Sustainable Futures 8 (2024) 100244

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures

Barriers to adopting circular procurement in the construction industry: The way forward

Zeerak Waryam Sajid [a], Usman Aftab [b], Fahim Ullah [c,*]

[a] Graduate Student, NUST Institute of Civil Engineering (NICE), National University of Sciences and Technology, H-12, Islamabad 44000, Pakistan
[b] Postgraduate Student, Department of Construction Engineering & Management, School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
[c] Program Director and Senior Lecturer (Construction Project Management), School of Surveying and Built Environment, University of Southern Queensland - Springfield Campus, Springfield Central QLD 4300, Australia

ARTICLE INFO

Keywords:
Barriers
Circular economy
Circular procurement
Construction industry
Systematic literature review

ABSTRACT

Circular Economy (CE) is a necessary intervention for enabling resource efficiency, energy conservation, waste minimization, and sustainability within the construction industry (CI). Among its many facets, circular procurement (CP) is a nascent concept that enables CE in CI. Despite the extensive literature and review studies conducted on CE and its intricacies, critical studies documenting the barriers to the adoption of CP within the CI remain scarce. This study systematically reviews the existing literature on CP in CI retrieved from the Scopus database. A systematic literature review was conducted on 46 shortlisted articles published between 2010-2023 using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, and the key barriers to the adoption of CP in CI were identified. The results reveal both hard barriers (HB), such as *lack of circular design and production, lack of reverse logistics, lack of standardization, lack of reliable information management*, and *lack of profitable business models,* and soft barriers (SB), such as *lack of stakeholder engagement, lack of trust on CP routes, resistance to change, perceived performance issues* and *lack of collaboration* as impediments to adoption of CP in CI. Further, the measures and strategies to mitigate the identified barriers were also identified from existing literature that are presented in the current study. Finally, a conceptual framework to facilitate the adoption of CP in CI is presented as a way forward to enable the transition from traditional to circular practices.

1. Introduction and background

The construction industry (CI) is responsible for the generation of significant Construction and Demolition Waste (CDW), which contributes to 44 % of landfilling in Australia and the UK and around 35 % globally [1,2]. The resource intensiveness of the CI strains the natural resources and contributes to climatic disasters [3]. To address these challenges, researchers and industry professionals have suggested various approaches to decrease the detrimental effects of construction work. Some examples include green and sustainable construction, modular construction (MC), and prefabrication [4]. One of the most promising related concepts is that of Circular Economy (CE), which encourages the reuse of materials in CI and reduces the CDW.

CE is defined as “a regenerative system in which resource input, waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops” [5]. CE can reduce emissions while enabling resource conservation and management within the built environment [6]. CE is labeled as an instrumental technique for achieving the United Nations’ Sustainable Development Goals (UN SDGs), such as *resilient and sustainable cities* and *climate change mitigation*, among others [7]. Given its importance and potential impact, CE has been at the center of extensive research and scrutiny aimed at highlighting its different aspects, such as effectiveness, enablers, and implementation methods, in the context of the CI [8]. One such aspect is circular procurement (CP), which is a crucial element in implementing CE in the CI.

CP is defined as “the process by which organizations purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains while minimizing, and in the best case avoiding, negative environmental impacts and waste creation across their whole life cycle” [9]. CP involves strategies to procure products and services that prioritize CE principles by enabling recycling, reuse,

* Corresponding author.
E-mail address: fahim.ullah@unisq.edu.au (F. Ullah).

https://doi.org/10.1016/j.sftr.2024.100244
Received 17 November 2023; Received in revised form 22 April 2024; Accepted 30 June 2024
Available online 1 July 2024

durability, and long service lives of assets [10]. CP is a critical aspect of CE and the building block of applying circularity in CI. In essence, CP is a crucial constituent in bridging the gap between the aspiration of CE in the CI and its practical application [11].

CP emphasizes the reuse and recycling of materials to close the loops and prompt CDW minimization and resource efficiency. In contrast, traditional procurement (TP) relies on linear economy models (LEMs) and principles like extracting raw materials, producing goods, and disposing of waste at the end [12]. CP opens avenues for resource optimization in the CI as opposed to TP routes by maximizing the use of available resources through recycling and reuse [12]. By optimizing the use of available resources, CP increases its lifespan, which addresses the demand for the extraction of virgin resources. Meanwhile, TP relies on extracting new resources instead of leveraging the existing ones, which inhibits resource intensiveness [13]. CP also creates opportunities for reducing carbon emissions, a key issue with LEMs [14]. The production of raw materials like cement and asphalt is a carbon-intensive process. The resource efficiency of CP promises to limit the production of raw materials, thereby lowering the high embodied emissions attributed to the CI [15].

In contrast, LEMs promote the extraction of raw materials, leading to high carbon emissions [15]. CP also enables energy conservation by allowing material reuse at the end of the lifecycle, unlike LEMs, where energy is consumed in bulk to extract virgin materials [16]. Similarly, CP has the potential to foster social sustainability by cultivating new jobs and businesses that prioritize CE within the CI and instigate positive outcomes for sustainable development [17]. LEMs, on the other hand, do not offer such exciting prospects for the advancement of social sustainability in the CI. Further, the value chain of CP targets lifecycle thinking to impart environmental and social benefits for everyday well-being [17].

On the contrary, TP prioritizes the economic benefits over lifecycle thinking, as well as environmental and social well-being [18]. Nevertheless, CP is not colossal, and there are some challenges associated with it, such as the high upfront costs of transition from LEMs to CP [18]. Similarly, the labor and equipment costs in CP are higher than in TP due to the reverse logistics of CDW in CP [19]. Since reverse logistics are not involved in TP, the costs incurred during the maintenance and demolition stages of projects are lower than CP [19].

Multiple review studies have summarized and presented state-of-the-art research on the practical application of CE models within the CI [20]. Such studies have shed light on various intricacies of CE, such as urban waste management and resource recovery, and synthesized CE strategies [21]. Similarly, the links between CE and innovative construction processes such as Design for Deconstruction (DfD), Prefabrication, and MC have also been reviewed [22]. Extant literature helps understand the infrastructural and technological requirements to accommodate circularity within the CI [23]. Further, previous studies have also presented the state of CE adoption, stakeholder engagement, awareness, and the prioritization of CE at the government level [24]. Accordingly, deficiencies such as ineffective segregation of CDW for recycling, immature recycling market, and lack of trained personnel and technical knowledge have been highlighted as key impediments [25].

The current state of CE adoption is not up to the mark on a holistic scale. For example, a study pointed out that only 9 % of circularity is observed across different industries. 84Gt of materials are extracted from virgin resources, and only 8.4Gt are recycled annually [26]. CI, being a major resource consumer, is a key focus industry when it comes to CE adoption. However, the adoption of CE in the CI remains insufficient. For instance, CI is the largest consumer of raw materials globally, as it consumes 50 % of global steel production and an estimated 3 billion tons of raw materials annually, which reflects its resource intensiveness [27]. The resource intensiveness of the CI has been regarded as an instigator of climate change. Relevant research has emphasized that the adoption of CE in the CI is essential for climate change mitigation [28]. In the case of the CI, for a stagnant transition to CE, researchers have identified certain barriers [29]. Such barriers hindering the adoption of CE in construction are well documented, and their enablers have been discussed by various studies [30]. However, concerning CP, the literature is limited, if not non-existent. As the CI is gearing to shift from linear economy models to a CE, a review of the barriers inhibiting the adoption of CP in construction is necessary since CP remains instrumental for the adoption of CE in the built environment [31].

1.1. The need for this review study and research questions

Extant literature has addressed the impediments to the adoption of a CE in the built environment, revealing technical deficiencies, inadequate governmental policies, lack of legal frameworks, and economic risks in construction projects as major barriers [32]. A lack of supply chain optimization, stakeholder engagement, and high upfront costs are other major inhibitors to CE adoption [33]. Similarly, the social impacts of adopting CE in construction and its implications for the associated stakeholders have been investigated to highlight the social and cultural factors that hinder the transition to CE [34]. The circularity of construction materials such as bitumen, concrete, and steel, especially in the transportation industry, has also been reviewed [35]. Further, specific determinants and inhibitors of CE, which include economic, environmental, social, technical, infrastructural, legal, behavioral, and temporal factors, have been identified and reviewed, which correspond to the circularity of building materials in the CI [36]. Thus, the literature on generic barriers of CE and the circularity of building materials in CI exists. However, despite existing research and an excessive discourse on the barriers to CE, a comprehensive review of CP adoption in construction is missing. More specifically, no study to date has reviewed the barriers to the successful adoption of CP in CI, providing a serious gap targeted in this study. CP, a nascent concept, is regarded as a pivotal stepstone in the successful implementation of CE [31]. A dearth of literature on the barriers inhibiting its uptake in construction presents a significant research gap in the prevailing literature. While CP is a subset of CE, sharing certain principles [25,37], no previous review studies focusing on the barriers to CE holistically documented the inhibitors to CP as an enabler of CE [25].

To date, little effort has been made to understand the intricacies of CP and its failure to be realized within the CI [38]. Further, the limited studies on CP address its adoption across various industries, such as textile [39], food [40], beverages [41], etc., but fail to capture the essence of the CI and how its inherently complex nature impedes the adoption of CP. To respond to this gap, the current study explores the existing literature for comprehending and illustrating the barriers hindering CP adoption in CI. Two research questions are addressed in this study:

(1) What are the barriers to the adoption of CP within the CI?
(2) What measures could be taken to facilitate the adoption of CP in the CI as a way forward?

1.2. Novelty of the current study

The current study has multi-fold novelty. First, it explores a novel topic in line with modern contemporary research. Second, it extrapolates a topic (CP) explored in other industries and establishes its basis in the CI. Third, this study has both breadth and depth, breadth in terms of contribution to CE and the built environment, and depth in terms of a narrow focus on the impediments to the adoption of CP in complex CI. While existing review studies have highlighted the barriers to CE, including social, environmental, technical, legal, and governmental impediments, a narrow focus on CP is missing, presenting a gap targeted in the current study [36]. Similarly, the barriers to material circularity in the CI have been addressed by prevailing literature, but discourse on the barriers to CP in CI is missing [35]. The limited literature that addresses the impediments to CP has targeted industries such as textile, food, etc., and their findings do not present the true essence of the barriers to CP that are rooted in the complexity of CI [38,39]. Further, existing studies on CP have also not reviewed strategies for CP implementation in the CI, which is another novel contribution of the current study. Overall, no previous research has examined the barriers to CP in CI or presented strategies for its adoption based on a comprehensive literature review, making the current study a novel and avant-garde work.

1.3. The adopted approach and organization of the current study

To provide critical insight into the existing literature regarding barriers to CP, the current study leverages a systematic literature review (SLR) to identify, characterize, and document the key findings of published literature. The SLR conducted in the study encompassed both a meta-analysis, including the bibliometric analysis and an in-depth content analysis. In the meta-analysis, the Google Trends for the topic were observed and reported in addition to the bibliometric analysis. The SLR was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique in order to streamline the literature review process. The bibliometric analysis in this study aimed to highlight different trends regarding publications on CP in CI. These trends include the number of studies published per year, countries contributing to the literature, and the academic journals with the most contributions to the literature on CP in CI. These analyses aimed to highlight the growing interest in research domains regarding the adoption of CP in CI and put the spotlight on the leading countries and journals in the domain. This bibliometric analysis was followed by a detailed content analysis of the retrieved articles to outline the barriers to and enablers of the adoption of CP in the CI.

The identified barriers are characterized as hard and soft according to their intrinsic nature and complexity. Hard barriers (HB) refer to technical and technological barriers like infrastructural impediments, whereas soft barriers (SB) represent barriers rooted in cultural and behavioral aspects of the CI. Detailed reflections regarding the barriers are documented by the current study, followed by a review of strategies that can be taken to mitigate these barriers. The devised solutions are compared with the findings of existing studies and mitigation strategies, and a conceptual framework is presented to help policy and decision-makers implement CP in CI.

The rest of the paper is structured as follows: Section 2 illustrates the methodology of this study. Section 3 presents the results and key findings of the review. It also includes strategies for mitigating barriers and a conceptual framework for implementing CP in CI. Section 4 delves into the theoretical and practical ramifications of the study's findings and discusses its results. Finally, Section 5 concludes the study and presents its limitations and future directions.

2. Methodology

Fig. 1 outlines the research methodology of the current study. As shown in Fig. 1, three major steps were taken in the study. In the first step, literature pertinent to the concerned research theme was retrieved. In the second step, meta-analysis and content analysis were performed on the retrieved articles to outline the barriers to the adoption of CP within the CI. In the third step, results were synthesized from the literature review, and a conceptual framework was devised based on the findings. In accordance with the first step, the literature was retrieved from the Scopus database, employing a search string based on pre-defined keywords, which included different combinations of CP, CE, CI, and barriers, as listed in Section 2.2.

The search timeline was kept between 2010 and 2023 as the authors wanted to retrieve recent studies. Engagement with recent literature provides a more refined, up-to-date, and progressive collection of contemporary research. While engagement with basic literature is considered useful for traditional topics, modern and contemporary topics such as CP have only recently emerged. Therefore, engagement with outdated literature can lead to redundancy or retrieval of unrelated literature. CP is a novel topic in the realm of CE, and a preliminary literature search indicated that most of the studies that address it were published in the last decade. Considering these facts, the decision was made to restrict the literature to the mentioned timeframe, as reviewing studies published before 2010 was deemed futile. This approach also aligns with the existing literature on novel concepts like CE and MC that have focused on research from this period [28,42].

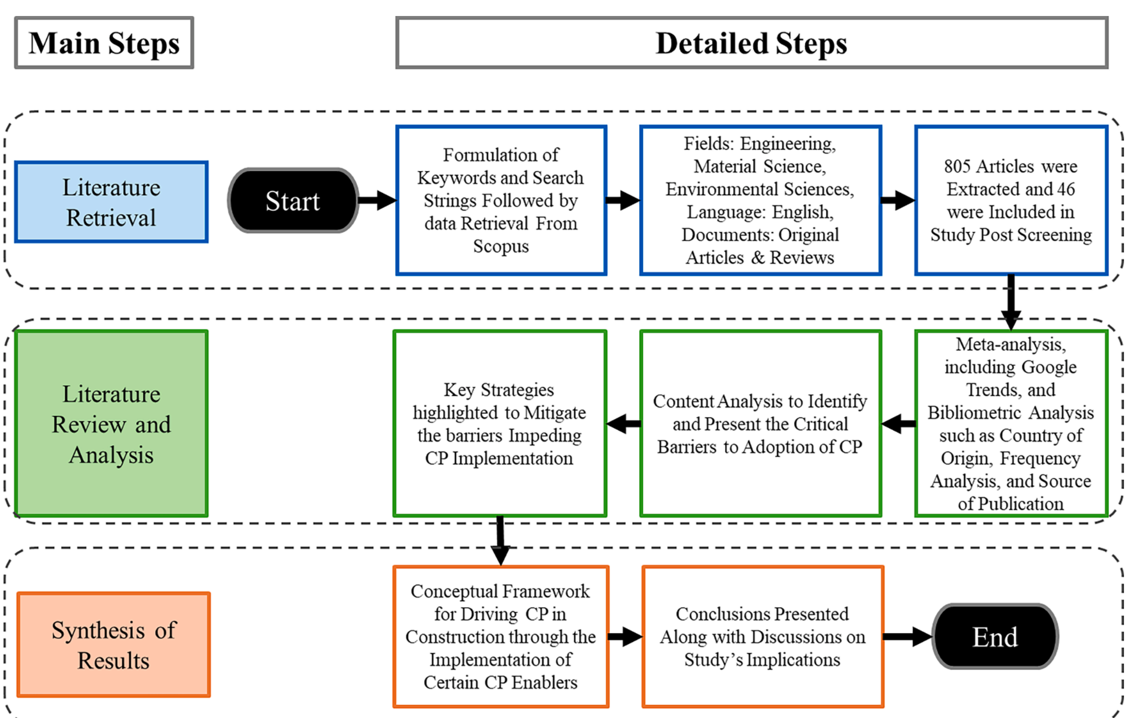

Fig 1. Method flowchart for the current study

Out of 805 articles returned by Scopus, 46 relevant studies were selected following predetermined criteria, which included shortlisting articles only in the English language and limiting the type to "articles" and "review papers." Sources of studies other than journal articles were excluded.

Further, the articles were limited to engineering, material, and environmental sciences. Following the second step, a detailed review and content analysis of these shortlisted studies was conducted to extract metadata and critical CP barriers. The barriers were then classified as HB (technical, technological, infrastructural impediments) and SB (social, cultural, behavioral impediments) barriers. Further mitigation measures were also extracted and compiled to alleviate identified CP barriers. Finally, in the third step, a conceptual framework was presented that outlines enablers for implementing CP in the CI. The key steps in this context include (i) Implementation of soft enablers to instigate social and cultural readiness for CP in CI; (ii) Implementation of hard enablers to bring about infrastructural and technical readiness in CI; (iii) Implementing circular strategies in different phases of project lifecycle to facilitate the adoption of CP in CI.

2.1. Research strategy

This study deployed the systematic literature review (SLR) technique as the main research methodology to consolidate the findings of existing literature on the barriers to adopting CP in CI.

Different review approaches, such as narrative or traditional literature reviews, critically appraised topics (CAT), scoping reviews, SLR, and annotated bibliographies or bibliometric analyses, can be leveraged to conduct meaningful literature reviews. SLR was chosen for this study due to its comprehensive nature and systematic procedure. It has been employed in various studies to understand barriers to adopting different techniques and technologies [43,44]. Specifically, SLR was adopted instead of simple bibliometric analysis in the current study as bibliometric analysis focuses on descriptive attributes of the reviewed literature. Whereas SLR not only provides insights into the descriptive aspects of studies through meta-analysis, as seen in bibliometric analysis, instead it goes a step ahead by enabling detailed content analysis, synthesis of results, and extrapolation of findings from previous studies to devise literature-based frameworks [45]. Overall, bibliometric analyses are more suited to single authors' short turnaround articles.

In contrast, SLR usually involves multiple authors combining their efforts to solicit cross-domain knowledge and move beyond analyzing the bibliometry to a more holistic capture of the development in the field, as well as proposing conceptual frameworks. This is also a limitation of preferring SLR over bibliometric studies, as SLR consumes more time than its counterpart. The combination of multiple analyses, in the case of SLR, makes it a superior literature review technique to bibliometric analysis [46]. The increased use of SLR over bibliometric analysis is an emerging trend in recent studies. Authors looking to devise conceptual frameworks through literature review have preferred SLR over other literature review approaches [45,47]. For example, Wuni and Shen [48] used SLR to characterize the barriers to the application of MC, validating its appropriateness and suitability for similar studies. The current study was performed by strictly adhering to the protocols of PRISMA as an established SLR method [49]. As per the PRISMA guidelines, the following key points were considered for conducting the SLR in this study following Ullah et al. [47].

