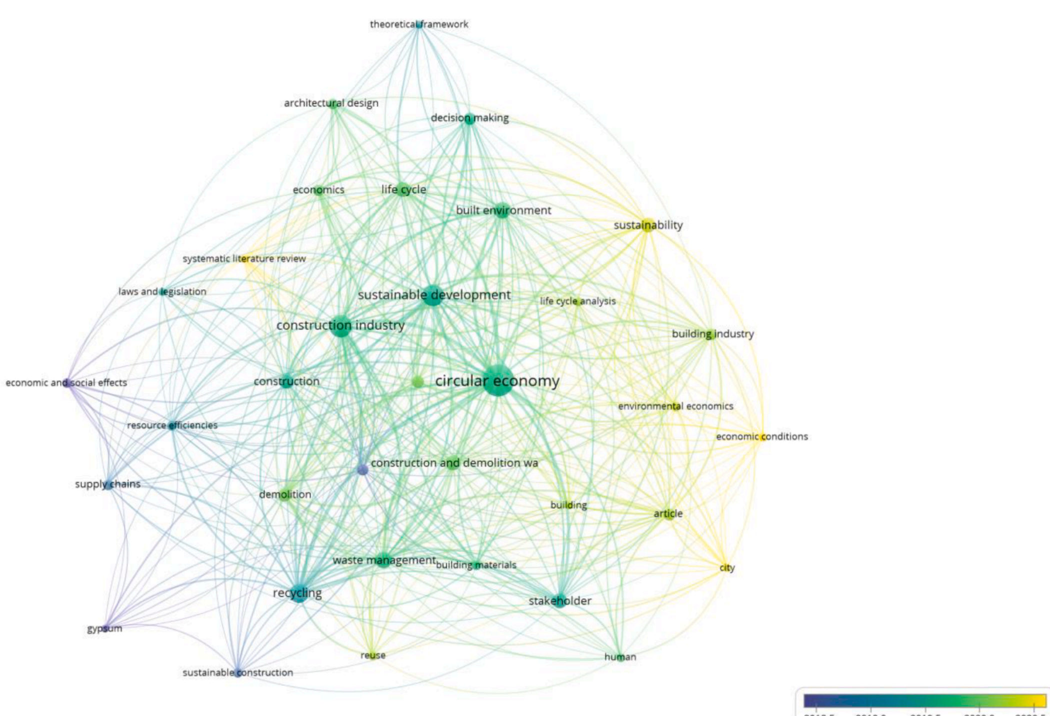

Fig. 2. Network of keywords on stakeholders for circular economy in construction.

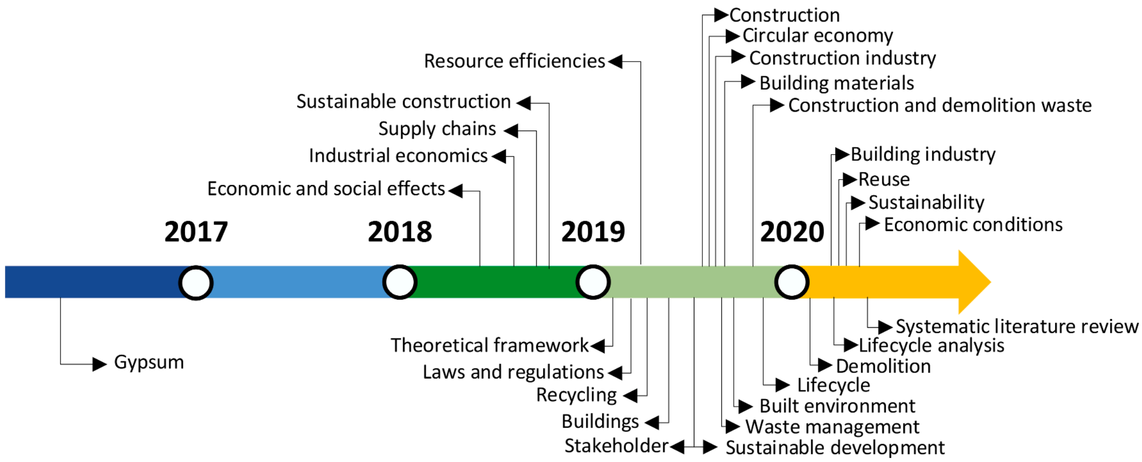

Fig. 3. Timeline of dominant research areas related to stakeholders and circular economy in construction.

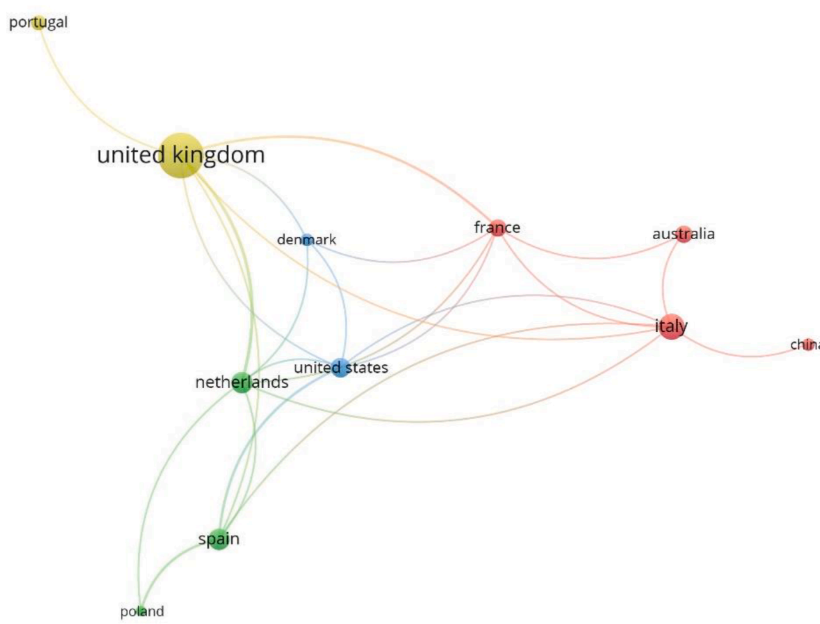

Fig. 4. Countries researching on stakeholder involvement in circular economy.

3.2. *Research trends in CE through qualitative systematic literature review*

Several research trends were identified through the content analysis of the selected 54 papers and summarised in Table 2.

The above-identified research trends have been discussed in detail under 4 themes, (1) models and frameworks related to CE, (2) actions for CE adaption; (3) strategies for stakeholder collaboration for CE; and (4) potential use of various digital technologies for improvements in CE, in Sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4 respectively. Then, in Section 3.2.5, future research directions by identifying gaps in current research are discussed.

3.2.1. *Models and frameworks related to CE*

A **CE framework and stakeholder network** representing the construction sector was developed by Volk et al. (2019) to capture the material stocks and flows, relations, conflicting relations and adversarial leverages. Stakeholder networks are commonly neglected and, along with them, their impact on the decision-making process, materials demand and policy measures, or simply identifying who they are. This leads to an incomplete understanding of the demand and supply for recycled C&D waste and the material stocks and flows system (Volk et al., 2019). Moreover, construction projects involve several parties and processes that interact temporarily, with different levels of interest, sometimes lacking in information on their duties and roles which leads to time delays and cost overruns, making construction projects complicated and inefficient (Yang et al., 2009).

Volk et al. (2019), to address this problem, started by identifying the main stakeholders involved in construction, targeting the production, consumption and reduction economy of materials. Stakeholders were divided into four main groups: 'public authorities', 'clients and owners', 'planners and construction companies', and 'recycling, demolition and disposal companies and construction material manufacturers'. Then influences and conflicts of interest amongst stakeholders were identified from environmental, financial, customer, staff and development, and process perspectives. The research considers building lifecycle and stakeholder levels and their effective influence during building lifecycle stages. However, the current models lack validation on both national and regional levels (Wu et al., 2014). The collaboration amongst different stakeholders will not only improve the transparency of construction processes but also increase the level of trust amongst all

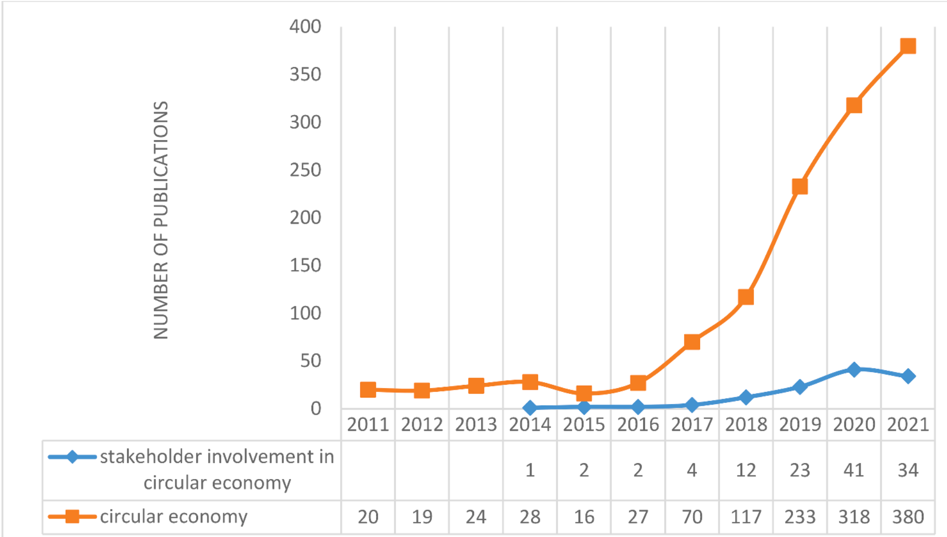

Fig. 5. Annual publications related to circular economy.

Table 1
Key contributing journals/conferences related to research on stakeholders for circular economy in construction.

Name of Journal/Conference	Number of Publications
IOP Conference Series: Earth and Environmental Science	17
Journal of Cleaner Production	13
Sustainability	12
Resources, Conservation and Recycling	7
Journal of Environmental Management	3
Recycling	3
Research for Development	3
Clean Technologies and Environmental Policy	2
Ecological Economics	2
International Journal of Life Cycle Assessment	2
International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM	2
Journal of Construction Engineering and Management	2
Procedia CIRP	2
Smart Innovation, Systems and Technologies	2
Waste Management and Research	2
Others (36 journals and 9 conference papers had only 1 publication within the search)	1

parties, promoting solid and cohesive partnerships (Hart et al., 2019).

A **theoretical framework for waste minimisation** considering CE has been presented by Esa et al. (2016), which included strategies that could be used at micro, *meso* and macro levels. At the micro level, the focus is on waste minimisation; at the *meso* and macro levels, the most concern is reuse and recycling. It also identified the stakeholders as well as the stage that these strategies could be implemented. Coordination between stakeholders could influence waste minimisation and contribute to a better CE.

Modular buildings, when paired with computational tools for lifecycle traceability, could have vital social importance in addressing sustainability and CE. Rausch et al. (2020) introduced a **product cycling model for modular buildings**, including computational components to generate modular topology, lifecycle costs and lifecycle analysis.

Charef et al. (2019) developed **a conceptual framework to use BIM** for implementing CE at the end-of-life phase. BIM allows improving stakeholder collaboration while improving CE related to the construction industry. It includes the project, asset, and deconstruction information models demonstrating how these could be used in the deconstruction/end-of-life stage. This assists in changing a linear system to a CE.