1. The review process is based on evaluating keyword-based articles published between 2010-2023 retrieved from the Scopus repository. The timeline was selected as most of the contributions to CE were made in this period [50]
2. The eligibility criteria entail articles that incorporate the specified keywords within their title, abstract, introduction, or keywords sections.
3. The information source or database utilized for this research is the Scopus repository (accessible at scopus.com/search/form.uri?display=basic).
4. The search process employed comprehensive search strings, as listed in Section 2.2 of this study.
5. The study selection process consisted of searching and screening articles by limiting the study to original articles and review papers since they undergo rigorous peer review, providing high-quality, evidence-based scientific knowledge [51]. Conference papers, book chapters, and data papers were excluded from the scope due to the limited peer review involved in their assessment. The selection process limited the study to articles published in English. Relevant fields of study like engineering, material, and environmental sciences were selected, and studies from irrelevant disciplines, such as chemistry, psychology, etc, were excluded. Disciplines that do not address CP and CI, such as arts, medical science, agriculture, and mathematics, were excluded to only retrieve relevant literature with a strong focus on the research theme. It also involved qualitative analysis in the form of reading titles and abstracts. The deduplication of repeating articles was not needed as the data was extracted from one repository only.
6. The retrieved articles were analyzed for metadata through the Scopus "Analyze Results" tool. Metadata regarding the articles addressing the chosen research themes, such as frequency of publications per year, country of origin, co-occurrence of keywords, number of citations received by studies, and source of publications, were extracted and presented in the meta-analysis section of this article.
7. A thorough screening of the extracted studies to filter irrelevant articles was conducted by reading the titles, abstracts, introductions, and conclusions of the extracted studies. Once filtered, the content analysis of the eligible articles was performed by reading the full texts of the shortlisted articles and identifying the critical CP barriers listed in each study. The strategies to mitigate such barriers were also traced in the selected literature and recorded accordingly.
8. The risk of bias in the study was mitigated by circulating the articles between authors. Each author analyzed the contents of the eligible articles separately. The pertinent findings were collated and combined. This triangulation helped tackle potential authors' bias.
9. The summary measures consist of critical barriers to implementing CP in CI and their distributions into pertinent categories of HB and SB, depending upon their intrinsic nature.
10. The findings of the current study were compared with the existing literature for validity and consistency of results.
11. The additional analyses conducted in this study comprise devising strategies for mitigating the barriers to CP in CI and proposing a conceptual framework based on enablers of CP to implement it in the CI.

2.2. Data collection

A visual summary of the PRISMA literature sampling process used in this study is illustrated in Fig. 2. PRISMA is one of the most reliable techniques for SLR owing to its globally accepted guidelines [52]. PRISMA addresses the shortcomings of other review protocols by providing an organized and structured approach to the literature review. Accordingly, it has been widely used in recent studies [52,53]. Therefore, PRISMA, one of the most established SLR techniques, was adopted in the current study. However, this is not to say that PRISMA is the only technique that uses systematic protocols for literature review. There are other such techniques listed below; however, PRISMA remains the most widely used protocol globally and, hence, the best candidate for the current study.

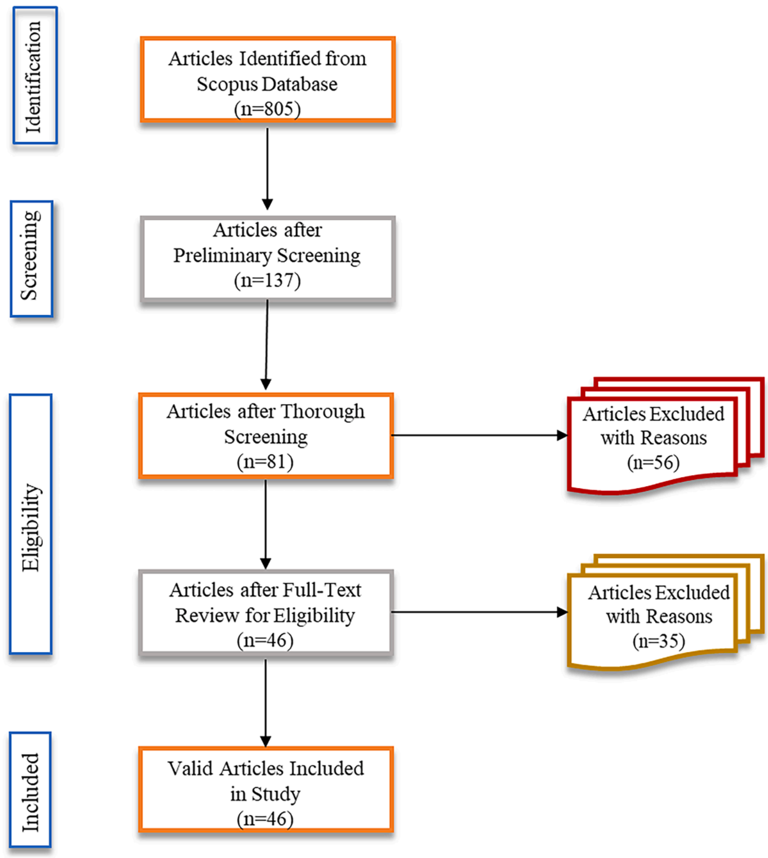

Fig 2. PRISMA flow diagram for the literature sampling process.

- Assessing the Methodological Quality of Systematic Reviews (AMSTAR)
- AMSTAR 2
- Enhancing the QUAlity and Transparency Of health Research (EQUATOR)
- Cochrane Handbook
- Methodological Expectations of Cochrane Intervention Reviews (MECIR)
- System for the Unified Management of the Assessment and Review of Information (JBI SUMARI)
- International Prospective Register of Systematic Reviews (PROSPERO)
- Patient, Intervention, Comparison, Outcome (PICO)
- Sample, Phenomenon of Interest, Design, Evaluation, Research (SPIDER)
- Consolidated Standards of Reporting Trials (CONSORT)
- Meta-analysis Of Observational Studies in Epidemiology (MOOSE)
- Appraisal of Guidelines for Research & Evaluation (AGREE II)

The Scopus database was used to retrieve relevant studies following PRISMA protocols. Other repositories, such as Web of Science (WoS), were not used due to limited institutional access. Two authors of the study are affiliated with an institution in a developing country where access to WoS is not available. Since the review and all retrieved articles were to be cross-verified by all authors, it is important that all authors had access to the repositories to avoid any authors or location bias. Thus, owing to the unavailability of WoS to each author, it was not utilized for literature retrieval in the study.

Similarly, Google Scholar was not used to avoid retrieving location-based results since it uses Google's location-based algorithms for retrieving articles and, thus, a potential for retrieving location-specific articles, which may not be consistent for results across the globe [54]. In comparison, Scopus access was available to all authors, making it the preferred literature retrieval and verification database for the current study. Further, Scopus has been regarded as the state-of-the-art literature indexation and management database in Construction, Engineering, and Management (CEM) studies, further strengthening its suitability for the current study [55]. This also aligns with recent studies that have only used the Scopus database for literature review, especially in the domain of CEM [6,28].

Boolean operators "AND" and "OR" were used to consolidate the search string leveraged in this study. The search strings, inclusions, exclusions, and limits used to retrieve data, are as follows:

- **Inclusions:** TITLE-ABS-KEY (("Circular Procurement" OR "Circular Economy") AND ("Construction Industry" OR "Built environment" OR "Building*") AND ("Barrier" OR "Challenge" OR "Inhibitor" OR "Constraint" OR "Hindrance"))
- **Exclusions:** (SUBJAREA, "ENER") OR (SUBJAREA, "COMP") OR (SUBJAREA, "EART") OR (SUBJAREA, "ECON") OR (SUBJAREA, "CENG") OR (SUBJAREA, "SOCI") OR (SUBJAREA, "PHYS") OR (SUBJAREA, "CHEM") OR (SUBJAREA, "DECI") OR (SUBJAREA, "AGRI") OR (SUBJAREA, "MATH") OR (SUBJAREA, "BIOC") OR (SUBJAREA, "ARTS") OR (SUBJAREA, "MEDI") OR (SUBJAREA, "PHAR") OR (SUBJAREA, "IMMU") OR (SUBJAREA, "VETE") OR (SUBJAREA, "PSYC") OR (SUBJAREA, "DENT").
- **Limits:** (DOCTYPE, "re") OR (DOCTYPE, "ar") AND (LANGUAGE, "English") AND (SRCTYPE, "j")

The identification of articles based on the mentioned search string yielded unfiltered results (805 studies), which put forth data in a raw form having a peripheral focus on the CP. For the preliminary screening of studies, several constraints and filters were applied to the search string. These filters included the exclusion of literature other than articles and review papers and the exclusion of content from irrelevant disciplines such as medical sciences and arts. The studies originating from trade journals and grey literature were also excluded by limiting the search to academic journals. Six hundred sixty-eight studies were excluded as they failed to meet the listed merits, reducing the total to 137 relevant articles. Subsequently, the articles were screened thoroughly based on pre-determined inclusion and exclusion standards, which were derived from previous studies of a relevant nature [56]. These include:

(1) Articles exclusively addressing the barriers to the adoption of CP in CI.
(2) Articles with full text available for readers through standard Scopus access.
(3) Articles mentioning CP or CE in their title, abstract, keywords, introduction, or conclusion.

The title, abstract, introduction, and conclusion sections of the filtered literature were carefully read by authors for the thorough screening of relevant studies based on the mentioned set of standards. The studies whose research themes did not align with barriers to CP in CI were excluded from the retrieved list. At the end of the screening process, 81 articles bearing strong relevance to the objectives of the current study were chosen for the in-depth review. Ultimately, the complete texts of the remaining articles underwent a thorough examination, and after validating their eligibility and strong alignment with the research theme, 46 studies were finally shortlisted and reviewed. The selected articles are listed in Table A in the Appendix.

2.3. Data analyses

A multi-step approach was adopted to analyze data on the topic and from the shortlisted articles. In the first step, Google trends for the topic keywords were observed using the website https://trends.google.com/trends/ (last access date 19 April 2024). The trends for the keywords “circular economy” and “circular procurement” were observed and reported. In the second step, metadata from Scopus was extracted, analyzed using Microsoft EXCEL, and visualized using Scopus’s “Analyze Results” tool. Table 1 illustrates the types of analysis conducted on the articles and the relevant tools used. Keyword-based co-occurrence analysis and citation analysis were performed on the selected articles using VOSviewer. Co-occurrence analysis was employed to reveal the commonly occurring research themes and their inter-relationships. Citation analysis was conducted on the retrieved studies to unveil the studies with the highest number of citations. The preference for VOSviewer over similar software like NVivo or Perish was inspired by the extensive use of VOSviewer in contemporary studies as well as its detailed quantitative analysis capacity [57]. Comparatively, Nvivo® and Publish or Perish® are primarily used in literature retrieval instead of quantitative analysis, rendering them inappropriate for the current study [57]. The citation and co-occurrence analysis for authors have not been included in the study because the majority of authors have contributed only one article to the research theme. As a result, such an analysis does not provide any valuable insights to the readers.

Table 1
Type of data and tools.

Sr No.	Type of Data / Analysis	Output	Tools Data Extraction	Visualization
1	Frequency analysis	Number of papers published per year	Scopus Analyze	MS Excel
2	Journal/source	Number of articles published by various journals	Scopus Analyze	MS Excel
3	Number of publications by country	Number of articles originating from different countries	Scopus Analyze	MS Excel
4	Co-occurrence of keywords	Most commonly occurring themes based on keywords	Scopus Analyze	VOSviewer
5	Citation analysis of articles	Number of citations received by retrieved articles	Scopus Analyze	VOSviewer

Table 2 shows the inclusion criteria for the keyword analysis and citation analysis of the articles. The “full counting” function of VOSviewer was used to count the number of articles and their citations. To limit the number of keywords, a minimum criteria of 5 occurrences was set for keywords to be considered for the co-occurrence analysis. As a result, 37 keywords were determined that met the defined inclusion criterion. Similarly, a minimum of ten citations per document was set for the retrieved articles for the citation analysis. After applying the criterion, 41 documents were shortlisted that met the mentioned standards.

The subsequent step of the current study involved an in-depth content analysis of the shortlisted articles to identify and comprehend the barriers to implementing CP in the CI. For this purpose, all shortlisted articles were downloaded as Portable Document Format (PDF) files. The content analysis was performed manually by reading the full texts of the retrieved articles and recording the findings of each study in an Excel sheet.

Diverse barriers were identified from previous studies belonging to the financial, organizational, technical, technological, and regulatory domains of the construction sector. These were divided into two groups, i.e., HB and SB. The operational barriers, such as technical constraints, technological gaps, and lack of infrastructural readiness in CI to adopt CP, were categorized as HB. These barriers require sound structural reforms and the investment of significant resources for their effective resolution. In contrast, SB, being rooted in social and cultural norms and behavioral challenges, can be more malleable, necessitating awareness and behavioral modifications to overcome. Therefore, barriers such as lack of organizational commitment, misconceptions regarding recycled products, and lack of awareness were deemed SB to CP in CI [35]. A similar grouping for the characterization of barriers was utilized by Jesus and Medonca [58] and Campbell-Johnston et al. [59] in their studies.

A critical detailed review was performed in this study to synthesize the most significant and cardinal barriers to CP adoption. Based on the findings, the different strategies for addressing the identified barriers were retrieved and presented. The strategies highlight institutional, industrial, technological, academic, and regulatory initiatives that can alleviate the outlined barriers to CP adoption. MS Excel was used to record the barriers and enablers in each study for implementing CP in CI. Finally, a conceptual framework is presented to overcome the barriers to the successful take-up of CP in the CI.

The conceptual framework is devised on the basis of the reviewed literature. The findings from previous studies regarding the enablers of CP in the CI were compiled and integrated to develop a literature-based conceptual framework. It has become an established practice in review studies whereby the findings from previous studies are extrapolated and consolidated to form a literature-based conceptual framework that holistically integrates the findings of the study [47,60]. The conceptual framework in the current study is inspired by the studies of Wuni and Shen [48] and Ullah and Turjman [60], who devised literature-based

Table 2
Criterion for keyword analysis and citation analysis.

Type of Analysis	Counting Method.	Unit of Analysis	Minimum Occurrence	Results	
				Unfiltered	Filtered
Keyword Analysis	Full Counting	Documents	5	525	37
Citation Analysis	Full Counting	Documents	10	110	41

conceptual frameworks in their respective studies.

3. Analyses and results

3.1. Results of meta-analysis

As discussed in the method section, Google Trends analysis was conducted for the keywords of the current study. Fig. 3 presents the pertinent results. As shown in Fig. 3(a), the global interest in CE has been gradually increasing since 2012 and appears to have peaked in 2022. In comparison, as shown in Figure 3(b), the interest in CP is currently on the rise and still peaking in 2024. These results are also aligned with the authors' initial findings, where most research on CE and CP appeared to have started in the last decade, extending to 2010. This reinforces the authors' position on the start year of the current review study as 2010.

A frequency analysis of the retrieved publications was conducted to present the traction gained by the research theme over the previous years and comprehend its popularity [61]. The results of the undertaken frequency analysis are illustrated in Figure 4(a). An increase in the number of publications across recent years has been observed, suggesting increased interest among researchers in understanding the barriers hindering CP practices within the CI. CP started getting attention during 2017-2018 as a novel and developing concept within the ranks of CE. The number of studies increased relatively in 2019 due to the emerging focus on implementing circularity across various industries triggered by the second CE action plan signed by the European Union (EU). However, the trend in 2020 slowed down compared to previous years. The COVID-19 pandemic slowed research, inhibiting prominent

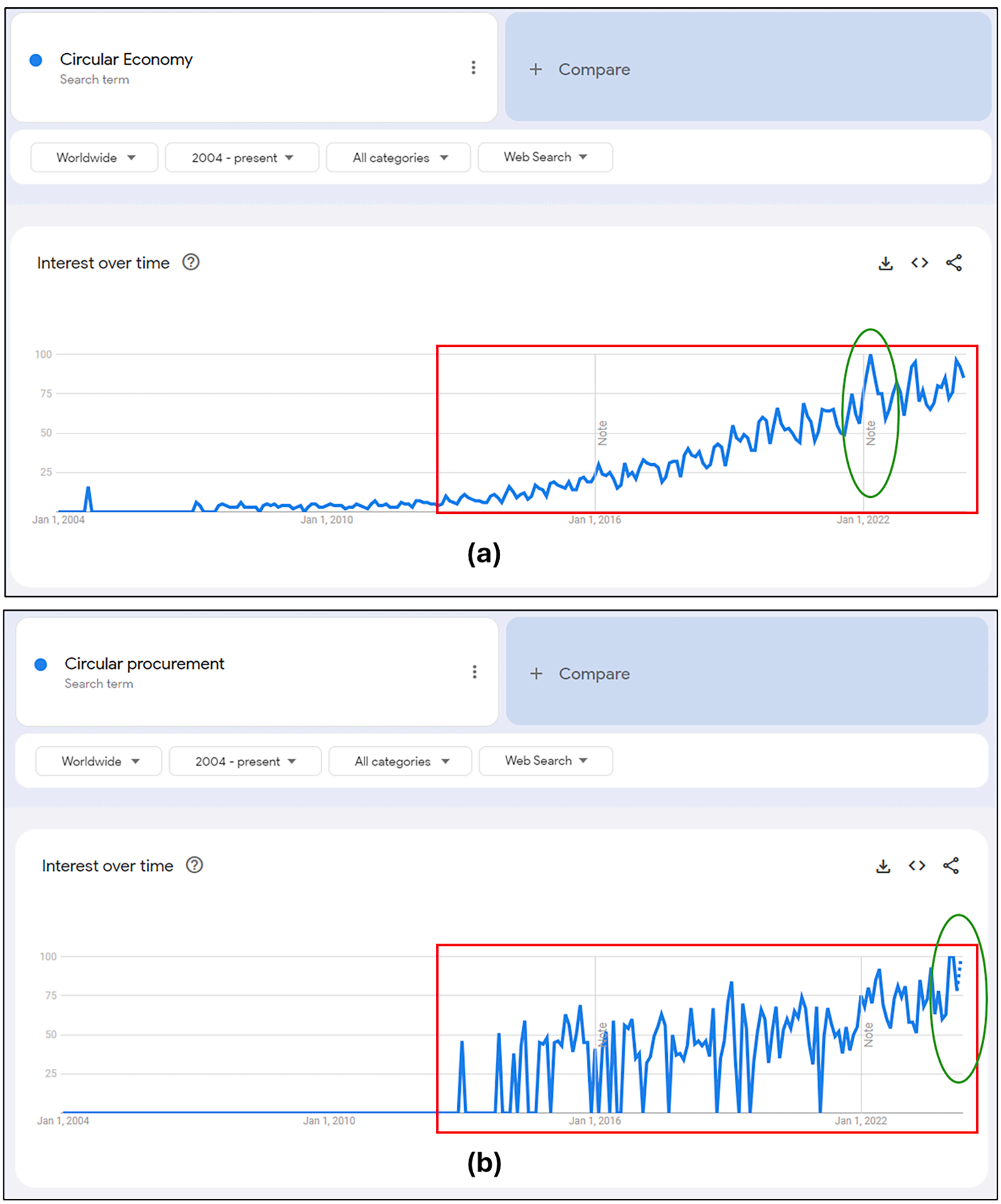

Fig 3. (a) Google Trends for the search term "Circular Economy" (b) Google Trends for the search terms "Circular Procurement" (*Source: Google Trends*).

and widespread contributions in this domain like other sectors. However, the research theme experienced a massive inflow of academic breakthroughs in 2021 following the recovery from the global pandemic. The maximum number of studies were conducted in 2022, which is likely to increase due to the surging emphasis on the implementation of CE and CP within the CI.