A design process map has been developed to connect building materials reuse stakeholders during the design phase of a project (Ali, 2019). The proposed business process workflows are integrated with the BIM project execution planning guide. Architects and building professionals could use the introduced decision support system to integrate sustainable solutions, including reusing building materials and components. Coordination between stakeholders at the design stage could minimise waste in construction and contribute to a CE.

A probabilistic model using machine learning techniques was developed by Rakhshan et al. (2021) to predict the reuse of structural elements at a building's end-of-life stage. This model used the Random Forests (RF) model, showing the lowest error rate and the highest overall accuracy. It also provides the rules to be followed when using the model.

Jansen et al. (2020) introduced a **Circular Economy Life Cycle Cost (CE-LCC) model** that could be used to assess circular building products. A case study was used to test the model considering multiple interests, lifespan, and re-manufacturing and recycling scenarios.

***Re*-Manufacturing Networks for Tertiary Architectures (*Re*-NetTA)** is an ongoing project that identifies re-manufacturing and reuse networks and processes to reduce waste generation from renewals in short-term cycles, lifecycle management and sustainable business models (Talamo et al., 2020).

3.2.2. *Actions for CE adaption*

Charef and Lu (2021) identified 64 **factors that impact CE adaption** in the construction industry and categorised them under (1) organisational; (2) political and procedural; and (3) technical factors. An entity relationship diagram maps how these factors are connected to the entities: stakeholders, asset lifecycle, material circularity, regulations, and facilitating technologies. Similarly, various other studies identified actions for improving the adaptability of CE. Cristiano et al. (2021) proposed actions as well as a SWOT-TOWS analysis after evaluating the C&D waste management system used in Naples, Italy.

Many countries in the European region, including Germany, the UK and others, have introduced CE principles into their **policies and legislation** (Smol et al., 2017). These policies emphasise the involvement of countries' governments in adapting circularity to contribute to the United Nations Sustainable Development Goals. A study by Lv et al. (2020) analysed China's national, provincial and municipal policies to identify and promote CE and waste management performance. Aslam et al. (2020) reviewed the C&D waste management regulations and policies in China and the USA, where many actions, such as economic

Table 2
Summary of the identified research trends.

Models and frameworks related to CE	Actions for CE adaption	Strategies for Stakeholder collaboration for CE	Potential use of various digital technologies in CE
• CE framework and stakeholder network (Senaratne et al., 2021; Volk et al., 2019) • Theoretical framework for waste minimisation (Esa et al., 2016) • Product cycling model for modular buildings (Rausch et al., 2020) • A conceptual framework to use BIM • A design process map (Ali, 2019) • A probabilistic model using machine learning techniques (Rakhshan et al., 2021) • Circular Economy Life Cycle Cost (CE-LCC) model (Jansen et al., 2020) • *Re*-Manufacturing Networks for Tertiary Architectures (*Re*-NetTA) (Talamo et al., 2020)	• Consider organisational, political and technical factors that impact CE adaption (Charef et al., 2019; Munaro et al., 2019; Volk et al., 2019) • Introduce policies and legislation (Cruz Rios et al., 2021; Ghaffar et al., 2020; Karhu and Linkola, 2019) • Introduce circular business models (Giorgi et al., 2020; Mhatre et al., 2021; Munaro et al., 2020; Ratnasabapathy et al., 2021; Talamo et al., 2020) • Circular design (Cristiano et al., 2021; Dokter et al., 2020) • Focus on resource efficiency in industrialised housing construction (Ghaffar et al., 2020; Kedir and Hall, 2021; Rausch et al., 2020)	• Comprehensive collaboration between stakeholders (Karhu and Linkola, 2019; Shooshtarian et al., 2020) • Multi-stakeholder engagement (Guerra and Leite, 2021) • Double field of interest (Migliore et al., 2020) • Long-term partnerships (Hart et al., 2019)	• Blockchain for waste management (Senaratne et al., 2021) • BIM for CE (Charef, 2022; Kovacic et al., 2020) • IoT, Big Data and AI for CE (Argus et al., 2020)

incentives and technical education, have been implemented. Oliveira et al., 2021 identified strategies to be incorporated within policies at the regional level focusing on Manaus, Brazil, which could be applied to other Brazilian municipalities and other countries as well.

Castillo and Angelis-Dimakis (2019) reviewed the European policy and suggested ways to improve the current limitations. A study conducted for the Danish built environment suggested including lifecycle assessment and water and biodiversity calculations when processing building permits as sustainable measures (Hansen and Lynge, 2020), which could be continued to improve CE. A CE is strongly featured in Finland' common objectives are being set within various ministries to promote CE in the property and construction industry (Karhu and Linkola, 2019). The UK has introduced a **landfill tax**, which encourages stakeholders to pursue waste recycling instead of landfilling (Casas-Arredondo et al., 2018). Landfill tax increased the quantity of crushing/recycling sites. However, more emphasis is required on better segregation on site and improving regulation of the waste industry (Ghaffar et al., 2020).

The circular business model is a novel concept explored recently to create a potential driver for CE transitions (Lacy et al., 2014). Adapting circular flows of material and information assist in decreasing resource extraction, fossil energy consumption and environmental pollution, which could be achieved through new business models (Zabek et al., 2020). The business model perspective is important in sustainability as it highlights an organisation's value creation and allows for new governance forms while enhancing profit-maximising models (Schaltegger et al., 2015). According to Bocken et al. (2016), circular business models encourage the reuse of products through business model innovation and improvements in manufacturing inefficiencies. Various tools related to circular business models have been developed to guide business developers in overcoming challenges to design business models towards circularity (Bocken et al., 2019). Adding collaboration of stakeholders for the circular business model could contribute to more improvements in a CE. Circular building design involves design for disassembly, allowing future repair, remanufacture, and reuse of building components; adaptive reuse of buildings; and using salvaged materials in new construction (Cruz Rios et al., 2021). Dokter et al. (2020) studied the current practices related to **circular design** and how it could be improved through circular design methods. The results revealed that a lack of collaboration with stakeholders in the design processes could make it difficult to carry out the circular design. This could be resolved by supporting collaboration throughout the design process and considering the lifecycle of materials. Similarly, the barriers to implementing circular design could be mitigated through several actions. Andrade et al. (2019) identified two methods that could be used to practice sustainability and CE by incorporating them at the early design stage. The two methods are: (1) compare design alternatives to select the most sustainable choice, and (2) cost-benefit analysis method to analyse alternative building solutions.

Industrialised housing construction extends beyond the prefabrication of elements. Using industrialised housing construction, including Information Communication Technology (ICT), planning and control processes, and strong stakeholder relationships could increase productivity (Kedir and Hall, 2021; Lessing et al., 2005). Kedir and Hall (2021) identify various product-related, process-related and other strategies to improve resource efficiency in industrialised housing construction across building lifecycle phases. Resource efficiency assists in balancing sustainable requirements as well as the demand for affordable housing. This can be achieved with the collaboration and clear identification of all stakeholders involved during the lifecycle of a building (Senaratne et al., 2021).

3.2.3. Strategies for stakeholder collaboration for CE

Zabek et al. (2020) observed stakeholders' involvement in a building project, especially to explore their impact on CE processes and to identify the most important stakeholder groups that lead projects towards circularity in the regional context. CE in the building and construction sector demands comprehensive **stakeholder collaboration** (Karhu and Linkola, 2019; Shooshtarian et al., 2020). Giorgi et al. (2020) looked at changing the building renovation process and stakeholders' relationships to a circular building renovation process by adding a waste management phase and connecting the stakeholders effectively to collaborate and carry out waste management practices. According to Cruz Rios et al. (2021), the stakeholders, policymakers, Non-Governmental Organizations (NGOs), industry associations, and researchers have the highest leverage to enable CE in the US building sector. Guerra and Leite (2021) suggested that **multi-stakeholder engagement,** especially related to government, business and academia, would push forward adapting a CE model in the built environment.

In a CE, stakeholders may share a **double field of interest**, which at one point involves by-products and, on the other hand, waste that would reach the end-of-waste status (Migliore et al., 2020). Occasionally, the manufacturer of building materials and components may also become the receiver of recyclable waste from other sectors. For example, old car tyres can be used in asphalt road construction. According to Hart et al. (2019), **long-term partnerships** improve value chain management resulting in effective collaboration to achieve common goals in a less adversarial approach. Collaboration tends to be successful when the parties trust each other. Trust is usually developed over the years. Therefore, long-term partnerships tend to collaborate and work towards common goals for achieving CE. Stakeholder collaboration is the key remedy to improve this kind of situation in reality. Ghaffar et al. (2020) opined that a tool is required for C&D waste management to compel stakeholders such as industrial, research, civil organisations, public authorities, and policymakers to invest in closed-loop construction.

3.2.4. Potential use of various digital technologies for improvements in CE

Digital technologies have a significant potential to predict and optimise waste and recycling while contributing to CE (Kovacic et al., 2020). Especially when the focus is on stakeholder engagement, digital technologies may promote traceability and enhance the confidentiality, transparency and reliability of circular projects with a reduced environmental impact (Asim et al., 2021; Turk and Klinc, 2017; Charef, 2022).

Building Information Modelling (BIM) can potentially resolve the C&D waste-related issues by using it for end-of-life asset management (Charef et al., 2019). According to Munaro et al. (2019), building materials passports are tools for inserting CE in buildings. The information stored within the building material passport could be managed through BIM. Chang and Hsieh (2019) mentioned that the major strength of BIM for circular buildings would be its capacity to store and share meaningful properties of different building elements amongst stakeholders. Charef et al. (2021) identified the socioeconomic and environmental barriers to implementing CE in a BIM environment. These barriers include the lack of client demand, second-hand materials, reused and recycled products.

Additionally, good coordination between demand and supply, aiming for profitability instead of innovation or improvement on current processes, inefficient marketing for reclaimed materials and the lack of its planning are pointed out as barriers to the implementation of CE, together with the lack of sustainability criteria during the design stage to implement waste minimization strategies and the 3Rs benefits in construction and demolition wastes (Charef et al., 2021; Zaman et al., 2018). Social barriers were identified as people's behaviours on waste management, including the fear of extra costs or disbelief in eliminating waste, lack of awareness of CE or life-cycle principles and identifying the value of reusing or recycling. Finally, the resistance to change, especially from manufacturers, is seen as one of the significant social barriers (Couto and Couto, 2010).

BIMaterial is a **BIM-based material passport** introduced by Kovacic and Honic (2020), which could be used as a design-optimisation tool, as material inventory and as a document on material assets of building stocks. Accurate information about the existing building stock and recycling rates is essential for circularity. Kovacic et al. (2020) reviewed BIMaterial and SCI-BIM (Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling) to present a **digital platform** that could be used to achieve CE through inter and intra-firm digital ecosystems. A cloud-based blockchain system interacting with BIM can track products throughout a CE (Teisserenc and Sepasgozar, 2021; Argus et al., 2020). Blockchain integrated with BIM can improve stakeholder collaboration and beyond the benefits of the BIM-based material passport. Blockchain provides an immutable decentralised database that consists data captured through the BIM model within its entire lifecycle and it can be shared with construction stakeholders to contribute to single source of truth.

A study on smart cities identified that the **Internet of Things (IoT)** and **Big Data,** in terms of productivity and efficiency, has the outlined perspective for fielding the CE paradigm (Talamo et al., 2019). IoT and Big Data assist in optimising services, increase the efficiency of resources and, amongst others, creating small steps towards reaching a CE. Ghaffar et al. (2020) suggested that mobile robotic sorting and reprocessing machines with innovative technologies such as **Artificial Intelligence (AI)** and **IoT** could contribute to efficient waste management processes to improve stakeholder engagement and realise circular construction. IoT, AI and Big Data are technologies that could improve the coordination between stakeholders and contribute towards achieving CE in the construction industry.