Another analysis aimed to explore the source/journal of the selected studies was conducted. Identifying the source of publications for the literature under study helps identify the target reading outlets for readers interested in the topic. It also helps contextualize the research theme by organizing the existing body of knowledge and highlighting its key contributors. By illustrating the contributions of reputable journals regarding CP in construction, the source analysis establishes the importance of the concerned research theme among the leading academic forums and industry professionals [62]. The results are displayed in Fig. 4(b), which shows that the most significant contributor to the pertaining literature was the "Journal of Cleaner Production," with 16 articles addressing the research topic. The second significant source of publications was "Resources, Conservation, and Recycling," with six articles published in the domain of CP in CI. Both mentioned journals are indexed as "Q1" in the Scimago Journal & Country Rank (SJR), which reflects the superior quality of the retrieved articles.

Lastly, an analysis was performed to record the number of publications by authors affiliated with different countries. This analysis revealed the research trends and concentrations in different countries concerning CP in CI. It was aimed to identify the countries that are actively contributing to the body of knowledge regarding the research theme. The results are illustrated in Fig. 4(c), which shows that the UK had the highest number of publications with 24 articles. This leading number can be accredited to strict legislative frameworks and solid policy-making initiatives in the UK, such as plastic packaging tax, environmental bills, and extended producer responsibility schemes, taken by the government of the UK to ensure a successful take-up of CE in the country [63]. Australia and the Netherlands followed the UK with 11 and 10 publications, respectively. Region-wise, Europe was the highest contributor to literature, owing to the CE Action Plan declared by the EU, which has incentivized research and development in this domain [64].

A scientometric map was developed based on the keywords-based co-occurrence analysis of the retrieved articles, as shown in Fig. 5. Keywords such as "construction industry," "circular economy," and "sustainable development" are represented by larger bubbles in the map owing to a high number of occurrences in the relevant literature. The map is composed of 4 predominant clusters, differentiated by colors – red, green, blue, and yellow. The red cluster embodies the theme of construction materials, green represents waste management, blue represents economic aspects, and yellow represents sustainability. Taken holistically, these themes are the focus of CE and CP. A high link strength between keywords such as "construction industry" and "circular economy" highlights the focus of the retrieved articles on these keywords. It is worth mentioning that the keyword "circular procurement" had a very low occurrence in the retrieved studies, and subsequently, the bubble for the keyword is very small. "Circular Procurement" appeared only four times as a keyword in the retrieved literature, pointing to its nascency and a dearth of literature addressing it, hence supporting the need for the current study [37].

Fig. 6 presents the top 10 keywords with the highest number of appearances in the studies retrieved from Scopus. A total of 525 keywords were analyzed through VOSviewer, which were reduced to 37 keywords after applying the inclusion criteria. "Circular Economy" emerged as the top keyword with 85 appearances, which corresponds to 16 % of total keywords. It was followed by "Construction industry," which had 67 appearances (12.7 % share). "Sustainable Development" and "Built Environment" followed these with 32 and 27 occurrences (6 % and 4 % share respectively).

Finally, document citation analysis was conducted on 110 articles retrieved from Scopus, which were reduced to 41 after applying the minimum inclusion criteria of 10 citations per document. Fig. 7 provides a funnel diagram of the articles that have received the highest number of citations. The article by Hart et al. [65] has received the most citations (155 citations). The article by Ghisellini et al. [66] is next in line with 131 citations. The articles from Tingley et al. [67] and Guerra and Leite [27] follow up with 121 and 82 citations, respectively. Other articles with more than 50 citations include studies by Charef et al. [68], Campbell-Johnston et al. [59], Miller et al. [69], and Giorgi et al. [70] .

3.2. Content analysis

This section documents the findings of the content analysis conducted through manual scrutiny of the shortlisted articles to identify and

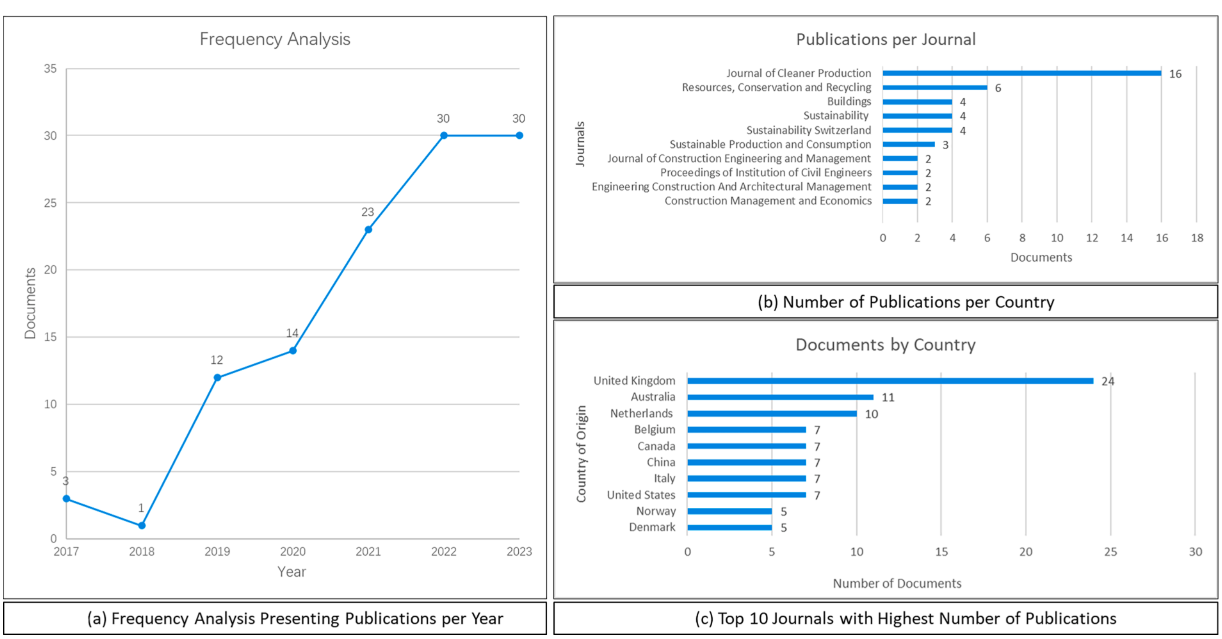

Fig 4. (a) Frequency analysis (b) Number of publications per country (c) Top 10 journals with the highest number of publications (*Source: Scopus Analyze*).

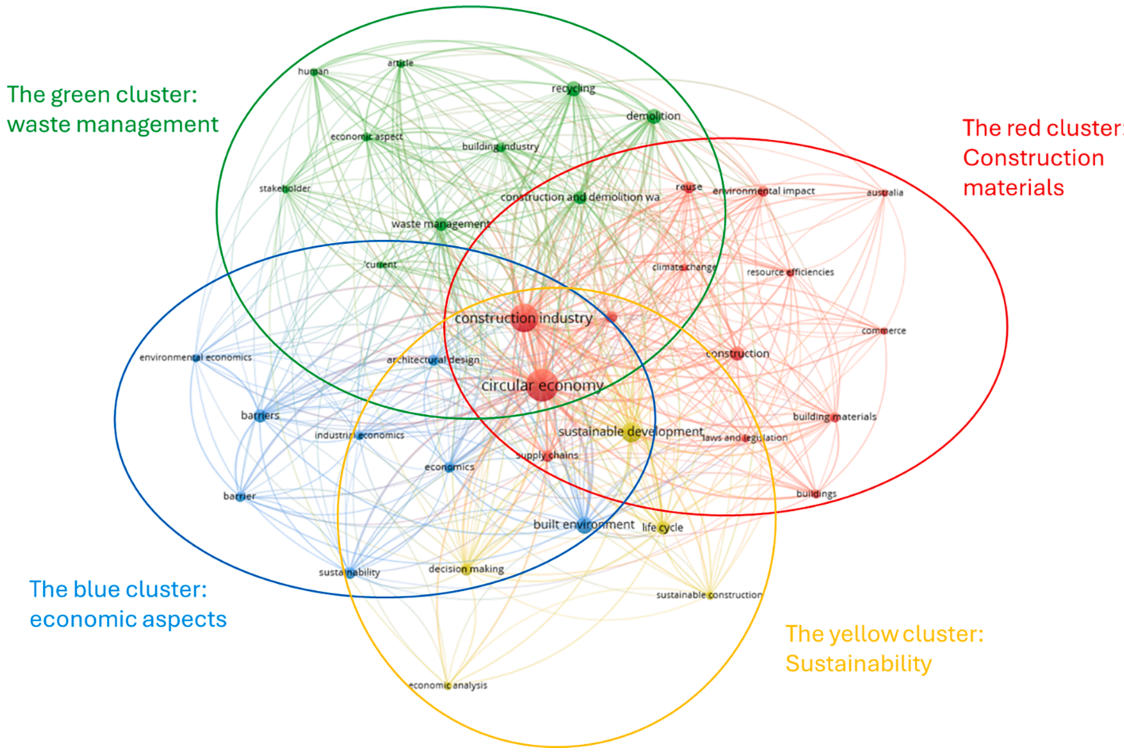

Fig 5. Scientometric map of keywords.

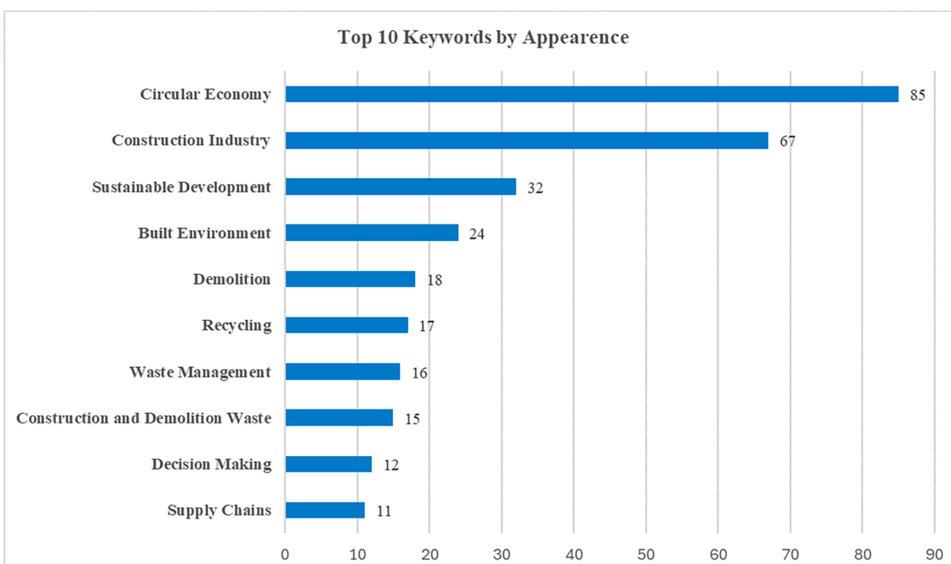

Fig. 6. Top keywords in terms of their occurrence in the relevant literature.

report the most significant barriers to adopting CP practices in CI. The barriers are listed in the pre-ascertained categories of HB and SB, as shown in Table 3, and discussed subsequently.

HB includes technical impediments such as a scarcity of construction materials that follow circular resource loops and a lack of design standards for construction using recycled materials (HB1). Similarly, the inadequacy of "take-back" systems and insufficient reverse flow of construction products within the construction industry's supply chains impede the adoption of CP (HB2). The unavailability of information exchange and management systems reduces the accessibility of circular building products to potential buyers, which reduces their substantial use in CI (HB3). SB encompassed social and cultural barriers like disinterest from stakeholders in making a transition to circular models due to a lack of incentives as compared to LEMs (SB1). The novelty of CP frameworks and a lack of successful precedents have led to stakeholders and investors distrusting CP routes, inhibiting its widespread adoption in the CI (SB2). The perception that circular building materials have inferior performance is listed as another SB to CP adoption in the current study (SB4). Strategies to resolve or mitigate the critical barriers were also cataloged during the content analysis, as presented later in this section.

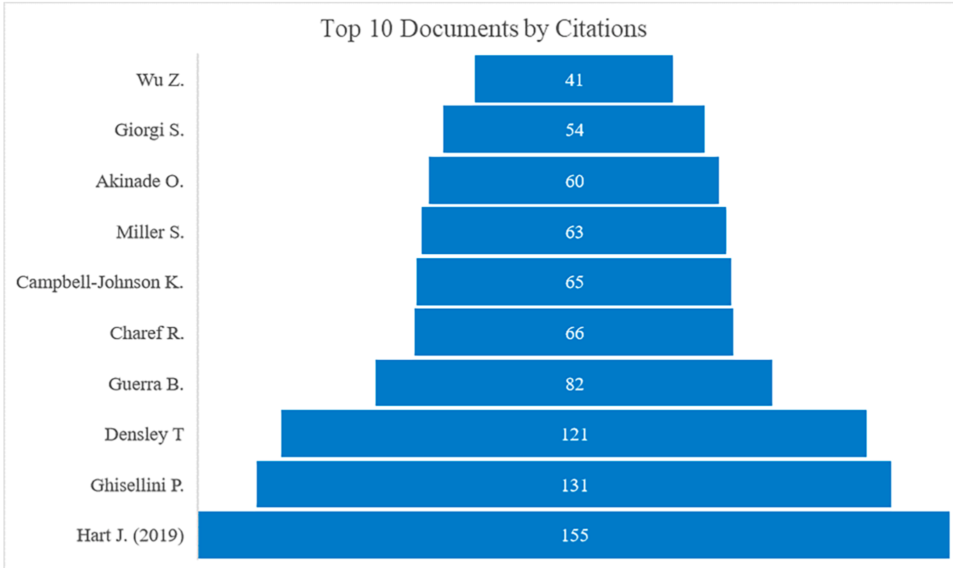

Fig 7. Top documents with the highest number of citations.

3.2.1. *Hard barriers (HB)*

3.2.1.1. Lack of circular design and products (HB1). One of the major impediments to the adoption of CP in CI is the insufficiency of the current circular design principles and the absence of associated products in the construction sector [78]. Inadequate information about the design of buildings constructed of reclaimed materials creates a lack of trust among the stakeholders in such materials [79]. Despite the increasing interest among nations in adopting CE, only limited countries such as the Netherlands, the UK, and Germany have devised construction standards, design codes, and guidelines for using recycled materials in construction works, whereas others are lagging [80].

Studies have also suggested that traditional construction practices do not consider the disposal of buildings at the end of their lifecycle during the design phase, which prevents the successful reclaiming of construction materials owing to a lack of front-end planning [81]. Novel design and construction techniques facilitating the adoption of CE, such as DfD and MC, also present unique challenges due to the complexity and the lack of knowledge about the design of such buildings [80]. Architects, Engineers, and Construction (AEC) managers hold differing opinions on practices such as DfD and their overall project impacts. Some managers have reported difficulty in leading such projects due to a lack of required technical knowledge [82]. The lack of design codes in the case of DfD and MC inhibits their use on a large scale within regions prone to earthquakes, cyclones, and extreme weather conditions due to safety concerns [83]. As a result, conventional methods and materials are preferred for construction. However, these methods restrict the adoption of CP. The CI suffers from the scarcity of circular products for various reasons, such as a lack of market demand for such products and the high cost of reclaimed materials [81]. The owners avoid venturing into reclaimed materials due to high initial costs, which exponentially increase the budget of construction projects [84]. Moreover, the perception of recycled materials being inferior to freshly conceived products in quality tarnishes the market demand for circular products, thus inhibiting investors from investing in such products [82]. As a result of the insufficient circular design standards, scarce circular products for building works, and perceived additional costs for the stakeholders involved in construction projects, the implementation of CP is hindered in the CI.

3.2.1.2. Lack of reverse logistics and take-back mechanisms (HB2). Lack of infrastructure for collecting used construction materials at the end of their lifecycle upon deconstruction and failure to develop mechanisms for the reverse flow of collected materials in the supply chain are other major barriers to CP adoption [85]. Reverse logistics (RL) refers to "the process of planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal"[86]. The inadequacy of RL in construction is credited to multiple reasons, such as:

(1) Lack of facilities and infrastructure for recovery of materials.
(2) The complexity of deconstructing buildings, especially the non-prefabricated components.
(3) Challenges in reclaiming materials due to the composite nature of construction materials.

The lack of facilities to collect the CDW at the end of the project lifecycle has been pointed out by existing studies [85]. Inadequate waste collection technology has been widely criticized as it prevents the recycling of materials from construction waste [87]. The availability of on-site waste sorting equipment is also scarce in the CI, resulting in off-site CDW sorting, thus preventing the reverse flow of construction materials [88]. This issue is further aggravated by the complex processes involved in disassembling complex buildings compared to the simpler demolition practices that drive LEMs [89].

Lack of technical skill and knowledge, inadequate equipment, limited on-site space in closed settings on construction sites, and a general lack of trust in approaches such as DfD hinder the deconstruction practices that enable adopting CE and associated CP practices in the CI [75]. Moreover, an increased end-of-lifecycle cost is observed for projects adopting a CE model due to the added labor, logistics, specialized equipment, and expenses of disassembling the building components [74]. The owners and other stakeholders are often reluctant to bear the increased disassembly and RL costs. The alternative, i.e., dumping waste in landfills, is cost-efficient in the short term and usually preferred by stakeholders, which hinders the circularity ambitions.

Another challenge in developing RL within the CI is the unavailability of construction materials tracing systems. The lack of an effective waste tracing system stalls the proper collection of CDW. Implementing circularity requires traceability of all or the maximum materials used in construction to facilitate collection and reclamation [85]. However, this is hard to implement due to the generic inability of existing systems to track construction materials and CDW after their disposal, which

Table 3
Summary of impediments to CP sorted as hard barriers and soft barriers.

Categories	Barriers	Description	Code	Ref
HB	(1) Lack of circular design principles and products in construction	A scarcity of construction materials that follow circular resource loops and a lack of design standards for construction using recycled materials	HB1	[27,42, 71–73]
	(2) Lack of reverse logistics and take-back systems	Insufficient reverse flow of construction products within the construction industry's supply chains	HB2	
	(3) Lack of reliable information exchange and management systems	Limited or lack of accessibility to circular products and vendors due to a lack of reliable information exchange and management systems	HB3	
	(4) Lack of standardization	The absence of infrastructure and frameworks for standardized material recycling within the CI due to high variability in building materials and procedures across construction projects	HB4	
	(5) Complex supply chain structure and lack of profitable business models	High upfront costs and complicated structure for transitioning the supply chains to CE and a lack of prospects for profitable business models as compared to LEMs	HB5	
SB	(1) Lack of stakeholder engagement and incentives	Lack of interest and participation from stakeholders in CE and CP due to a lack of financial or other incentives.	SB1	[59, 74–77]
	(2) Lack of trust in circular procurement routes	A lack of successful precedents leading to skepticism about CP routes and the practicality of its procedures from the stakeholders	SB2	
	(3) Resistance to change	Stakeholders holding onto the traditional LEMs due to their perceived reliability and unwillingness to adopt a change.	SB3	
	(4) Perceived poor performance and quality issues of recycled materials	The perception that circular building materials have inferior performance than traditional building materials.	SB4	
	(5) Lack of collaboration and value chain thinking among stakeholders	Fragmentation in the CI and an emphasis on economic gains as compared to lifecycle thinking from the stakeholders	SB5	

hinders the prospects of their reusability [90]. The use of the Internet of Things (IoT), digital twin, and BIM-based material passports can improve the traceability of construction materials to improve RL. However, these technologies still require further development for widespread use in the CI [91].

Lastly, the composite nature of construction materials poses difficulty in their recyclability as they are difficult to isolate. For example, concrete, one of the most widely used construction materials, is a heterogeneous mixture of cement, sand, aggregates, and reinforcing steel bars. Each of these materials has distinct intrinsic properties and must undergo different processes to be reclaimed. As a result of the composite nature of construction materials and the scarcity of on-site tools and techniques, it becomes difficult and costly to reclaim individual materials from their composite products for reuse [90]. To overcome these hindrances, the construction sector must establish a sound and efficient supply chain and RL systems. As CP relies on the reverse flow of materials and products to reclaim, inadequate RL within the CI prohibits the collection and reuse of materials at the end of their lifecycle, thus impeding the adoption of CP in the CI. A visual representation of the inhibitors of RL in construction is given in Fig. 8.

3.2.1.3. Lack of reliable information exchange and management systems (HB3). One of the key technological barriers to the adoption of CP in the CI is the lack of reliable information exchange and management systems. Such systems are necessary to facilitate the flow of information between stakeholders in the CI regarding the quality, quantity, and dynamics of materials and products [92]. Different information management systems, such as Procore and Aconex, are used for procurement in CI projects that traditionally follow LEMs [92]. However, the CI lacks a well-developed uniform information exchange and management system with a holistic database of circular construction materials and products. The situation is further exacerbated by the lack of transparency and technical data sharing in the CI [93]. Fig. 9 displays a summary of challenges that have emerged in the context of reliable information systems in the CI.

The profit-oriented nature of the CI also hinders transparency regarding material databases and information sharing. Moreover, studies have also questioned the quality and credibility of the data provided by existing information systems [94]. Environmental Product Declarations (EPDs) and Material Passports (MPs) offer potential solutions to information management and exchange in the CI due to their ability to store large amounts of data over the lifecycle of buildings. EPDs are voluntary, third-party verified labels for communicating transparent quantitative environmental data based on a Life Cycle Assessment (LCA) [94]. MPs are "qualitative and quantitative documentation of the material composition of a building, displaying materials embedded in buildings as well as showing their recycling potential and environmental impact" [95]. However, structuring, organizing, and storing accumulated big data and meaningfully analyzing it is a challenge on its own [95]. Some researchers have suggested BIM as a platform for storing the data accumulated from MPs. However, it is only a temporary solution since storing large amounts of data on BIM models makes them heavy, thus reducing their workability and requiring higher processing power of the on-site systems. Blockchains have also been highlighted as a possible platform that can revolutionize procurement in the CI by improving the accessibility of sustainable materials to buyers and enhancing transparency in procurement. However, limited efforts have been made to align blockchain-based procurement with CP principles. Further, the technology is in its infancy at this stage, so it is too early to offer a viable solution at present [96].

Another information exchange challenge is the unavailability of uniform data exchange formats for sharing data. Key stakeholders and organizations in the CI use different exchange formats, such as COBi (Construction Operations Building Information Exchange), IFC (Industry Foundation Classes), etc., for sharing data. A uniform exchange format has not been developed and applied in the CI till now, making the exchange of information challenging [97]. The lack of reliable information management and exchange systems for CE in the CI bars the awareness of key partners and stakeholders regarding the presence and quality of reclaimed construction products and materials available in the

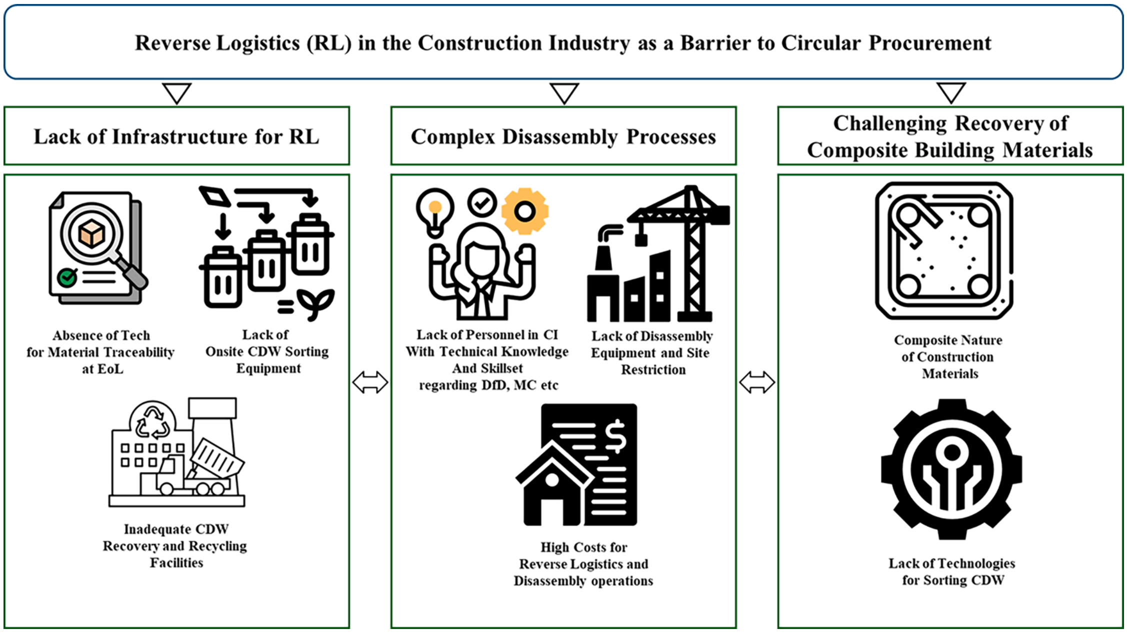

Fig 8. Barriers hindering reverse logistics in construction.

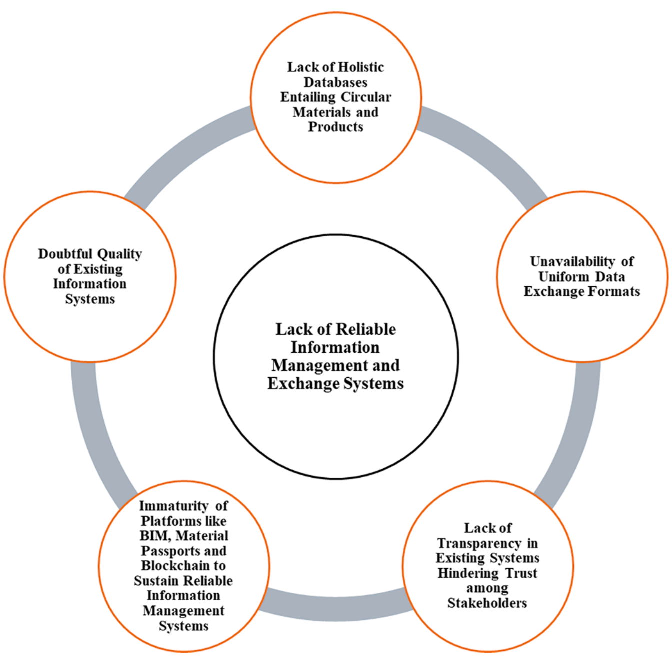

Fig 9. Challenges in the context of reliable information systems in the construction industry.

market. Consequently, stakeholders choose virgin materials and resources for construction projects during procurement, which impedes the implementation of CP practices in the CI [95].

3.2.1.4. Lack of standardization (HB4). CP relies on the intricate recycling and reuse of materials achieved commercially by applying standardized processes for collecting, processing, and reclaiming materials at the end of their lifecycle. However, CI lacks the standardization of relevant recycling procedures. This issue prevails since most construction materials or components are custom-made for specific projects or vary significantly from one project to another, making it difficult to establish standardized recycling processes to reclaim such highly variable materials [98].

Another barrier to devising standards for enforcing CP is the variation in building codes and local regulations across different regions and countries. Local building codes and by-laws heavily influence construction processes. Consequently, high diversity is observed in the CI regarding construction methods, materials, and projects across various regions and countries. Owing to such excessive customization, developing global standards for CP practices becomes challenging as demands vary drastically across regions [99]. Innovative construction techniques like MC and 3D printing can offer a potential solution due to a higher degree of standardization [100]. There are instances of wide use of MC in certain developed countries. However, these techniques (specifically 3D printing) are not being used on a global commercial scale, thereby inhibiting standardization in CI [101].

Another barrier hindering CP implementation is the lack of certified circular construction materials, products, and services vendors. A lack of preference prevails in the market regarding the usage of recycled construction products due to poor perceived quality, which entices owners and investors to opt for virgin materials and resources. This perception is further supported by the absence of certified vendors of circular products and services who are assessed for quality assurance through standardized practices [99]. A lingering trust gap in the CI due to the lack of standardization for processes, products, and quality assurance results in the procurement of fresh resources instead of recycled ones, which impedes the adoption of CP.

3.2.1.5. Complex supply chain systems and lack of profitable business models (HB5). The lack of efficient and profitable business models for circularity in the CI is another key barrier to implementing CP [102]. Traditionally, the construction sector has been running on a “take-use-dispose” business model, successfully profiting the stakeholders. However, the same cannot be said for CE models in the context of CI, as they result in higher upfront and end-of-life costs [103]. The higher upfront costs are due to the higher costs of circular materials. Recycled materials are expensive due to the costs accumulated in logistics and processes of reclaiming such materials for reuse [102]. The added costs at the deconstruction or demolition stage are due to specialized labor and equipment costs required to disassemble building components. The associated transportation costs for reverse materials logistics also increase the total costs [104].

Studies indicate that integrating a Cradle-to-Cradle Life Cycle

Assessment (C2C LCA) methodology into circular construction practices could be advantageous [104]. However, there are multiple hurdles related to this approach in terms of the business models and operational aspects. These challenges encompass factors such as estimating the total life cycle expenses, establishing and implementing new business models, absence of standards for refurbished products, elevated costs associated with recycled materials, insufficient economic incentives encouraging the CI to embrace the reuse of recycled materials, and lack of manufacturer-led take-back systems [105].

Moreover, there are insufficient precedents for successfully applying “take-back” or “producer responsibility” mechanisms for redesigning or refurbishing components and building materials in the CI. The increased budget results in stakeholders and investors shying away from investing in CE practices. Thus, inadequate and non-profitable business models hinder the adoption of CP and other CE practices in the CI. This issue is further exacerbated by the highly complex CI supply chain system.

Construction projects involve various materials, products, components, and equipment supplied by different stakeholders and vendors, resulting in an excessively fragmented supply chain network [105]. Key players within the industry and its supply chain must transition from LEMs to circular frameworks to implement CP. However, the supply chain in the construction sector poses challenges in realizing CE policies due to its excessive fragmentation. Therefore, many stakeholders with varying interests must be taken on board to successfully transition from the existing LEMs to CE models, which is challenging on its own [102].

Moreover, the supply chains within the CI work on “Just-in-Time (JIT)” delivery model in which materials and components are delivered to the construction site exactly when they are to be assembled. JIT prioritizes cost-effectiveness and efficient delivery of resources. Whereas the circular supply chain centers around RL, take-back systems, material loops, and Product-as-a-Service (PaaS) principles, which focus on material reuse and sustainability rather than cost and time efficiency as in the JIT model. This presents an integration gap between the existing and proposed systems, and hence, the existing supply chains within the CI fail to incorporate CP practices due to such incompatibility philosophies.

Another barrier posed by the existing supply chain frameworks to CP is the preference for sourcing local virgin material within construction projects compared to recycled products. Construction projects commonly prefer procuring materials and products from local sources whenever feasible, aiming to lower transportation expenses, reduce emissions, and minimize delivery lead times [106]. This practice does not currently facilitate the adoption of CP, as suppliers of reclaimed construction materials are limited globally. Moreover, the operational suppliers also import construction materials from sources worldwide due to a lack of local recycling facilities. The cost of recycled materials increases due to added transportation expenses incurred from importing such materials [106]. Such added costs bar CP adoption within the CI.

3.2.2. Soft barriers (SB)

3.2.2.1. Lack of stakeholder engagement and incentives for circularity (SB1). The lack of stakeholder engagement and insufficient incentives for developing circular businesses are key barriers to CP adoption in the CI. Even though the EU and some nations have acknowledged the importance of CE and started taking practical steps for its successful implementation [107], there is a global gap in incentivizing stakeholders to adopt circular practices, especially within the CI. Such incentives are pivotal to instigating a strong transition from LEMs to CE. Lack of support from administrative and government authorities adds to the adoption challenge. Undiscounted and higher labor costs, associated CDW disposal costs, and accompanying taxes are impeding the adoption of CP and deterring stakeholders from engaging in such practices [108]. The added challenges due to the absence of regulatory assistance and financial inducement make adopting CP challenging.

Some studies have identified stakeholders’ lack of awareness, understanding, and education as noteworthy reasons for reduced CP adoption [108]. Literature also suggests that the lack of client demand is a major barrier impeding the uptake of CP in the CI. Such lack of demand can be charted as a lack of awareness regarding the detrimental effects of CDW and resource straining on the natural environment [109]. Transitioning from established LEMs to circular business models brings economic risks that incite hesitation in the stakeholders to commit to the transition [110]. The lack of incentives from the governing bodies for stakeholders to make the transition aggravates this hesitation, thus inhibiting the adoption of CP [73]. Accordingly, the widespread adoption of CP in the CI faces hindrances due to the stakeholders being disengaged from circular business models and a lack of incentives for transitioning from LEMs to CP.

3.2.2.2. Lack of trust in circular procurement models (SB2). CI mostly adopts tried and tested methodologies for procurement due to the complex intrinsic nature, inherent risks, and high costs of its projects. The dependence of CI on convenient and trusted frameworks is a barrier to innovation and adopting CP [111]. Design Bid Build (DBB), Engineer Procure Construct (EPC), and Construction Management (CM) are some of the widely used TP models in CI [112]. Such traditional models are preferred for their reliability and history of successful project delivery. In comparison, there is a lack of trust in CP models such as PaaS, cradle-to-cradle procurement, buy-sell back, buy-resell, and extended producer responsibility. Even though these procurement strategies have proven to be effective in various industries, a lack of trust and insecurity regarding the effectiveness of these CP models prevails within the CI [111]. A comparison of TP and CP and the factors causing a lack of trust in CP routes is given in Fig. 10.

The CI domain is distinguished by a multitude of stakeholders, key players, and supply chain actors, which makes it less amenable to applying models like PaaS. This incongruity between CP models and the intricate CI supply chains contributes to a lack of trust in the viability of CP models. Stakeholders may perceive these models as ill-suited for the intricate web of relationships and dependencies in CI [113]. There is also a significant gap in CI regarding the technical knowledge, skillset, and understanding of CP models, which discourages owners and stakeholders with decision-making authority from adopting circular practices [59]. The deficiency of pilot projects and precedents of successful projects delivered through CP models also hinder their application in the CI. The absence of proof of the reliability and evidence of successful implementation of CP models in the CI deters the confidence of stakeholders, leading to a lack of interest in adopting such practices.

3.2.2.3. Resistance to change (SB3). The CI’s resistance to change is a major barrier to adopting CP practices. CI’s fixation on traditional methods and conventional approaches can be attributed to their inherent elevated risks and high costs. The industry’s continued reliance on manual labor instead of transitioning towards automated and robotic construction technology is an example of the industry’s resistance to change. The stubborn attitude prevailing in the CI against innovation is a major impediment to the adoption of CP [77].

Another factor adding to the lack of CP adoption in CI is the tendency for short-term thinking and goals instead of lifecycle aims. This tendency is driven by financial, cultural, and organizational factors that are enforced by the profit-oriented nature of the CI. Traditionally, the CI has focused less on sustainability, circularity, and long-term benefits [114]. The affinity of the CI for immediate returns causes reluctance in the adoption of CP as the implementation of CP would require divergence from financial gains for holistic environmental and social benefits [27]. The implication of reduced financial profits or incurring upfront loss in projects instills a strong reluctance to change in the CI regarding CP. The dearth of technical knowledge and reliable frameworks regarding CP breeds uncertainty regarding the economic success of projects, which adds to the stakeholders’ reluctance to change [115].

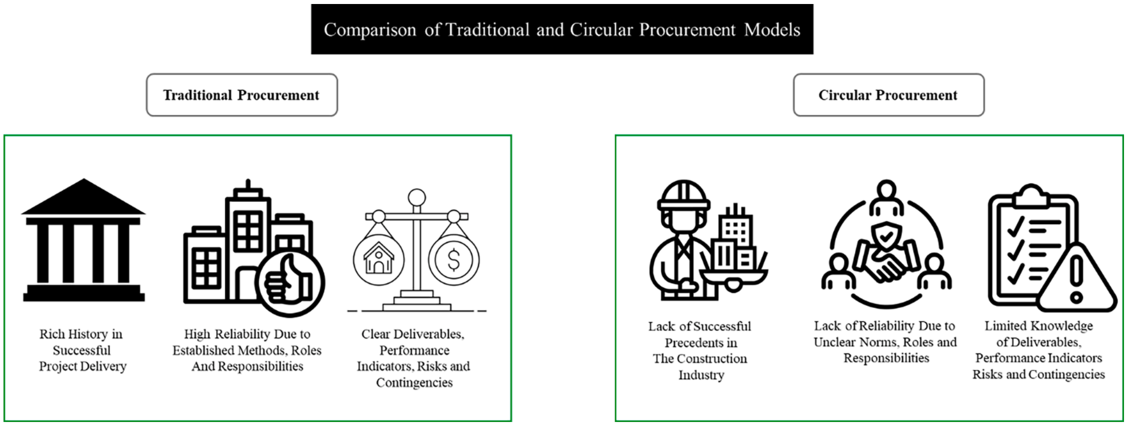

Fig 10. Comparison of traditional and circular procurement routes.

Regulatory and political challenges further instigate resistance to change in the CI. CE has been applauded widely as a solution for resource management to meet the increasing needs of the modern world. However, its application has faced challenges due to a lack of regulatory initiatives by authorities that facilitate the adoption of CE and CP in CI [114]. Due to a lack of cooperation and incentives, businesses are hesitant to change their traditional methods, which hinders CP adoption in the CI.