Blockchain is a decentralised and distributed technology that can be used for data management and accounting transactions. The potential use of blockchain in waste trading processes for sharing, reporting, and auditing waste materials, eliminating trusted intermediaries, is to create wider circular business networks (Steenmans et al., 2021). An incentive mechanism integrated with a blockchain-based waste trading system that connects all stakeholders together would assist in reducing waste and contributing to CE through recycle, reproduce and reuse strategies.

The above sections (Sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4) discussed research trends on various CE models, actions for CE adaption, strategies for stakeholder collaboration for CE, and digital technologies that contribute to circularity. The following section discusses the future research directions to further improve stakeholder collaboration in a CE by identifying current gaps.

3.2.5. Future research directions by identifying gaps in current research

The Sections 3.2.1, 3.2.2, 3.2.3, and 3.2.4 discussed how to achieve circularity through introduction of various models, actions for CE adaption, strategies for stakeholder collaboration and use of technologies. When implementing stakeholder collaboration, it is important to identify the steps within the process that could lead towards achieving CE. A construction project involves multiple stakeholders usually having ad-hoc arrangements. Therefore, trust, transparency, accountability, security are some of the key concerns for stakeholders. Stakeholders collaborate and cooperate with each other, when these qualities exist.

The models and frameworks identified in Section 3.2.1 emphasise the importance of stakeholder collaboration to exchange materials, minimise waste, trace products, improve accuracy, and improve sustainability (Esa et al., 2016; Charef et al., 2019; Rausch et al., 2020). Section 3.2.2 discussed actions for CE adaption to achieve several benefits related to improving waste recycling instead of landfilling, decrease resource extraction and environmental pollution, implementing circular design and improve resource efficiency (Casas-Arredondo et al., 2018; Dokter et al., 2020). Similarly, Section 3.2.3 highlighted how multi-stakeholder collaboration, double field of interest, long term partnerships can be practiced with more trust and transparency (Guerra and Leite, 2021; Hart et al., 2019; Migliore et al., 2020). The above research findings on models, actions and strategies for stakeholder collaboration establish the importance and needs for stakeholder collaboration, but inadequate in extending to create circularity in construction. On the other hand, the research trends identified on digital technologies, except blockchain (see Section 3.2.4) were also limited in enabling evidence-based trusted transactions and pursue the goals of transparent, tracked and immutable transactions to advance CE propagation in society and industry through effective stakeholder collaboration.

Use of blockchain is a common solution in achieving trust, transparency, accuracy, immutability, security and so forth (Rodrigo et al., 2020). Blockchain has the potential to be used for waste trading with a reward/penalty mechanism to improve stakeholder involvement as well as collaboration (Ratnasabapathy et al., 2021). It contributes to minimise wastage connecting buyers and sellers efficiently without the involvement of a third party. Tracing of products and monitoring each step in the process without losing any data could be easily achieved through blockchain. Rather than having several systems for resource handling, procurement, delivery and so forth, all stakeholders connected through one common database through blockchain, would be easy to avoid issues related to redundancy and miscommunications.

Building information modelling (BIM) can potentially improve management and stakeholder collaboration issues related to construction projects (Asim et al., 2021; Charef, 2022). It was found that there was some BIM-related research to enable CE in construction. However, there is clear evidence that greater stakeholder collaboration is not yet achieved using BIM (BELAYUTHAM et al., 2016; Chan et al., 2019; Liu et al., 2015). The centralised nature of BIM expects to have central control and authority that could be problematic, which is negated by the decentralised distributed ledger technology such as blockchain. The salient features of blockchain make it a better option than other technologies such as BIM, augmented reality, virtual reality, internet of things, amongst others, to improve stakeholder collaboration in achieving circularity. Blockchain has the better potential not only to connect all transacting stakeholders with higher reliability, transparency, confidentiality, accuracy and traceability but also it offers a better opportunity to create circularity by reducing the environmental impacts and consequent resources depletion, costs and inefficiencies throughout a building lifecycle (Asim et al., 2021; Charef, 2022; Turk and Klinc, 2017). Smart contracts within the blockchain can provide the algorithms required to govern CE. As such, amongst different technologies, blockchain could be identified as a suitable technology for implementing industrywide CE applications. However, the systematic review of current research trends established that blockchain as an enabler for stakeholder collaboration for a CE is yet to be explored and it could be an imperative further research focus.

4. Conclusion

Many stakeholders are involved at different stages throughout a project's lifespan. Due to deficiencies in awareness, communication, a collaboration of stakeholders and supply chains, the construction project and its critical decisions are affected. Stakeholder collaboration is vital to achieve circularity and minimise negative impacts during the whole lifecycle of a project. Hence, this paper aims to explore current research trends and gaps on stakeholder collaboration towards a circular built environment.

A systematic literature review, along with the PRISMA framework, was adapted. The literature review was carried out in two parts. The first part involved a quantitative analysis using bibliometric networks, while the second part focused on an in-depth content analysis carried out manually. The quantitative analysis revealed that, in the last decade, there has been a focus on exploring circularity in the construction industry to promote sustainable developments, recycling, and waste management. Fig. 3 demonstrated the timeline of dominant research areas where concepts related to circular economy and stakeholders have been researched in very recent years emphasising the current trend towards researching in these areas. The analysis of the geographical spread of CE research revealed that the UK has carried out several pieces of research on the involvement of stakeholders for CE in construction, followed by the Netherlands, the US, Spain, France and Australia. Fig. 5 indicates a great tendency towards CE-related research in the past decade, while stakeholder aspects of CE research have also gradually grown. IOP conference series and the Journal of Cleaner Production reported the highest number of CE-related papers under the conference proceedings and journal publications categories, respectively.