3.2.2.4. Perceived poor performance and quality issues of recycled materials (SB4). Another barrier to adopting CP in the CI is the perception that recycled materials are inferior in quality to virgin materials. Such perceptions are common in the skeptical environment and culture of the CI, which usually opposes change and innovation [76]. Some studies have argued that recycled materials lose their potency and durability over the years, making them unfit for reuse in CI [116]. The efficacy of recycling processes has also been questioned due to a lack of knowledge and studies that indicate an inferior quality of materials following such processing [117]. For example, earthen products in construction that facilitate CE are criticized due to their lack of durability and limited usage [117]. Similarly, timber construction, which is hailed as a huge prospect for CE, is highly criticized due to performance issues, especially in high-rise construction, and environmental detriments such as deforestation [84]. Studies have also argued that implementing CE in CI would cause environmental pollution, leading to more issues as old building materials contain asbestos and lead, which are toxic, and recycling them may lead to further environmental pollution and health concerns, thus increasing the problems rather than addressing them [116].

Detailed studies to comprehend and present strong evidence of the benefits of CP to the environment and sustainability within the CI are scarce, which does not help the case of CP adoption in the CI [117]. Similarly, loss in material mass leads to additional virgin feedstock during the recycling process, which results in counterproductivity, limiting CP's applicability. Finally, the increased emission resulting from added transportation requirements and reconditioning for the 3Rs (reduce, reuse, and recycle) and Prefabrication Approaches (PFA) also add to the industry's perception regarding performance issues of CE and associated CP approaches [118].

3.2.2.5. Lack of collaboration and value chain thinking (SB5). The CI fails to adopt innovative processes due to a lack of collaboration and cooperation among its stakeholders and professionals. Such an attitude hinders value chain thinking in the industry. A value chain is described as a series of organizational activities that creates, delivers, and captures value at each step, starting from the processing of raw materials to the finished product [119]. Value chain thinking is the tendency of industry stakeholders to cooperate and strive to provide maximum value and achieve a larger common goal instead of chasing short-term benefits [119]. However, the CI is highly fragmented and involves multiple stakeholders; hence, it becomes difficult to implement innovative approaches like CP due to often conflicting interests [72]. The issue regarding collaboration is further exacerbated by the profit-centered thinking within the industry and the risk-averse nature of stakeholders. Due to the high stakes and costs of construction projects, innovation margins are smaller than in other industries [120]. The interest in innovation further declines due to stakeholders' lack of interest in such practices. Another factor adding to this conundrum is the lack of lifecycle thinking in the CI [121]. The value chain of CI is focused on generating maximum economic value, which at times comes at the cost of environmental and social well-being [80]. The transition towards circularity in procurement requires stakeholders to prioritize lifecycle thinking instead of maximizing economic gains, sometimes at the cost of sustainable development [80,122].

The conflict of interests of various stakeholders leads to an adversarial environment responsible for communication gaps and coordination deficits in the CI [123]. Holistic adoption requires collective efforts and coordination among stakeholders, which is challenging in the CI due to fragmentation and sometimes unaligned stakeholders' interests [123].

Another factor impeding collaboration in CI is the lack of transparency and information sharing, which prohibits adopting CP practices such as PFA and RL. Such approaches require sound communication, frequent information exchange, and transparency among project teams, which is challenging in the case of the CI [124]. Owing to the coordination deficit and collective thinking in the CI, implementing sustainable practices in the industry has been inherently challenging. Such initiatives require abandoning financial and personal objectives to achieve larger goals aimed at the betterment of the community at large [14]. Such social goals may not align well with the profit-centric nature of the CI and its stakeholders. Therefore, CP has faced reluctance in its adoption within the CI.

3.2.3. Strategies for addressing barriers to CP

The potential solutions and strategies for addressing the identified barriers were reviewed in the current study, as presented in Table 4. Addressing HB to CP requires a multifaceted approach involving technical, technological, financial, entrepreneurial, and supply chain reforms in the CI. Key strategies involve advancing the design and production of circular products in CI [125]. Enabling on-site storage and reverse supply chains can also promote circularity [126]. Leveraging MPs, BIM-based material inventories, and IoT can enhance transparency and decision support for CP adoption [126]. The 3Rs and end-of-life processes can pave the way for instilling consumer confidence and standardizing product rejuvenation [127]. Governmental prioritization

Table 4
Strategies to mitigate and resolve barriers to CP.

Barrier	Strategies	Reference
Strategies to address HB		
HB1	• Develop design standards and regulations for circular processes through extensive research. • Establish structural design codes for recycled materials. • Increase production of recycled construction products to facilitate their availability.	[127,129]
HB2	• Develop facilities to manage, store, and use CDW at the construction Site. • Formulate take-back mechanisms to facilitate the recycling of waste. • Design for deconstruction to simplify the process of disassembly.	[118,130]
HB3	• Create and maintain sound databases of circular products. • Increase accessibility of information to facilitate decision-making. • Enable data management through BIM and IoT-based frameworks for managing large amounts of data accumulated in MPs.	[128,131]
HB4	• Standardize recycling processes to ensure superior quality of recycled products. • Establish standardized procedures for waste collection and recovery. • Develop standards for distributing circular products to enhance trust in their quality.	[132,133]
HB5	• Devise policies to facilitate and encourage business models dedicated to circularity. • Take measures to reduce the market price of circular products to incentivize supply chain actors to invest in recycled products. • Prioritize CE businesses in public procurement to inspire future entrepreneurs.	[75,110]
Strategies to address SB		
SB1	• Increase awareness of CE and its importance among the stakeholders. • Provide incentives to stakeholders for adopting CP through legislation and policy-making.	[34,123]
SB2	• Develop CP routes tailored to the requirements of the CI through research. • Scrutinize the CP methods for useability in construction through pilot projects. • Uplift technical skillset regarding CP practices in industry professionals through training.	[134,135]
SB3	• Break the cultural norms through education and emphasize the importance of innovation in the CI. • Provide incentives to the stakeholders to transition from LEMs to CE models. • Take initiatives to discourage LEM practices such as using landfills, disposing, and usage of fresh materials through legislation and taxes.	[27,136]
SB4	• Ensure quality compliance of products and processes through rigorous testing, standardization, and transparency. • Invest in pilot projects to build trust in recycled products and circular construction practices.	[95,137]
SB5	• Increase information transparency among stakeholders to encourage coordination. • Provide financial insurance to supply chain actors to inspire collective efforts for a common goal of sustainability.	[138,[139]

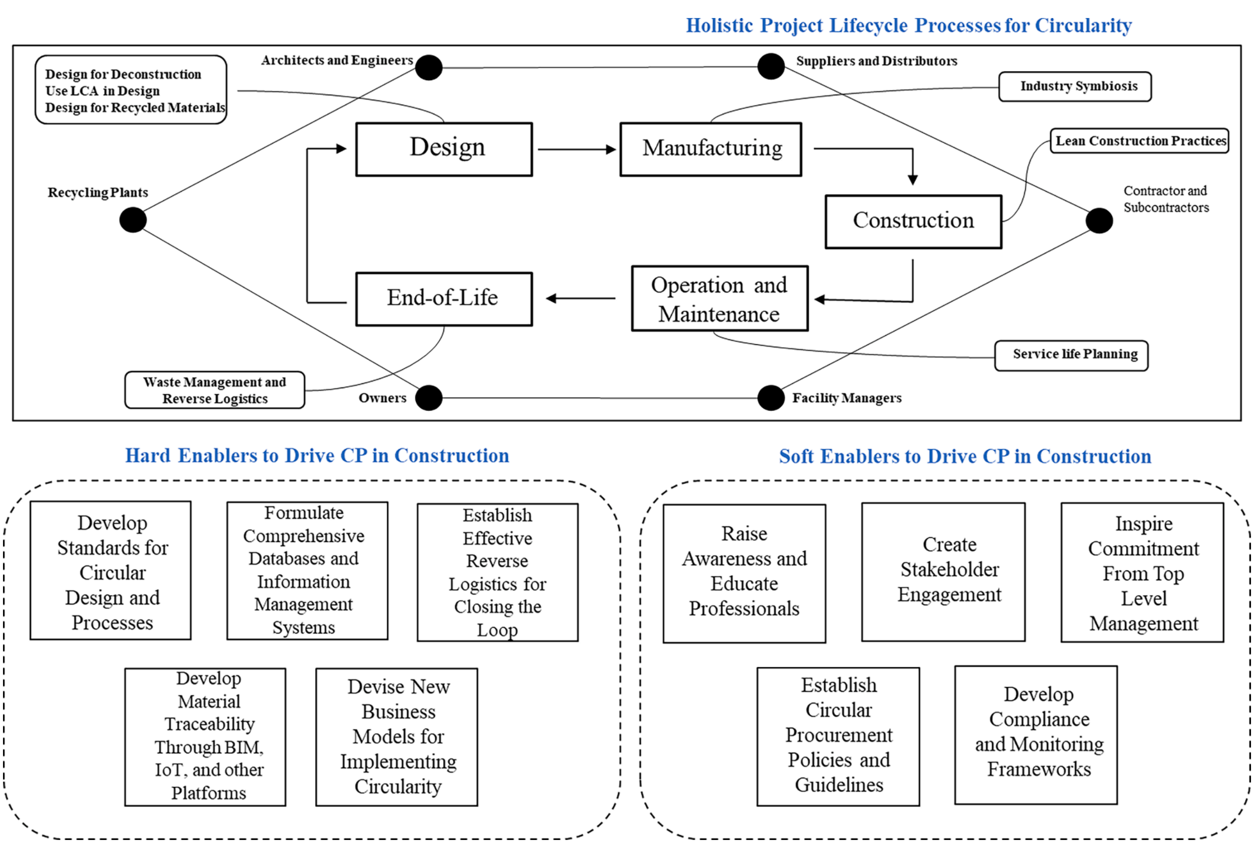

Fig 11. Conceptual framework to facilitate the implementation of CP in CI.

of CP through economic reforms, such as reducing upfront costs for recycled products, can foster a profitable CE environment [128].

Addressing SB requires multidimensional efforts involving organizational, institutional, regulatory, and policy reforms. Awareness campaigns and incentives to engage stakeholders in CP adoption are necessary [128]. Compatibility of CP routes, such as PaaS, with existing construction frameworks, requires comprehensive evaluation. Tailoring CP routes to CI's unique needs is vital for this purpose [132]. The conservative nature of CI can be mitigated through CE incentives and discouragement of LEMs. Stakeholder education is pivotal for CP transition [139]. Similarly, to address misconceptions about recycled construction products, initiatives like transparent recycling processes, quality standards, and showcasing recycled materials' merits through pilot projects should be taken [123]. Finally, promoting transparency and collaboration among CI stakeholders can remedy cooperation issues arising from the adversarial environment [134].

3.2.4. *Conceptual framework for promoting the adoption of CP in CI*

Implementing the strategies suggested in the current study can pave the way for adopting CP and other CE practices in CI. Fig. 11 presents a conceptual framework that highlights essential initiatives serving as enablers for CP in CI. These enablers, categorized as "soft" and "hard" enablers, synonymous with HB and SB, foster a conducive environment for CP adoption in CI based on their barrier-alleviating roles.

Soft enablers, encompassing building trust through education, promoting stakeholder engagement, ensuring organizational commitment, and cultivating a collaborative value chain, lay the foundation for the subsequent hard enablers. These hard enablers target the mitigation of technical impediments to CP and involve the development of design codes and standards, establishment of decision support systems and databases, creation of RL mechanisms, enhancement of material traceability, and innovation in CI. Additionally, the framework underscores the integration of circular practices across project lifecycle stages, including prioritizing DfD in the design phase, adopting lean construction methodologies during the construction phase, and implementing effective waste management practices at the project's end of life. The framework also addresses the role of different stakeholders in the project lifecycle, paving the way for adopting CP. These roles include the circular design of projects by engineers and architects, industry symbiosis by vendors and distributors for circularity, and service life planning by facility managers and owners taking responsibility for RL. Further discourse on the mitigating strategies and the proposed framework is presented in the discussion section.

4. Discussion

Critical barriers impeding the adoption of CP and strategies to mitigate such obstacles in the CI were identified and put forth in this study. The findings imply that the CI faces HB in CP adoption, which is attributed to a lack of technological prowess, knowledge gaps, technical skills, unreliable information exchange and decision support systems, and the inherent complexities of CI. These identified barriers are consistent with the findings of earlier studies [58]. Inadequate circular design standards and guidelines, coupled with limited production of circular construction products, are major hindrances to CP adoption in CI. Lack of research regarding the behavior, quality, and performance of recycled materials, absence of design standards, and a deficient body of knowledge regarding circular processes contribute to the lack of CP adoption [140]. To address these, the current study proposes investing in research aimed at understanding the structural behavior of recycled materials and developing relevant standards for CI. Increasing the production of recycled materials for construction and subsidizing their upfront costs can create market demand for such products in CI [71]. The backflow of used materials poses a challenge in construction due to difficulties in material traceability, segregation of individual materials, and limited RL. Innovative approaches like PFA and DfD present opportunities in this regard, but they also pose unique challenges in the form of incurring more labor and equipment costs, which disincentivizes the stakeholders [104]. Developing mechanisms for tracing CDW through IoT and BIM, as well as enabling on-site storage of CDW, can allow the reverse flow of construction materials for reuse [94]. Insufficient information management and decision support systems discourage the procurement of circular products. Procurers fail to identify available recycled products and their vendors due to poorly maintained or absent databases and information management systems [94]. EPDs and MPs are potential solutions for managing the information pertinent to circular products. However, these solutions are in nascency and have not been tested for mass deployment [20]. Development and rigorous maintenance of insightful databases are necessary to provide decision support systems for CP adoption. Utilization of modern tools and techniques like big data, IoT, and BIM-based MPs for creating inventories of recycled products is beneficial in providing transparent and comprehensive data to stakeholders and decision-makers in CI [20]. CP is a novel concept in construction, and its intricate principles are often at odds with the prevailing practices of the CI. There is a lack of successful and profitable CP-based business models in CI, which hinders its adoption [110]. However, this barrier can be addressed by devising policies to increase the profitability of CE models and associated CP, as witnessed in the case of the Netherlands [43]. Increasing the costs of virgin materials and resources while lowering the price of recycled ones will serve as a financial incentive for stakeholders, thus garnering their engagement in CP [110].

SB to CP adoption in CI exists due to a lack of awareness, incentives, and cultural factors [74]. Among such SBs, lack of stakeholder engagement is a major impediment to CP adoption. The key players of the AEC industry are not encouraged via sufficient financial incentives and awareness campaigns to actively partake in adopting CP. Similarly, poor market demand for circular products is another reason for stakeholders shying away from CP adoption [63]. Providing financial incentives to stakeholders and favoring CE-based business models in public procurement and government projects offers a potential solution to this barrier [42]. Prioritizing the award of contracts to vendors and contractors who prefer and operate CE-based businesses can motivate the stakeholders [107].

Similarly, misconceptions regarding the quality and performance of recycled materials also impede CP adoption. Educating the stakeholders and transparent quality compliance assessments of recycled products can develop trust in the use of circular products. Conducting pilot projects to demonstrate the eligibility of recycled products would also address the misconceptions regarding circular products [139]. Likewise, the resistance to change and innovation in CI presents another barrier that can be addressed through education, awareness, and incentivization, such as financial rewards [136]. Lastly, fostering value chain thinking in the CI is needed to encourage CP adoption. However, the adversarial atmosphere and conflicting stakeholders' interests within CI projects inhibit the effective collaboration of key players and stakeholders [72]. Establishing national goals for CP and promising perks for compliance can drive the CI and its stakeholders towards the common goal and develop value chain thinking [123].

Based on the documented strategies to mitigate barriers impeding CP, the conceptual framework proposed in the current study provides a pathway to implement the identified enablers. The first phase of prospective initiatives encompasses soft enablers of CP. Initiatives such as educating industry practitioners and instigating stakeholder engagement through prioritization of CE-abled businesses can enable CP adoption [95]. Similarly, management's commitment is necessary to instigate a behavioral change whereby a compliant attitude would trickle down to everyone within the organization to enable CP adoption. Devising policies facilitating CE and making legislative changes to discourage LEMs is the next strategy presented in the framework to foster a behavioral shift toward CP adoption [95]. Setting monitoring strategies in place to ensure CP process compliance is the final soft enabler. Implementing the mentioned soft enablers would enhance CI readiness for the adoption of intense CP adoption strategies, which are presented as hard enablers in the current study.

Developing design guidelines and process standardization is the first step in enabling technical reforms for CP adoption in CI. The framework recommends the development of data management and decision support systems to allow for the accessibility of data on recycled products and services for procurers to enhance decision-making [97]. It is followed by establishing RL mechanisms as a requisite for enabling the backflow of materials to process them for reuse at the end of the project lifecycle. Such mechanisms involve establishing on-site storage facilities and take-back and resell frameworks for reverse supply chain operations [118]. Enabling material traceability for effective recycling and reuse is underlined as another enabler. Finally, the framework suggests the development of CE business models as a strong financial and institutional driver for CP adoption.

Unfortunately, the existing models in construction do not align with the principles of CP. Therefore, devising new business models that allow construction to accommodate CP is vital for its adoption in CI [55]. The framework also proposes project phase-specific initiatives that will enable CP to thrive in CI throughout the project life cycle. Architects and engineers are responsible for designing the projects based on CE principles. Conducting LCA and designing for deconstruction are a couple of measures that, if taken by designers, can facilitate CP adoption.

Similarly, industrial symbiosis, the collaboration of interdisciplinary organizations for mutual benefits during the manufacturing phase of construction projects, can optimize resource consumption in CI [141]. The key stakeholders involved in this process are the suppliers and distributors of CP-compliant construction materials. Contractors are expected to adopt lean construction practices during the construction phase as they minimize the generation of CDW, which allows for the on-site collection and return of CDW to recycling plants. Service life planning is assigned to facility managers along with owners who take responsibility for facilitating the RL of CDW in the proposed framework. Service life planning and RL of materials allow the refurbishment or reuse of construction materials that offer bright prospects for CP adoption by allowing waste minimization and resource efficiency in the CI.

The findings of the current study build on the existing literature and provide new insights into the adoption of CP in the CI. The current study consolidates the strategies to facilitate the adoption of CP in the CI, which is an original contribution of the study. Previous efforts had only highlighted the barriers inhibiting the uptake of CP without discussing strategies to facilitate the uptake. For example, a study by Qazi and Appolloni [38] shed light on some of the barriers to CP, which include factors like lack of interest from stakeholders, economic challenges, and government-related barriers. In comparison, the current study not only highlights these factors but also goes beyond to present new insights, such as a lack of information exchange and management systems, inadequacy of reverse logistics, and distrust in CP routes, which inhibit CP adoption.

Moreover, the findings of the current study are tailored to reflect the complex nature of CI in terms of CP adoption, which has not been a focus of previous studies [33,38]. Overall, the current study steps into the under-investigated territory of CP and provides insights into its inhibitors from the CI and wider built environment perspectives, which is exclusive to this study. While previous studies have investigated the generic barriers and enablers of CE, including technical, economic, legal, and behavioral obstacles [32], the current study narrows its focus to CP only. It provides barriers exclusive to CI, which sets it apart from previously published works.

The rapid adoption of CE and CP in the EU offers valuable insights and lessons for other countries aiming to transition toward circularity in their CI. Nations from the EU have adopted a diverse range of approaches to adopt CE [33]. For example, the Netherlands has relied on innovating its business models and value chain to accelerate the adoption of CE. By implementing novel business models such as product as a service (PaaS), resource recovery model, and shared economy in their CI, the Netherlands has paved the way for CE adoption in its CI [142]. Germany, on the other hand, has concentrated its efforts on reducing and controlling material flow to implement resource efficiency [143]. The Danish public procurement has targeted the acquisition of circular goods and services in the public sector in an effort to further enhance CE in its CI [21]. Finally, Norway has introduced legislation to enforce the preparation of waste management plans for new buildings, which will enable the sorting of CDW on the construction site and improve reverse logistics in its CI [142]. The sourcing of construction materials by independent organizations to assess their circularity is another exciting facet adopted by France to promote circularity in its resource loops [144]. Despite variances in the approaches to adopting CE, a strong commitment from the government, a structured approach to adopting circular practices, a clear framework, and firm legislation to enforce compliance from the integral stakeholders have emerged as critical enablers of CE and CP from the EU. In addition, industrial symbiosis has also emerged as a crucial enabler of CE, as waste from the CI can be upcycled or downcycled to serve elsewhere across different industries to impart resource efficiency, as seen in the case of China [145]. A collaborative effort by the governing bodies, policymakers, and key stakeholders guided by a clear framework and structured approach to adopting CP is necessary for the CI to transition from LEMs to CE.

5. Conclusions

As the CI looks for sustainable solutions such as CP in its projects, the barriers impeding CP pose challenges and hinder the transition from the existing LEMs. Through an extensive and in-depth literature review, the barriers to adopting CP in the CI were highlighted and categorized into two major groups, i.e., HB and SB. The HB constitutes a lack of (1) circular design and products in construction, (2) RL, (3) information exchange and management, (4) standardization, and (5) feasible business models, in addition to complicated supply chains. On the other end of the spectrum, the SB involves a lack of (1) stakeholder engagement, (2) trust in CP routes, (3) resistance to change, (4) perceived performance and quality issues, and (5) transparency and collaboration.

The strategies to mitigate and resolve the barriers impeding CP in CI are also presented, which include initiatives such as incentivizing the stakeholders to adopt circularity, formulating regulatory reforms to facilitate CP, discouraging LEMs, and bridging the gaps between theory and practice through pilot projects, which would also build trust regarding CP processes among stakeholders. A conceptual framework has also been presented that illustrates enablers of CP adoption within the CI.

This study adds to the literature by addressing the important thematic topic of CP within the CI and barriers to its adoption. This research serves as a crucial contribution for construction scholars and industry professionals, offering valuable insights into the enhanced management of forthcoming construction projects with optimized resource utilization in line with the UN SDGs to achieve ambitious goals such as "Net Zero Emissions" by the year 2050. CP can offer avenues for climate change mitigation caused by the CI through a reduction of GHG emissions and resource efficiency, aligning with UN SDG 13 (Climate Action). The study also highlights the development of new business models in the backdrop of CP focused on value chain thinking, which could have positive effects on social sustainability in the CI. CP can contribute to UN SDG 12, which aims for responsible production and consumption of resources that CP can foster by closing the resource loops. This could also be a facilitator in terms of developing sustainable communities and urbanization as it paves the way for the efficient use of valuable resources. While this study is not the first review covering barriers to circularity within the CI, it focuses on a less discussed aspect of CE, i.e., CP, and identifies hindrances to its adoption. It further presents a conceptual adoption framework to enable the transition from linear to CP.

This study identifies knowledge gaps in CI for CP adoption, such as the absence of standards and limited circular products. CI's complex supply chains require new frameworks and CI-specific business models to enable CP adoption. Industrial reforms and encouraging personnel training, Prefabrication, CDW storage, DfD implementation, and circular product prioritization in public procurement are needed for holistic CP adoption. Establishing on-site recycling facilities, BIM, material passports, and digital tracking is essential for CP adoption in CI. Strategic and regulatory inadequacies favor LEMs over CP in CI. To promote CP, regulatory reforms and stakeholder incentives are necessary, emphasizing government intervention to address financial, knowledge, regulatory, and supply chain challenges, aligning with UN SDGs. Strong global legislation and standardization are essential for effective CP adoption in CI.

While this study presented a holistic overview of the barriers impeding CP, it is limited in its approach to identification only and did not delve deep into the specifics of each aspect. For example, the study addressed the lack of knowledge and technical skillset regarding CP-related construction methods like DfD and PFA, which are elemental to circularity in construction. However, the study did not conduct an in-depth analysis of DfD and PFA and their specific challenges. Similarly, the incompatibility of existing business models is discussed in the study, but their intricacies have not been discussed. In addition, the study did not focus on the context of developing and developing countries separately but presented a rather generic approach. The study retrieved literature from Scopus only instead of including multiple repositories in the literature retrieval process. Another limitation that stems from the use of Scopus only is that Scopus does not specifically use "management" as a subfield; hence, articles on management are included in "engineering" and allied fields.

Future studies can focus on building upon this research work by conducting in-depth scrutiny of each mentioned technical, financial, market, business, and technological gap to dig deep into prevailing issues. The following studies can also devise detailed strategies for mitigating individual barriers that would help in applying CP. Exploration of digital twin, IoT, and MP in the backdrop of CE and CP and their implementation are also potential topics for future studies. Further, individual studies conducted for developing and developed countries and a comparative analysis of such countries in terms of CP adoption is another area for potential exploration. Future researchers should devise dedicated measures and clauses in the tendering of construction projects to promote CP in the CI. Project delivery methods should be investigated to determine which methods are aligned with CP principles and encourage their wider usage. The interface between CP and emerging construction technologies like 3D printing and MC should also be assessed in future works. The effects of implementing CP on climate change should also be analyzed to devise climate change mitigation strategies for the CI and the built environment. This study is beneficial for the built environment researchers as it sheds light on the prospective role of CP in fostering resource efficiency in the CI. It inspires future research into the intricacies of CP. It also guides the policymakers towards better decision-making regarding the uptake of CP in CI by highlighting the major impediments to CP and addressing them by employing the outlined strategies and key enablers of CP.

Funding

This research received no external funding.

CRediT authorship contribution statement

Zeerak Waryam Sajid: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Usman Aftab:** Writing – review & editing, Visualization, Validation, Software, Methodology, Data curation, Conceptualization. **Fahim Ullah:** Writing – review & editing, Visualization, Supervision, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Appendix

Table A
Studies included in this review article.

ID	Title	Authors	Year	Journal	Reference
1	Understanding and overcoming the barriers to structural steel reuse, a UK perspective	D Tingley, S Cooper	2017	Journal of Cleaner Production	[67]
2	Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy	Mohd Reza Esa, Anthony H, Lucia R	2017	Journal of Material Cycles and Waste Management	[146]
3	Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review	P Ghisellini, Xi J, S Ulgiati	2018	Journal of Cleaner Production	[66]
4	City level circular transitions: Barriers and limits in Amsterdam, Utrecht and The Hague,	K C. Johnston, J T. Cate, J Gupta	2019	Journal of Cleaner Production	[59]
5	Procurement innovation for a circular economy of construction and demolition waste: Lessons learnt from Suzhou, China	Z. Bao, Weisheng Lu, J. Hao, Bin. C	2019	Waste Management	[133]
6	Exploring barriers to implementing different circular business models	D.A. Vermunt, M.P Hekkert, D. V. Kuppens	2019	Journal of Cleaner Production	[56]
7	Exploiting the Potential of Public Procurement: Opportunities for Circular Economy	K Alhola, H Salmenpera	2019	Journal of Industrial Ecology	[147]
8	Implementation at a city level of circular economy strategies and climate change mitigation – the case of Brussels	M Christis, A Athanassiadis	2019	Journal of Cleaner Production	[130]
9	Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction	Md. Uzzal Hossain, S. Thomas, Ben Amor	2020	Renew. Sustain. Energy Rev.	[148]
10	An exploratory study on challenges of circular economy in the built environment in Oman	Al Hosni, Omar A, N Callaghan	2020	Management, Procurement and Law	[149]

(continued on next page)

Table A (*continued*)

ID	Title	Authors	Year	Journal	Reference
11	Policies for transitioning towards a circular economy: Expectations from the European Union (EU)	K Hartley, R V. Santen, J Kirchher	2020	Resources, Conservation and Recycling	[129]
12	Encouraging Circular Waste Economies for the New Zealand Construction Industry: Opportunities and Barriers	J K. Low, S Wallis, G Hernandez	2020	Frontiers in Sustainable Cities	[77]
13	Procurement 4.0 and its implications on business process performance in a circular economy,"	S Bag, Lincoln W, Sunil L	2020	Resources, Conservation and Recycling	[150]
14	Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers	Beatriz C. Guerra, F. Leite	2021	Resources, Conservation and Recycling	[27]
15	Circular Economy: Challenges and Opportunities in the Construction Sector of Kazakhstan	Beibut Torgautov 1, Asset Zhanabayev, A. Tleuken, M Mustafa	2021	Buildings	[151]
16	A Qualitative-Based Study on Barriers to Change from LEMs to Circular Economy Model in Built Environment—Evidence from Bangladesh	M S Hossain, Mahfuja K	2021	Circular Economy and Sustainability	[115]
17	Barriers to Implementing the Circular Economy in the Construction Industry: A Critical Review	Rabia Charef, J C Morel, K Rakshshan	2021	Sustainability	[122]
18	Towards Circular Social Housing: An Exploration of Practices, Barriers, and Enablers	Sultan Çetin, V Gruis	2021	Sustainability	[152]
19	Reuse of building elements in the architectural practice and the European regulatory context: Inconsistencies and possible improvements	M Condotta, E Zatta	2021	Journal of Cleaner Production	[153]
20	Achieving net zero greenhouse gas emissions in the cement industry via value chain mitigation strategies	G Habert, J Harvey, Sabbie A	2021	One Earth	[69]
21	Drivers and barriers leading to a successful paradigm shift toward regenerative neighborhoods	E Haselsteiner, Paola Saez	2021	Sustainability	[154]
22	Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability	S A. Rehman, A Razzaq, S Miller	2021	Business Strategy and the Environment	[155]
23	Space Matters: Barriers and Enablers for Embedding Urban Circularity Practices in the Brussels Capital Region	Giulia Caterina, A Z Khan	2022	Frontiers in Built Environment	[156]
24	A systematic literature review on Circular Economy implementation in the construction industry: a policy-making perspective	Yifei Yu, D M. Yazan, M E. Iacob	2022	Resources, Conservation and Recycling	[42]
25	Barriers to a circular economy in small- and medium-sized enterprises and their integration in a sustainable strategic management framework	Fabian Takacs, D. Brunner, K. Frankenberger	2022	Journal of Cleaner Production	[74]
26	Barriers impeding circular economy (CE) uptake in the construction industry	Safowaa Osei-Tutu, J Ayarkwa, G Nani,	2022	Smart and Sustainable Built Environment	[131]
27	Application of Sustainable Procurement Policy to Improve the Circularity of Construction and Demolition Waste Resources in Australia	Salman Shooshtarian, T Maqsood, P S. Wong	2022	Materials Circular Economy	[157]
28	An investigation into challenges and opportunities in the Australian construction and demolition waste management system	Shooshtarian, T Riley, M Khalfan	2022	Eng., Constr. Arch. Manag.	[158]
29	Design for Deconstruction and Disassembly: Barriers, Opportunities, and Practices in Developing Economies of Central Asia	A Tleuken, B Torgautov, Ferhat K, Ali T	2022	Procedia CIRP	[159]
30	The Private Sector Role as a Key Supporting Stakeholder towards Circular Economy in the Built Environment: A Scientometric and Content Analysis	M Owajoro, C Okoro	2022	Buildings	[135]
31	An evaluation of determinants influencing the adoption of circular economy principles in Nigerian construction SMEs	T Zuofa, E Ocheing, Ode-Ichakpa	2022	Building Research and Innovation	[160]
32	The role of public procurement to foster social equity and justice: critical reflections on the circular procurement concept	Gabriella Gyori	2022	The International Journal of Justice and Sustainability	[161]
33	Measuring the Effect of Circular Public Procurement on Government's Environmental Impact	M Zijp, E Dekker, L Posthuma, A Hollander	2022	Sustainability	[162]
34	A framework to integrate circular economy principles into public procurement	I Nikolaou, Thomas T, K I. Vatalis	2022	Circular Economy and Sustainability	[163]
35	Circular procurement: A systematic literature review	Xu, Linqi	2022	Journal of Cleaner Production	[37]
36	Complete re-utilization of waste concretes–Valorisation pathways and research needs	V Zaccardi, Alastair M, Susan B, Maria S	2022	Resources, Conservation and Recycling	[164]
37	Forward and reverse logistics for circular economy in construction: A systematic literature review,"	Lu Ding, Tong Wang, P. Chan	2023	Journal of Cleaner Production	[165]
38	Startups and circular economy strategies: Profile differences, barriers and enablers	Wim Van Opstal, L Borms	2023	Journal of Cleaner Production	[75]
39	A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective	Mayara R. Munaro, S Fernando	2023	Cleaner and Responsible Consumption	[72]
40	Implementation of circular economy in construction projects: a procurement strategy approach	Siraj Ahmed, J Majava, K Aaltonen	2023	Construction Innovation	[166]
41	A New Framework for Circular Refurbishment of Buildings to Operationalize Circular Economy Policies	J Fernandes, Paulo F	2023	Environments	[139]
42	Assessment of symmetries and asymmetries on barriers to circular economy adoption in the construction industry towards zero waste: A survey of international experts	B. Oluleye, Timothy O, Abdullah S	2023	Building and Environment	[167]
43	Facades-as-a-Service: Systemic managerial, financial, and governance innovation to enable a circular economy for buildings. Lessons learnt from a full-scale pilot project in the Netherlands	J F Aguerre, Alexander H, Monique A	2023	Frontiers in Built Environment	[168]
44	Growing role of concrete in sand and climate crises	T Watari, Z Cho, J Cullen	2023	iScience	[169]
45	Design for Manufacturing and Assembly (DfMA) and Design for Deconstruction (DfD) in the Construction Industry: Challenges, Trends and Developments	Roxas, Cheryl Lyne C, Johnathan D, Bernardo L	2023	Buildings	[140]
46	Barriers for the circular reuse of steel in the Belgian construction sector: an industry-wide perspective	K Anastasiades, Sander M, Henderik W	2023	Management, Procurement and Law	[170]

References

[1] J. Solís-Guzmán, M. Marrero, M.V. Montes-Delgado, A. Ramírez-de-Arellano, A Spanish model for quantification and management of construction waste, Waste Manag. 29 (9) (2009) 2542–2548, https://doi.org/10.1016/J.WASMAN.2009.05.009.

[2] S.O. Ajayi, et al., Reducing waste to landfill: A need for cultural change in the UK construction industry, J. Build. Eng. 5 (2016) 185–193, https://doi.org/10.1016/J.JOBE.2015.12.007.

[3] G. Athira, A. Bahurudeen, S. Appari, Sustainable alternatives to carbon intensive paddy field burning in India: A framework for cleaner production in agriculture, energy, and construction industries, J. Clean. Prod. 236 (2019) 117598, https://doi.org/10.1016/J.JCLEPRO.2019.07.073.

[4] C. De Wolf, E. Hoxha, C. Fivet, Comparison of environmental assessment methods when reusing building components: A case study, Sustain. Cities. Soc. 61 (2020) 102322, https://doi.org/10.1016/J.SCS.2020.102322.

[5] A. Ashby, Developing closed loop supply chains for environmental sustainability: Insights from a UK clothing case study, J. Manuf. Technol. Manag. 29 (4) (2018) 699–722, https://doi.org/10.1108/JMTM-12-2016-0175/FULL/XML.

[6] A. Gallego-Schmid, H.M. Chen, M. Sharmina, J.M.F. Mendoza, Links between circular economy and climate change mitigation in the built environment, J. Clean. Prod. 260 (2020) 121115, https://doi.org/10.1016/J.JCLEPRO.2020.121115.

[7] J.M.F. Mendoza, M. Sharmina, A. Gallego-Schmid, G. Heyes, A. Azapagic, Integrating Backcasting and Eco-Design for the Circular Economy: The BECE Framework, J. Ind. Ecol. 21 (3) (2017) 526–544, https://doi.org/10.1111/JIEC.12590.

[8] K.M. Jemal, et al., Facilitating Circular Economy Strategies Using Digital Construction Tools: Framework Development, Sustainability. 15 (1) (2023) 877, https://doi.org/10.3390/SU15010877.

[9] S.A.H. Zaidi, F.M. Mirza, F. Hou, R.U. Ashraf, Addressing the sustainable development through sustainable procurement: What factors resist the implementation of sustainable procurement in Pakistan? Socioecon. Plann. Sci. 68 (2019) 100671 https://doi.org/10.1016/J.SEPS.2018.11.008.

[10] L. Fuertes Giné, E. Vanacore, A.D. Hunka, Public procurement for the circular economy: a comparative Study of Sweden and Spain, Circ. Econ. Sustain. 2 (3) (2022) 1021–1041, https://doi.org/10.1007/s43615-022-00150-4.

[11] M. Saidani, B. Yannou, Y. Leroy, F. Cluzel, A. Kendall, A taxonomy of circular economy indicators, J. Clean. Prod. 207 (2019) 542–559, https://doi.org/10.1016/J.JCLEPRO.2018.10.014.

[12] J. Ntsondé, F. Aggeri, Stimulating innovation and creating new markets – The potential of circular public procurement, J. Clean. Prod. 308 (Jul. 2021) 127303, https://doi.org/10.1016/J.JCLEPRO.2021.127303.

[13] N. Gregson, M. Crang, S. Fuller, H. Holmes, Interrogating the circular economy: the moral economy of resource recovery in the EU, Econ. Soc. 44 (2) (2015) 218–243, https://doi.org/10.1080/03085147.2015.1013353.

[14] J.I. Sudusinghe, S. Seuring, Supply chain collaboration and sustainability performance in circular economy: A systematic literature review, Int. J. Prod. Econ. 245 (2022), https://doi.org/10.1016/J.IJPE.2021.108402.

[15] Z. Liu, et al., How does circular economy respond to greenhouse gas emissions reduction: An analysis of Chinese plastic recycling industries, Renew. Sustain. Energy Rev. 91 (2018) 1162–1169, https://doi.org/10.1016/J.RSER.2018.04.038.