The content analysis assisted in reviewing the short-listed papers in detail and identifying the current trends, gaps and future directions in CE-related research in the built environment. There were a few methodological limitations in this study. For example, the time-related constraints, where only the papers published until September 2021 was considered for the systematic literature review. As a result, even if more papers related to this area may have been published afterwards, they could not be included. When shortlisting papers for the qualitative content analysis using inclusion and exclusion criteria, researcher's judgement was required. Mainly the abstracts of 119 papers were reviewed to make such judgements. However, all steps in the PRISMA protocol were followed to reduce the impact of these limitations.

There is a tendency to adapt various digital technologies to improve CE in construction. Several studies have developed various frameworks and models to adapt CE or improve CE within the built environment/construction context. Some frameworks and models have been tested or validated using case studies or interviews. The findings also indicated that the stakeholders could adapt various actions for CE adaption, strategies for stakeholder collaboration, and technologies to implement CE in their current practices. These include the introduction of policies, the introduction of new business models, and circular design concepts, amongst others. Stakeholder involvement and collaboration were identified as critical steps towards improving CE in the built environment. The findings identified several digital technologies such as BIM, IoT, Big Data, and AI for stakeholder collaboration in circular processes, but they were still limited in extending circularity. Even though blockchain has the potential in this context, there was little information on the possibility of using blockchain as a reliable technology to enhance stakeholder collaboration in CE.

This paper contributes to knowledge by identifying the current research trends and gaps related to stakeholder collaboration for CE. In addition, it established the lack of current research on using blockchain as an enabler for stakeholder collaboration for circular built environments and the need for future research in this area. The potential of blockchain for stakeholder involved applications to achieve CE could create a novel approach in the built environment domain and possibly beyond it. A blockchain-based application can provide seamless access to reliable data and act as a platform to facilitate interactions between the stakeholders within the construction supply chain.

Funding

This research was funded by Western Sydney University.

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.

Data availability

No data was used for the research described in the article.

References

Adams, K.T., Osmani, M., Thorpe, T., Thornback, J., 2017. Circular economy in construction: current awareness, challenges and enablers. Proceedings of the Institution of Civil Engineers - Waste and Resource Management 170, 15–24.

Ali, A.K., 2019. Mapping a Resource-Based Design Workflow to Activate a Circular Economy in Building Design and Construction. In: SBE19 Brussels BAMB-CIRCPATH, 6-7 February 2019. Brussels, pp. 1–8.

ANDRADE, J., ARAÚJO, C., CASTRO, M.F., BRAGANÇA, L, 2019. New Methods for Sustainable Circular Buildings. In: SBE19 Brussels BAMB-CIRCPATH, 6-7 February 2019. Brussels, 012037.

ARGUS, K., IYER-RANIGA, U., VAN BUEREN, B., MULHERIN, P., 2020. Data quality as an antecedent for commercial viability of circular economy business models: a case study. In: IOP Conference Series: Earth and Environmental Science. Vancouver, Canada, pp. 1–8.

Asim, J., Ahmed, R.R., Streimikiene, D., Rasheed, S., StreimikIs, J., 2021. Assessing design information quality in the construction industry: Evidence from building information modeling. Acta Montan. Slovaca 26, 235–251.

Aslam, MS., Huang, B., Cui, L., 2020. Review of construction and demolition waste management in China and USA. J. Environ. Manag. 264, 110445.

AYODELE, O.A., CHANG-RICHARDS, A., GONZÁLEZ, V, 2020. Factors Affecting Workforce Turnover in the Construction Sector: A Systematic Review. Journal of Construction Engineering and Management 146.

BELAYUTHAM, S., GONZÁLEZ, V.A., YIU, T.W, 2016. A cleaner production-pollution prevention based framework for construction site induced water pollution. Journal of Cleaner Production 135, 1363–1378.

BOCKEN, N., STRUPEIT, L., WHALEN, K., NUßHOLZ, J., 2019. A Review and Evaluation of Circular Business Model Innovation Tools. Sustainability 11.

BOCKEN, N.M.P., DE PAUW, I., BAKKER, C., VAN DER GRINTEN, B., 2016. Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering 33, 308–320.