[16] F. Cicculo, M. Pero, A.S. Patrucco, Designing circular supply chains in start-up companies: evidence from Italian fashion and construction start-ups, Int. J. Logist. Manag. 34 (3) (2023) 553–581, https://doi.org/10.1108/IJLM-04-2022-0158/FULL/PDF.

[17] E. Blinova, T. Ponomarenko, V. Knysh, Analyzing the concept of corporate sustainability in the context of sustainable business development in the mining sector with elements of circular economy, Sustainability. 14 (13) (2022) 8163, https://doi.org/10.3390/SU14138163.

[18] N.K. Sharma, K. Govindan, K.K. Lai, W.K. Chen, V. Kumar, The transition from linear economy to circular economy for sustainability among SMEs: A study on prospects, impediments, and prerequisites, Bus. Strategy. Environ. 30 (4) (2021) 1803–1822, https://doi.org/10.1002/BSE.2717.

[19] A. AlJaber, E. Alasmari, P. Martinez-Vazquez, C. Baniotopoulos, Life cycle cost in circular economy of buildings by applying building information modeling (BIM): A State of the Art, Buildings 13 (7) (2023) 1858, https://doi.org/10.3390/BUILDINGS13071858.

[20] M. Honic, I. Kovacic, H. Rechberger, Improving the recycling potential of buildings through Material Passports (MP): An Austrian case study, J. Clean. Prod. 217 (2019) 787–797, https://doi.org/10.1016/J.JCLEPRO.2019.01.212.

[21] L.C. Malabi Eberhardt, J. Rønholt, M. Birkved, H. Birgisdottir, Circular Economy potential within the building stock - Mapping the embodied greenhouse gas emissions of four Danish examples, J. Build. Eng. 33 (2021) 101845, https://doi.org/10.1016/J.JOBE.2020.101845.

[22] X. Wang, Z. Zhou, X. Lv, L. Yang, P.F. Yuan, L. Chen, Intelligent renovation of existing Olympic venues: digital design and construction strategy of a DfD-based prefabricated structure system, Architect. Intell. 2 (1) (2023) 1–14, https://doi.org/10.1007/S44223-022-00018-5.

[23] P. Ghisellini, C. Cialani, S. Ulgiati, A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, J. Clean. Prod. 114 (2016) 11–32, https://doi.org/10.1016/J.JCLEPRO.2015.09.007.

[24] K. Hartley, J. Roosendaal, J. Kirchherr, Barriers to the circular economy: The case of the Dutch technical and interior textiles industries, J. Ind. Ecol. 26 (2) (2022) 477–490, https://doi.org/10.1111/JIEC.13196.

[25] V. Davydenko, O. Harmash, O. Ovdiienko, Circular procurement management in the circular economy system, Electron. Sci. J. Intellectual. Logist. Supply Chain Manag. (6) (2021) 55–62, https://doi.org/10.46783/SMART-SCM/2021-6-5.

[26] "The Circularity Gap Report: The World is Only 9% Circular." Accessed: Sep. 30, 2023. [Online]. Available: https://www.circularity-gap.world/updates-collection/the-circularity-gap-report-our-world-is-only-9-circular.

[27] B.C. Guerra, F. Leite, Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers, Resour. Conserv. Recycl. 170 (2021) 105617, https://doi.org/10.1016/J.RESCONREC.2021.105617.

[28] Z.W. Sajid, F. Ullah, S. Qayyum, R. Masood, Climate change mitigation through modular construction, Smart Cities 7 (1) (2024) 566–596, https://doi.org/10.3390/SMARTCITIES7010023.

[29] J. Kirchherr, et al., Barriers to the circular economy: evidence from the European Union (EU), Ecol. Econ. 150 (2018) 264–272, https://doi.org/10.1016/J.ECOLECON.2018.04.028.

[30] N. Millar, E. McLaughlin, T. Börger, The Circular Economy: Swings and roundabouts? Ecol. Econ. 158 (2019) 11–19, https://doi.org/10.1016/J.ECOLECON.2018.12.012.

[31] M. Wijayasundara, M. Polonsky, W. Noel, A. Vocino, Green procurement for a circular economy: What influences purchasing of products with recycled material and recovered content by public sector organisations? J. Clean. Prod. 377 (2022) 133917 https://doi.org/10.1016/J.JCLEPRO.2022.133917.

[32] P. Mhatre, V.V. Gedam, S. Unnikrishnan, R.D. Raut, Circular economy adoption barriers in built environment- a case of emerging economy, J. Clean. Prod. 392 (2023) 136201, https://doi.org/10.1016/J.JCLEPRO.2023.136201.

[33] V.V. Gedam, R.D. Raut, A.B. Lopes de Sousa Jabbour, A.N. Tanksale, B. E. Narkhede, Circular economy practices in a developing economy: Barriers to be defeated, J. Clean. Prod. 311 (2021) 127670, https://doi.org/10.1016/J.JCLEPRO.2021.127670.

[34] P. Mhatre-Shah, V. Gedam, S. Unnikrishnan, Estimation of the potential changes in the social impacts of transitioning to circular economy for multiple stakeholders — a case of Indian transportation infrastructure, Int. J. Life Cycle Assess. 28 (12) (2023) 1773–1798, https://doi.org/10.1007/S11367-023-02215-4/METRICS.

[35] P. Mhatre, V.V. Gedam, S. Unnikrishnan, Material circularity potential for construction materials – The case of transportation infrastructure in India, Resour. Policy 74 (2021) 102446, https://doi.org/10.1016/J.RESOURPOL.2021.102446.

[36] P. Mhatre, V.V. Gedam, S. Unnikrishnan, Management insights for reuse of materials in a circular built environment, Waste Manage Res. (2023), https://doi.org/10.1177/0734242X231187570.

[37] L. Xu, F. Jia, F. Yan, L. Chen, Circular procurement: A systematic literature review, J. Clean. Prod. 365 (2022) 132845, https://doi.org/10.1016/J.JCLEPRO.2022.132845.

[38] A.A. Qazi, A. Appolloni, A systematic review on barriers and enablers toward circular procurement management, Sustain. Prod. Consum. 33 (2022) 343–359, https://doi.org/10.1016/J.SPC.2022.07.013.

[39] I. Skøien, Implementing circular public procurement : the case of textiles in the City of Oslo, 2023. Accessed: Mar. 04, 2024. [Online]. Available: https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/3076799.

[40] N. Ada, Y. Kazancoglu, M.D. Sezer, C. Ede-Senturk, I. Ozer, M. Ram, Analyzing barriers of circular food supply chains and proposing industry 4.0 solutions, Sustainability. 13 (12) (2021) 6812, https://doi.org/10.3390/SU13126812.

[41] A. Urbinati, D. Chiaroni, G. Toletti, Managing the introduction of circular products: evidence from the beverage industry, Sustainability. 11 (13) (2019) 3650, https://doi.org/10.3390/SU11133650.

[42] Y. Yu, V. Junjan, D.M. Yazan, M.E. Iacob, A systematic literature review on Circular Economy implementation in the construction industry: a policy-making perspective, Resour. Conserv. Recycl. 183 (2022) 106359, https://doi.org/10.1016/J.RESCONREC.2022.106359.

[43] W. Reim, V. Parida, D. Örtqvist, Product–Service Systems (PSS) business models and tactics – a systematic literature review, J. Clean. Prod. 97 (2015) 61–75, https://doi.org/10.1016/J.JCLEPRO.2014.07.003.

[44] M. Pan, Y. Yang, Z. Zheng, W. Pan, Artificial intelligence and robotics for prefabricated and modular construction: a systematic literature review, J. Constr. Eng. Manage 148 (9) (2022) 03122004, https://doi.org/10.1061/(ASCE)CO.1943-7862.0002324.

[45] F. Ullah, S.M.E. Sepasgozar, C. Wang, A Systematic review of smart real estate technology: drivers of, and barriers to, the use of digital disruptive technologies and online platforms, Sustainability. 10 (9) (2018) 3142, https://doi.org/10.3390/SU10093142.

[46] M.K. Linnenluecke, M. Marrone, A.K. Singh, Conducting systematic literature reviews and bibliometric analyses, Austral. J. Manag. 45 (2) (2020) 175–194, https://doi.org/10.1177/0312896219877678/ASSET/IMAGES/LARGE/10.1177_0312896219877678-FIG7.JPEG.

[47] F. Ullah, S. Qayyum, M.J. Thaheem, F. Al-Turjman, S.M.E. Sepasgozar, Risk management in sustainable smart cities governance: A TOE framework, Technol. Forecast. Soc. Change 167 (2021) 120743, https://doi.org/10.1016/J.TECHFORE.2021.120743.

[48] I.Y. Wuni, G.Q. Shen, Barriers to the adoption of modular integrated construction: Systematic review and meta-analysis, integrated conceptual framework, and

strategies, J. Clean. Prod. 249 (2020) 119347, https://doi.org/10.1016/J.JCLEPRO.2019.119347.
[49] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, BMJ 339 (7716) (2009) 332–336, https://doi.org/10.1136/BMJ.B2535.
[50] A. Alcalde-Calonge, F.J. Sáez-Martínez, P. Ruiz-Palomino, Evolution of research on circular economy and related trends and topics. A thirteen-year review, Ecol. Inform. 70 (2022) 101716, https://doi.org/10.1016/J.ECOINF.2022.101716.
[51] I.Y. Wuni, G.Q.P. Shen, R. Osei-Kyei, Scientometric review of global research trends on green buildings in construction journals from 1992 to 2018, Energy Build. 190 (2019) 69–85, https://doi.org/10.1016/J.ENBUILD.2019.02.010.
[52] M.J. Page, et al., The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, Syst. Rev. 10 (1) (2021) 1–11, https://doi.org/10.1186/S13643-021-01626-4/FIGURES/1.
[53] J. Zhang, L. Han, L. Shields, J. Tian, J. Wang, A PRISMA assessment of the reporting quality of systematic reviews of nursing published in the Cochrane Library and paper-based journals, Medicine 98 (49) (2019), https://doi.org/10.1097/MD.0000000000018099.
[54] N.G. Akhimien, E. Latif, S.S. Hou, Application of circular economy principles in buildings: A systematic review, J. Build. Eng. 38 (2021) 102041, https://doi.org/10.1016/J.JOBE.2020.102041.
[55] T. Häkkinen, K. Belloni, Barriers and drivers for sustainable building, Build. Res. Inf. 39 (3) (2011) 239–255, https://doi.org/10.1080/09613218.2011.561948.
[56] D.A. Vermunt, S.O. Negro, P.A. Verweij, D.V. Kuppens, M.P. Hekkert, Exploring barriers to implementing different circular business models, J. Clean. Prod. 222 (2019) 891–902, https://doi.org/10.1016/J.JCLEPRO.2019.03.052.
[57] H.S. Munawar, S. Qayyum, F. Ullah, S. Sepasgozar, Big Data and Its applications in smart real estate and the disaster management life cycle: a systematic analysis, Big Data Cognit. Comput. 4 (2) (2020) 4, https://doi.org/10.3390/BDCC4020004.
[58] A. de Jesus, S. Mendonça, Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy, Ecol. Econ. 145 (2018) 75–89, https://doi.org/10.1016/J.ECOLECON.2017.08.001.
[59] K. Campbell-Johnston, J. ten Cate, M. Elfering-Petrovic, J. Gupta, City level circular transitions: Barriers and limits in Amsterdam, Utrecht and The Hague, J. Clean. Prod. 235 (2019) 1232–1239, https://doi.org/10.1016/J.JCLEPRO.2019.06.106.
[60] F. Ullah, F. Al-Turjman, A conceptual framework for blockchain smart contract adoption to manage real estate deals in smart cities, Neural Comput. Appl. 35 (7) (2023) 5033–5054, https://doi.org/10.1007/S00521-021-05800-6/METRICS.
[61] S.M. Hussain, N. Ahmad, S. Ahmed, Applications of high-frequency data in finance: A bibliometric literature review, Int. Rev. Financ. Anal. 89 (2023) 102790, https://doi.org/10.1016/J.IRFA.2023.102790.
[62] H. Snyder, Literature review as a research methodology: An overview and guidelines, J. Bus. Res. 104 (2019) 333–339, https://doi.org/10.1016/J.JBUSRES.2019.07.039.
[63] J. Hill, Circular economy and the policy landscape in the UK, Taking Stock Ind. Ecol. (2015) 265–274, https://doi.org/10.1007/978-3-319-20571-7_13/TABLES/1.
[64] "Circular economy action plan." Accessed: Sep. 30, 2023. [Online]. Available: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en.
[65] J. Hart, K. Adams, J. Giesekam, D.D. Tingley, F. Pomponi, Barriers and drivers in a circular economy: the case of the built environment, Procedia CIRP. 80 (2019) 619–624, https://doi.org/10.1016/J.PROCIR.2018.12.015.
[66] P. Ghisellini, X. Ji, G. Liu, S. Ulgiati, Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review, J. Clean. Prod. 195 (2018) 418–434, https://doi.org/10.1016/J.JCLEPRO.2018.05.084.
[67] D. Densley Tingley, S. Cooper, J. Cullen, Understanding and overcoming the barriers to structural steel reuse, a UK perspective, J. Clean. Prod. 148 (2017) 642–652, https://doi.org/10.1016/J.JCLEPRO.2017.02.006.
[68] R. Charef, S. Emmitt, Uses of building information modelling for overcoming barriers to a circular economy, J. Clean. Prod. 285 (2021) 124854, https://doi.org/10.1016/J.JCLEPRO.2020.124854.
[69] S.A. Miller, G. Habert, R.J. Myers, J.T. Harvey, Achieving net zero greenhouse gas emissions in the cement industry via value chain mitigation strategies, One Earth. 4 (10) (2021) 1398–1411, https://doi.org/10.1016/J.ONEEAR.2021.09.011.
[70] S. Giorgi, M. Lavagna, K. Wang, M. Osmani, G. Liu, A. Campioli, Drivers and barriers towards circular economy in the building sector: Stakeholder interviews and analysis of five European countries policies and practices, J. Clean. Prod. 336 (2022) 130395, https://doi.org/10.1016/J.JCLEPRO.2022.130395.
[71] M.S. Hossain, M. Khatun, A qualitative-based study on barriers to change from linear business model to circular economy model in built environment—evidence from Bangladesh, Circ. Econ. Sustain. 1 (3) (.2021) 799–813, https://doi.org/10.1007/s43615-021-00050-z.
[72] M.R. Munaro, S.F. Tavares, A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective, Clean. Respons. Consumpt. 8 (2023) 100107, https://doi.org/10.1016/J.CLRC.2023.100107.
[73] S. Witjes, R. Lozano, Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models, Resour. Conserv. Recycl. 112 (2016) 37–44, https://doi.org/10.1016/J.RESCONREC.2016.04.015.
[74] F. Takacs, D. Brunner, K. Frankenberger, Barriers to a circular economy in small- and medium-sized enterprises and their integration in a sustainable strategic management framework, J. Clean. Prod. 362 (2022) 132227, https://doi.org/10.1016/J.JCLEPRO.2022.132227.
[75] W. Van Opstal, L. Borms, Startups and circular economy strategies: Profile differences, barriers and enablers, J. Clean. Prod. 396 (2023) 136510, https://doi.org/10.1016/J.JCLEPRO.2023.136510.
[76] B. Torgautov, A. Zhanabayev, A. Tleuken, A. Turkyilmaz, C. Borucki, F. Karaca, Performance assessment of construction companies for the circular economy: A balanced scorecard approach, Sustain. Prod. Consum. 33 (2022) 991–1004, https://doi.org/10.1016/J.SPC.2022.08.021.
[77] J.K. Low, S.L. Wallis, G. Hernandez, I.S. Cerqueira, G. Steinhorn, T.A. Berry, Encouraging circular waste economies for the new zealand construction industry: opportunities and barriers, Front. Sustain. Cities 2 (2020), https://doi.org/10.3389/FRSC.2020.00035.
[78] V. Veleva, G. Bodkin, S. Todorova, The need for better measurement and employee engagement to advance a circular economy: Lessons from Biogen's 'zero waste' journey, J. Clean. Prod. 154 (2017) 517–529, https://doi.org/10.1016/J.JCLEPRO.2017.03.177.
[79] A. Mahpour, Prioritizing barriers to adopt circular economy in construction and demolition waste management, Resour. Conserv. Recycl. 134 (2018) 216–227, https://doi.org/10.1016/J.RESCONREC.2018.01.026.
[80] R. Charef, W. Lu, D. Hall, The transition to the circular economy of the construction industry: Insights into sustainable approaches to improve the understanding, J. Clean. Prod. 364 (2022) 132421, https://doi.org/10.1016/J.JCLEPRO.2022.132421.
[81] A. Baldwin, C.S. Poon, L.Y. Shen, S. Austin, I. Wong, Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction, Renew. Energy 34 (9) (2009) 2067–2073, https://doi.org/10.1016/J.RENENE.2009.02.008.
[82] F.C. Rios, S. Panic, D. Grau, V. Khanna, J. Zapitelli, M. Bilec, Exploring circular economies in the built environment from a complex systems perspective: A systematic review and conceptual model at the city scale, Sustain. Cities. Soc. 80 (2022) 103411, https://doi.org/10.1016/J.SCS.2021.103411.
[83] E.F. Deng, et al., Seismic performance of mid-to-high rise modular steel construction - A critical review, Thin-Walled Struct 155 (2020) 106924, https://doi.org/10.1016/J.TWS.2020.106924.
[84] M.H. Ramage, et al., The wood from the trees: The use of timber in construction, Renew. Sustain. Energy Rev. 68 (2017) 333–359, https://doi.org/10.1016/J.RSER.2016.09.107.
[85] W. Bi, W. Lu, Z. Zhao, C.J. Webster, Combinatorial optimization of construction waste collection and transportation: A case study of Hong Kong, Resour. Conserv. Recycl. 179 (2022) 106043, https://doi.org/10.1016/J.RESCONREC.2021.106043.
[86] G.N. Yossen, G.P. Henning, Optimal Design of the reverse logistics network of empty agrochemical containers, Comput Aided Chem. Eng. 50 (2021) 1781–1786, https://doi.org/10.1016/B978-0-323-88506-5.50276-X.
[87] A.R. Pitti, O. Espinoza, R. Smith, The case for urban and reclaimed wood in the circular economy, Bioresources 15 (3) (2020) 5226–5245. Accessed: Sep. 30, 2023. [Online]. Available: https://jtatm.textiles.ncsu.edu/index.php/BioRes/article/view/BioRes_15_3_5226_Pitti_Urban_Reclaimed_Wood.
[88] S. Huuhka, T. Kaasalainen, J.H. Hakanen, J. Lahdensivu, Reusing concrete panels from buildings for building: Potential in Finnish 1970s mass housing, Resour. Conserv. Recycl. 101 (2015) 105–121, https://doi.org/10.1016/J.RESCONREC.2015.05.017.
[89] S. Caldera, T. Ryley, N. Zatyko, Enablers and barriers for creating a marketplace for construction and demolition waste: a systematic literature review, Sustainability. 12 (23) (2020) 9931, https://doi.org/10.3390/SU12239931.
[90] H. Suliman Eissa Mohammed, W. Jamal Salem Alharthi, Blockchain technology and the future of construction industry in the arab region :applications, challenges, and future opportunities, Eng. Res. J. 173 (0) (2022) 411–441, https://doi.org/10.21608/ERJ.2022.223618.
[91] Y. Chen, X. Wang, Z. Liu, J. Cui, M. Osmani, P. Demian, Exploring building information modeling (bim) and internet of things (iot) integration for sustainable building, Buildings 13 (2) (2023) 288, https://doi.org/10.3390/BUILDINGS13020288.
[92] H. Wilts, The digital circular economy: can the digital transformation pave the way for resource-efficient materials cycles? Int. J. Environ. Sci. Nat. Resour. 7 (5) (2017) https://doi.org/10.19080/IJESNR.2017.07.555725.
[93] S. Millette, E. Williams, C.E. Hull, Materials flow analysis in support of circular economy development: Plastics in Trinidad and Tobago, Resour. Conserv. Recycl. 150 (2019) 104436, https://doi.org/10.1016/J.RESCONREC.2019.104436.
[94] K. Demestichas, E. Daskalakis, Information and communication technology solutions for the circular economy, Sustainability. 12 (18) (2020) 7272, https://doi.org/10.3390/SU12187272.
[95] A. van Stijn, B. Wouterszoon Jansen, V. Gruis, G.A. van Bortel, Towards implementation of circular building components: A longitudinal study on the stakeholder choices in the development of 8 circular building components, J. Clean. Prod. 420 (2023) 138287, https://doi.org/10.1016/J.JCLEPRO.2023.138287.
[96] A. Rejeb, A. Appolloni, K. Rejeb, H. Treiblmaier, M. Iranmanesh, J.G. Keogh, The role of blockchain technology in the transition toward the circular economy: Findings from a systematic literature review, Resour., Conser. Recycli. Adv. 17 (2023) 200126, https://doi.org/10.1016/J.RCRADV.2022.200126.
[97] P. Kannisto, D. Hästbacka, A. Marttinen, Information exchange architecture for collaborative industrial ecosystem, Inf. Syst. Front. 22 (3) (2020) 655–670, https://doi.org/10.1007/S10796-018-9877-0/TABLES/2.
[98] A.K. Badraddin, R.A. Rahman, S. Almutairi, M. Esa, Main challenges to concrete recycling in practice, Sustainability. 13 (19) (2021) 11077, https://doi.org/10.3390/SU131911077.