CASAS-ARREDONDO, M., CROXFORD, B., DOMENECH, T., 2018. Material and decision flows in non-domestic building fit-outs. Journal of Cleaner Production 204, 916–925.
CASTILLO, A.C., ANGELIS-DIMAKIS, A., 2019. Analysis and recommendations for European carbon dioxide utilization policies. J Environ Manage 247, 439–448.
Chan, D.W.M., Olawumi, T.O., Ho, A.M.L., 2019. Critical success factors for building information modelling (BIM) implementation in Hong Kong. Eng. Constr. Archit. Manag. 26, 1838–1854.
CHANG, Y.T., HSIEH, S.H., 2019. A Preliminary Case Study on Circular Economy in Taiwan's Construction. SBE19 Brussels BAMB-CIRCPATH. In: , 6-7 February 2019. Brussels, 012069.
CHAREF, R., 2022. Supporting construction stakeholders with the circular economy: A trans-scaler framework to understand the holistic approach. Cleaner Engineering and Technology 8.
CHAREF, R., ALAKA, H., GANJIAN, E., 2019. A BIM-based theoretical framework for the integration of the asset End-of-Life phase. In: SBE19 Brussels - BAMB-CIRCPATH, 6-7 February 2019. Brussels, pp. 1–8.
CHAREF, R., GANJIAN, E., EMMITT, S., 2021. Socio-economic and environmental barriers for a holistic asset lifecycle approach to achieve circular economy: A pattern-matching method. Technological Forecasting and Social Change 170, 120798.
CHAREF, R., LU, W., 2021. Factor dynamics to facilitate circular economy adoption in construction. Journal of Cleaner Production 319, 128639.
CHEN, H.M., ZHOU, R., ULIANOV, C., 2020. Numerical Prediction and Corresponding Circular Economy Approaches for Resource Optimisation and Recovery of Underground Structures. Urban Rail Transit 6, 71–83.
CHEN, Q., FENG, H., GARCIA DE SOTO, B., 2022. Revamping construction supply chain processes with circular economy strategies: A systematic literature review. Journal of Cleaner Production 335.
COUTO, J., COUTO, A., 2010. Analysis of Barriers and the Potential for Exploration of Deconstruction Techniques in Portuguese Construction Sites. Sustainability 2, 428–442.
CRISTIANO, S., GHISELLINI, P., D'AMBROSIO, G., XUE, J., NESTICÒ, A., GONELLA, F., ULGIATI, S, 2021. Construction and demolition waste in the Metropolitan City of Naples, Italy: State of the art, circular design, and sustainable planning opportunities. Journal of Cleaner Production 293.
CRUZ RIOS, F., GRAU, D., BILEC, M., 2021. Barriers and Enablers to Circular Building Design in the US: An Empirical Study. Journal of Construction Engineering and Management 147, 04021117.
DOKTER, G., STIJN, A.V., THUVANDER, L., RAHE, U., 2020. Cards for circularity: Towards circular design in practice. In: IOP Conference Series: Earth and Environmental Science. Vancouver, Canada, pp. 1–8.
ESA, M.R., HALOG, A., RIGAMONTI, L., 2016. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. Journal of Material Cycles and Waste Management 19, 1144–1154.
GHAFFAR, S.H., BURMAN, M., BRAIMAH, N., 2020. Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. Journal of Cleaner Production 244.
GIORGI, S., LAVAGNA, M., CAMPIOLI, A., 2020. Circular Economy and Regeneration of Building Stock: Policy Improvements, Stakeholder Networking and Life Cycle Tools. Regeneration of the Built Environment from a Circular Economy Perspective.
GUERRA, B.C., LEITE, F., 2021. Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers. Resources, Conservation and Recycling 170.
HANSEN, H.T.R., LYNGE, K., 2020. Redesigning public governance of the Danish built environment from relative to absolute metrics. In: IOP Conference Series: Earth and Environmental Science. Vancouver, Canada, pp. 1–8.
HART, J., ADAMS, K., GIESEKAM, J., TINGLEY, D.D., POMPONI, F., 2019. Dimensional Metrology of Cell-matrix Interactions in 3D Microscale Fibrous Substrates. Procedia CIRP 80, 619–624.
JANSEN, B.W., VAN STIJN, A., GRUIS, V., VAN BORTEL, G., 2020. A circular economy life cycle costing model (CE-LCC) for building components. Resources, Conservation and Recycling 161.
KARHU, J., LINKOLA, L., 2019. Circular Economy in the Built Environment in Finland - A case example of collaboration. In: SBE 19 - Emerging Concepts for Sustainable Built Environment, 22-24 May 2019. Helsinki, Finland, pp. 1–10.
KEDIR, F., HALL, D.M., 2021. Resource efficiency in industrialized housing construction – A systematic review of current performance and future opportunities. Journal of Cleaner Production 286.
KOVACIC, I., HONIC, M., 2020. BIMATERIAL: Process-Design for a BIM-based Material Passport. Austria: Institute for Interdisciplinary Building Process management, Industrial building and Interdsiciplinary Planning. Vienna University of Technology.
KOVACIC, I., HONIC, M., SRECKOVIC, M., 2020. Digital Platform for Circular Economy in AEC Industry. Engineering Project Organization Journal 9, 1–16.
KPMG, 2020. Potential Economic Pay-Off of a Circular Economy. KPMG, Australia.
Lacy, P., Keeble, J., McNamara, R., Rutqvist, J., Eckerle, K., Haglund, T., Buddemeier, P., Cui, M., Sharma, A., Cooper, A., Senior, T., Pettersson, C., 2014. Accenture Circular Advantage, Accenture Strategy. Chicago, USA.
LEISING, E., QUIST, J., BOCKEN, N., 2018. Circular Economy in the building sector: Three cases and a collaboration tool. Journal of Cleaner Production 176, 976–989.
LESSING, J., STEHN, L., EKHOLM, A., 2005. In: Industrialised housing: definition and categorization of the concept. 13th International Group for Lean Construction Conference, 13 July 2005. Sydney, Australia, pp. 471–480.
Liu, S., Xie, B., Tivendal, L., Liu, C., 2015. Critical Barriers to BIM Implementation in the AEC Industry. Int. J. Mark. Stud. 7, 162.
LOVE, P.E.D., IRANI, Z., EDWARDS, D.J., 2004. A seamless supply chain management model for construction. Supply Chain Management: An International Journal 9, 43–56.
Lv, H., Li, Y., Yan, H-B., Wu, D., Shi, G., Xu., Q., 2020, Examining construction waste management policies in mainland China for potential performance improvements, Clean Technol. Environ. Policy, 23, (2), 445-462.
MAGAZZINO, C., MELE, M., SCHNEIDER, N., SARKODIE, S.A., 2021. Waste generation, wealth and GHG emissions from the waste sector: Is Denmark on the path towards circular economy? Science of the Total Environment 755, 142510.
MHATRE, P., PANCHAL, R., SINGH, A., BIBYAN, S., 2021. A systematic literature review on the circular economy initiatives in the European Union. Sustainable Production and Consumption 26, 187–202.
MIGLIORE, M., OBERTI, I., TALAMO, C., 2020. Circular Economy and Recycling of Pre-consumer Scraps in the Construction Sector. Cross-Sectoral Exchange Strategies for the Production of Eco-Innovative Building Products. Regeneration of the Built Environment from a Circular Economy Perspective.
MOHER, D., LIBERATI, A., TETZLAFF, J., ALTMAN, D.G., 2009. Reprint—Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. Physical Therapy 89, 873–880.
MOHER, D., SHAMSEER, L., CLARKE, M., GHERSI, D., LIBERATI, A., PETTICREW, M., SHEKELLE, P., STEWART, L.A., 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews 4, 1–9.
MUNARO, M.R., FISCHER, A.C., AZEVEDO, N.C., TAVARES, S.F., 2019. Proposal of a building material passport and its application feasibility to the wood frame constructive system in Brazil. In: SBE19 Brussels BAMB-CIRCPATH, 6-7 February 2019. Brussels, pp. 1–9.
MUNARO, M.R., TAVARES, S.F., BRAGANÇA, L, 2020. Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. Journal of Cleaner Production 260.
Oliveira, M.d.P.S.L., de Oliveira, E.A., Fonseca, A.M., 2021. Strategies to promote circular economy in the management of construction and demolition waste at the regional level: a case study in Manaus, Brazil. Clean Technol. Environ. Policy 23 (9), 2713–2725.
RAKHSHAN, K., MOREL, J.C., DANESHKHAH, A., 2021. Predicting the technical reusability of load-bearing building components: A probabilistic approach towards developing a Circular Economy framework. Journal of Building Engineering 42, 102791.
RATNASABAPATHY, S., ALASHWAL, A., PERERA, S., 2021. Exploring the barriers for implementing waste trading practices in the construction industry in Australia. Built Environment Project and Asset Management 11, 559–576.
RAUSCH, C., SANCHEZ, B., EDWARDS, C., HAAS, C., 2020. A computational model for product cycling of modular buildings. In: EG-ICE 2020 Workshop on Intelligent Computing in Engineering. Berlin, pp. 1–10.
RODRIGO, M.N.N., PERERA, S., SENARATNE, S., JIN, X., 2020. Potential Application of Blockchain Technology for Embodied Carbon Estimating in Construction Supply Chains. Buildings 10.
SARIATLI, F., 2017. Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability. Visegrad Journal on Bioeconomy and Sustainable Development 6, 31–34.
Schaltegger, S., Hansen, E.G., Lüdeke-Freund, F., 2015. Business Models for Sustainability. Organ. Environ. 29 (1), 3–10.
SENARATNE, S., KC, A., PERERA, S., ALMEIDA, L., 2021. Promoting stakeholder collaboration in adopting circular economy principles for sustainable construction. In: SANDANAYAKE, Y.G., GUNATILAKE, S., WAIDYASEKARA, K.G.A.S. (Eds.), 9th World Construction Symposium. CIOB, Sri Lanka.
SHAHRUDDIN, S., ZAIRUL, M., 2020. BIM Requirements across a Construction Project Lifecycle: A PRISMACompliant Systematic Review and Meta-Analysis. nternational Journal of Innovation, Creativity and Change 12, 569–590.
SHE, Y., UDAWATTA, N., TOKEDE, O., 2020. Research trends in construction and demolition waste management in Australia. In: ALI GHAFFARIANHOSEINI, E.A. (Ed.), The 54th International Conference of the Architectural Science Association (ANZAScA) 2020, pp. 915–924.
SHOOSHTARIAN, S., CALDERA, S., MAQSOOD, T., RYLEY, T., 2020. Using Recycled Construction and Demolition Waste Products: A Review of Stakeholders' Perceptions, Decisions, and Motivations. Recycling 5.
SMOL, M., KULCZYCKA, J., AVDIUSHCHENKO, A., 2017. Circular economy indicators in relation to eco-innovation in European regions. Clean Technologies and Environmental Policy 19, 669–678.
Steenmans, K., Taylor, P., Steenmans, I., 2021. Blockchain Technology for Governance of Plastic Waste Management. Where Are We? Soc. Sci. 10.
TALAMO, C., LAVAGNA, M., MONTICELLI, C., ATTA, N., GIORGI, S., VISCUSO, S., 2020. Re-NetTA. Re-Manufacturing Networks for Tertiary Architectures. Regeneration of the Built Environment from a Circular Economy Perspective.
TALAMO, C., PINTO, M.R., VIOLA, S., ATTA, N., 2019. Smart cities and enabling technologies: influences on urban Facility Management services. In: SBE19 - Resilient Built Environment for Sustainable Mediterranean Countries, 1-5 September 2019. Milan, Italy.
TEISSERENC, B., SEPASGOZAR, S., 2021. Adoption of Blockchain Technology through Digital Twins in the Construction Industry 4.0: A PESTELS Approach. Buildings 11.
Turk, Ž., Klinc, R., 2017. Potentials of Blockchain Technology for Construction Management. Procedia Eng. 196, 638–645.
VOLK, R., MÜLLER, R., REINHARDT, J., SCHULTMANN, F, 2019. An Integrated Material Flows, Stakeholders and Policies Approach to Identify and Exploit Regional Resource Potentials. Ecological Economics 161, 292–320.

WU, Z., YU, A.T., SHEN, L., LIU, G., 2014. Quantifying construction and demolition waste: an analytical review. Waste Manag 34, 1683–1692.
YANG, J., SHEN, Q., HO, M., 2009. An overview of previous studies in stakeholder management and its implications for the construction industry. Journal of Facilities Management 7, 159–175.
Zabek, M., Wirth, M., Hildebrand, L., 2020. Evaluating Regional Strategies towards a Circular Economy in the Built Environment, in IOP Conference Series. Earth and Environmental Science 588, 1–4.
ZAMAN, A., ARNOTT, J., MCLNTYRE, K., HANNON, J., 2018. Resource Harvesting through a Systematic Deconstruction of the Residential House: A Case Study of the 'Whole House Reuse' Project in Christchurch, New Zealand. Sustainability 10.