[99] D.L. Schodek, Effect of Building Regulations on Built Environment, Eng. Issues: J. Profess. Activ. 102 (3) (1976) 293–300, https://doi.org/10.1061/EGISBD.0000368.
[100] J.T. O'Connor, W.J. O'Brien, J.O. Choi, Standardization strategy for modular industrial plants, J. Constr. Eng. Manage 141 (9) (2015) 04015026, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001001.
[101] M.A. Nabi, I.H. El-adaway, Modular Construction: Determining Decision-Making Factors and Future Research Needs, J. Manag. Eng. 36 (6) (2020) 04020085, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000859.
[102] A.K. Mohanty, S. Vivekanandhan, J.M. Pin, M. Misra, Composites from renewable and sustainable resources: Challenges and innovations, Science (1979) 362 (6414) (2018) 536–542, https://doi.org/10.1126/SCIENCE.AAT9072.
[103] R. Álvarez, C. Ruiz-Puente, Development of the Tool SymbioSyS to support the transition towards a circular economy based on industrial symbiosis strategies, Waste BioMass Valorization. 8 (5) (2017) 1521–1530, https://doi.org/10.1007/S12649-016-9748-1/FIGURES/7.
[104] V.W.Y. Tam, C.M. Tam, S.X. Zeng, W.C.Y. Ng, Towards adoption of prefabrication in construction, Build. Environ. 42 (10) (2007) 3642–3654, https://doi.org/10.1016/J.BUILDENV.2006.10.003.
[105] D. Schraven, U. Bukvić, F. Di Maio, M. Hertogh, Circular transition: Changes and responsibilities in the Dutch stony material supply chain, Resour. Conserv. Recycl. 150 (2019) 104359, https://doi.org/10.1016/J.RESCONREC.2019.05.035.
[106] M.J. Polonsky, M. Wijayasundara, W. Noel, A. Vocino, Identifying the drivers and barriers of the public sector procurement of products with recycled material or recovered content: A systematic review and research propositions, J. Clean. Prod. 358 (2022) 131780, https://doi.org/10.1016/J.JCLEPRO.2022.131780.
[107] R. De Man, H. Friege, Circular economy: European policy on shaky ground, Waste Manag. Res. 34 (2) (2016) 93–95, https://doi.org/10.1177/0734242X15626015/ASSET/IMAGES/10.1177_0734242X15626015-IMG2.PNG.
[108] A. Nawaz, J. Chen, X. Su, H.M. Zahid Hassan, Material based penalty-cost quantification model for construction projects influencing waste management, Front. Environ. Sci. 10 (2022) 807359, https://doi.org/10.3389/FENVS.2022.807359/BIBTEX.
[109] T.B.J. Coenen, K. Visscher, L. Volker, A systemic perspective on transition barriers to a circular infrastructure sector, Constr. Manag. Econ. 41 (1) (2023) 22–43, https://doi.org/10.1080/01446193.2022.2151024.
[110] J.C. Fernandez de Arroyabe, N. Arranz, M. Schumann, M.F. Arroyabe, The development of CE business models in firms: The role of circular economy capabilities, Technovation 106 (2021) 102292, https://doi.org/10.1016/J.TECHNOVATION.2021.102292.
[111] W. Ey, J. Zuo, S. Han, Barriers and challenges of collaborative procurements: An exploratory study, Int. J. Constr. Manag. 14 (3) (2014) 148–155, https://doi.org/10.1080/15623599.2014.922725.
[112] A.E.J. Prakoso, C. Nitha, S. Tiwari, S. Tiwari, W. Chan, M.F. Mubarak, Critical analysis of procurement techniques in construction management sectors, IOP. Conf. Ser. Mater. Sci. Eng. 342 (1) (2018) 012100, https://doi.org/10.1088/1757-899X/342/1/012100.
[113] P. Gaiardelli, et al., Product-service systems evolution in the era of Industry 4.0, Service Bus. 15 (1) (2021) 177–207, https://doi.org/10.1007/S11628-021-00438-9/FIGURES/5.
[114] J.A. Gambatese, M. Hallowell, Enabling and measuring innovation in the construction industry, Constr. Manag. Econ. 29 (6) (2011) 553–567, https://doi.org/10.1080/01446193.2011.570357.
[115] M.S. Hossain, M. Khatun, A Qualitative-Based study on barriers to change from linear business model to circular economy model in built environment—Evidence from Bangladesh, Circ. Econ. Sustain. 1 (3) (2021) 799–813, https://doi.org/10.1007/S43615-021-00050-Z/METRICS.
[116] S. John and, et al., Design for deconstruction and reuse of timber structures-state of the art review Publication basic information Publication bibliographic details Projects Fundings, 2020.
[117] M.A. Camilleri, Case Study 5: Closing the Loop of the circular economy for corporate sustainability and responsibility,", Corp. Sustain., Soc. Responsib. Environ. Manag. (2017) 175–190, https://doi.org/10.1007/978-3-319-46849-5_10.
[118] M.R. Hosseini, R. Rameezdeen, N. Chileshe, S. Lehmann, Reverse logistics in the construction industry, 33, 2015, pp. 499–514, https://doi.org/10.1177/0734242X15584842.
[119] T.M. Simatupang, P. Piboonrungroj, S.J. Williams, The emergence of value chain thinking, Int. J. Value Chain Manag. 8 (1) (2017) 40–57, https://doi.org/10.1504/IJVCM.2017.082685.
[120] G. Wu, et al., Factors influencing the application of prefabricated construction in China: From perspectives of technology promotion and cleaner production, J. Clean. Prod. 219 (2019) 753–762, https://doi.org/10.1016/j.jclepro.2019.02.110.
[121] N. Sharma, P.P. Kalbar, M. Salman, Global review of circular economy and life cycle thinking in building Demolition Waste Management: A way ahead for India, Build. Environ. 222 (2022) 109413, https://doi.org/10.1016/J.BUILDENV.2022.109413.
[122] R. Charef, J.C. Morel, K. Rakhshan, Barriers to Implementing the circular economy in the construction industry: a critical review, Sustainability. 13 (23) (2021) 12989, https://doi.org/10.3390/SU132312989.
[123] O.T.K. Ho, A. Gajanayake, U. Iyer-Raniga, Transitioning to a state-wide circular economy: Major stakeholder interviews, Resour., Conser. Recycl. Adv. 19 (2023) 200163, https://doi.org/10.1016/J.RCRADV.2023.200163.
[124] N. Chileshe, R. Rameezdeen, M.R. Hosseini, Drivers for adopting reverse logistics in the construction industry: A qualitative study, Eng., Constr. Arch. Manag. 23 (2) (2016) 134–157, https://doi.org/10.1108/ECAM-06-2014-0087.
[125] D. Seth, V.K. Nemani, S. Pokharel, A.Y. Al Sayed, Impact of competitive conditions on supplier evaluation: a construction supply chain case study, Prod. Plann. Control 29 (3) (2018) 217–235, https://doi.org/10.1080/09537287.2017.1407971.
[126] M. Sadeghi, A. Mahmoudi, X. Deng, Adopting distributed ledger technology for the sustainable construction industry: evaluating the barriers using Ordinal Priority Approach, Environ. Sci. Pollut. Res. 29 (7) (2022) 10495–10520, https://doi.org/10.1007/S11356-021-16376-Y/FIGURES/7.
[127] J.M. Leal, S. Pompidou, C. Charbuillet, N. Perry, Design for and from recycling: a circular ecodesign approach to improve the circular economy, Sustainability. 12 (23) (2020) 9861, https://doi.org/10.3390/SU12239861.
[128] W. Naveed, M. Ammouriova, N. Naveed, A.A. Juan, Circular economy and information technologies: identifying and ranking the factors of successful practices, Sustainability. 14 (23) (2022) 15587, https://doi.org/10.3390/SU142315587.
[129] K. Hartley, R. van Santen, J. Kirchherr, Policies for transitioning towards a circular economy: Expectations from the European Union (EU), Resour. Conserv. Recycl. 155 (2020) 104634, https://doi.org/10.1016/J.RESCONREC.2019.104634.
[130] M. Christis, A. Athanassiadis, A. Vercalsteren, Implementation at a city level of circular economy strategies and climate change mitigation – the case of Brussels, J. Clean. Prod. 218 (2019) 511–520, https://doi.org/10.1016/J.JCLEPRO.2019.01.180.
[131] S. Osei-Tutu, J. Ayarkwa, D. Osei-Asibey, G. Nani, A.E. Afful, Barriers impeding circular economy (CE) uptake in the construction industry, in: Smart and Sustainable Built Environment, 12, Emerald Publishing, 2023, pp. 892–918, https://doi.org/10.1108/SASBE-03-2022-0049.
[132] M. Shamsuyeva, H.J. Endres, Plastics in the context of the circular economy and sustainable plastics recycling: Comprehensive review on research development, standardization and market, Compos. Part C: Open Access 6 (2021) 100168, https://doi.org/10.1016/J.JCOMC.2021.100168.
[133] Z. Bao, W. Lu, B. Chi, H. Yuan, J. Hao, Procurement innovation for a circular economy of construction and demolition waste: Lessons learnt from Suzhou, China, Waste Manag. 99 (2019) 12–21, https://doi.org/10.1016/J.WASMAN.2019.08.031.
[134] O. Lædre, K. Austeng, T.I. Haugen, O.J. Klakegg, Procurement routes in public building and construction projects, J. Constr. Eng. Manage 132 (7) (2006) 689–696, https://doi.org/10.1061/(ASCE)0733-9364(2006)132:7(689).
[135] O.M. Owojori, C. Okoro, The private sector role as a key supporting stakeholder towards circular economy in the built environment: a scientometric and content analysis, Buildings 12 (5) (2022) 695, https://doi.org/10.3390/BUILDINGS12050695.
[136] A.H. Darmawan, S. Azizah, Resistance to Change: Causes and Strategies as an Organizational Challenge, 2020, pp. 49–53, https://doi.org/10.2991/ASSEHR.K.200120.010.
[137] G. Santos, E. Esmizadeh, M. Riahinezhad, Recycling construction, renovation, and demolition plastic waste: review of the status quo, challenges and opportunities, J. Polym. Environ. (2023) 1–31, https://doi.org/10.1007/S10924-023-02982-Z/TABLES/10.
[138] S.H.A. Rahman, I.R. Endut, N. Faisol, S. Paydar, The Importance of Collaboration in Construction Industry from Contractors' Perspectives, Procedia Soc. Behav. Sci. 129 (2014) 414–421, https://doi.org/10.1016/J.SBSPRO.2014.03.695.
[139] J. Fernandes, P. Ferrão, A new framework for circular refurbishment of buildings to operationalize circular economy policies, Environments. 10 (3) (2023) 51, https://doi.org/10.3390/ENVIRONMENTS10030051.
[140] C.L.C. Roxas, et al., Design for Manufacturing and Assembly (DfMA) and Design for Deconstruction (DfD) in the Construction Industry: Challenges, Trends and Developments, Buildings 13 (5) (2023) 1164, https://doi.org/10.3390/BUILDINGS13051164.
[141] M.R. Chertow, Industrial symbiosis: Literature and taxonomy, Ann. Rev. Energy Environ. 25 (2000) 313–337, https://doi.org/10.1146/ANNUREV.ENERGY.25.1.313.
[142] M.A. Al-Sinan, A.A. Bubshait, The Procurement agenda for the transition to a circular economy, Sustainability. 14 (18) (2022) 11528, https://doi.org/10.3390/SU141811528.
[143] O.E. Ogunmakinde, A Review of Circular Economy Development Models in China, Germany and Japan, Recycling 4 (3) (2019) 27, https://doi.org/10.3390/RECYCLING4030027.
[144] "Which country is leading the circular economy shift?" Accessed: Apr. 20, 2024. [Online]. Available: https://www.ellenmacarthurfoundation.org/articles/which-country-is-leading-the-circular-economy-shift.
[145] F. Boons, M. Chertow, J. Park, W. Spekkink, H. Shi, Industrial symbiosis dynamics and the problem of equivalence: proposal for a comparative framework, J. Ind. Ecol. 21 (4) (2017) 938–952, https://doi.org/10.1111/JIEC.12468.
[146] M.R. Esa, A. Halog, L. Rigamonti, Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy, J. Mater. Cycles. Waste Manage 19 (3) (2017) 1144–1154, https://doi.org/10.1007/S10163-016-0516-X/METRICS.
[147] K. Alhola, S.O. Ryding, H. Salmenperä, N.J. Busch, Exploiting the Potential of Public Procurement: Opportunities for Circular Economy, J. Ind. Ecol. 23 (1) (2019) 96–109, https://doi.org/10.1111/JIEC.12770.
[148] M.U. Hossain, S.T. Ng, P. Antwi-Afari, B. Amor, Circular economy and the construction industry: Existing trends, challenges and prospective framework for

sustainable construction, Renew. Sustain. Energy Rev. 130 (2020) 109948, https://doi.org/10.1016/J.RSER.2020.109948.
[149] I.S. Al Hosni, O. Amoudi, N. Callaghan, An exploratory study on challenges of circular economy in the built environment in Oman, 173, 2020, pp. 104–113, https://doi.org/10.1680/jmapl.19.00034.
[150] S. Bag, L.C. Wood, S.K. Mangla, S. Luthra, Procurement 4.0 and its implications on business process performance in a circular economy, Resour. Conserv. Recycl. 152 (2020) 104502, https://doi.org/10.1016/J.RESCONREC.2019.104502.
[151] B. Torgautov, A. Zhanabayev, A. Tleuken, A. Turkyilmaz, M. Mustafa, F. Karaca, Circular Economy: s Kazakhstan, Buildings 11 (11) (2021) 501, https://doi.org/10.3390/BUILDINGS11110501.
[152] S. Çetin, V. Gruis, A. Straub, Towards Circular Social Housing: An Exploration of Practices, Barriers, and Enablers, Sustainability 13 (4) (2021) 2100, https://doi.org/10.3390/SU13042100.
[153] M. Condotta, E. Zatta, Reuse of building elements in the architectural practice and the European regulatory context: Inconsistencies and possible improvements, J. Clean. Prod. 318 (2021) 128413, https://doi.org/10.1016/J.JCLEPRO.2021.128413.
[154] E. Haselsteiner, B.V. Rizvanolli, P. Villoria Sáez, O. Kontovourkis, Drivers and barriers leading to a successful paradigm shift toward regenerative neighborhoods, Sustain. (Switzerland) 13 (9) (2021) 5179, https://doi.org/10.3390/SU13095179/S1.
[155] S.A.R. Khan, A. Razzaq, Z. Yu, S. Miller, Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability, Bus. Strategy. Environ. 30 (8) (2021) 4001–4014, https://doi.org/10.1002/BSE.2853.
[156] G.C. Verga, A.Z. Khan, Space matters: barriers and enablers for embedding urban circularity practices in the brussels capital region, Front. Built. Environ. 8 (2022) 810049, https://doi.org/10.3389/FBUIL.2022.810049/BIBTEX.
[157] S. Shooshtarian, T. Maqsood, P.S.P. Wong, L. Bettini, Application of sustainable procurement policy to improve the circularity of construction and demolition waste resources in Australia, Mater. Circ. Econ. 4 (1) (2022) 1–22, https://doi.org/10.1007/S42824-022-00069-Z.
[158] S. Shooshtarian, S. Caldera, T. Maqsood, T. Ryley, M. Khalfan, An investigation into challenges and opportunities in the Australian construction and demolition waste management system, Eng., Constr. Arch. Manag. 29 (10) (2021) 4313–4330, https://doi.org/10.1108/ECAM-05-2021-0439.
[159] A. Tleuken, B. Torgautov, A. Zhanabayev, A. Turkyilmaz, M. Mustafa, F. Karaca, Design for deconstruction and disassembly: barriers, opportunities, and practices in developing economies of central Asia, Procedia CIRP. 106 (2022) 15–20, https://doi.org/10.1016/J.PROCIR.2022.02.148.
[160] T. Zuofa, E.G. Ochieng, I. Ode-Ichakpa, An evaluation of determinants influencing the adoption of circular economy principles in Nigerian construction SMEs, Build. Res. Inf. 51 (1) (2023) 69–84, https://doi.org/10.1080/09613218.2022.2142496.
[161] G. Gyori, The role of public procurement to foster social equity and justice: critical reflections on the circular procurement concept, Local. Environ. 27 (10–11) (2022) 1242–1253, https://doi.org/10.1080/13549839.2021.2001798.
[162] M. Zijp, et al., Measuring the effect of circular public procurement on government's environmental impact, Sustain. (Switzerland) 14 (16) (2022) 10271, https://doi.org/10.3390/SU141610271/S1.
[163] I.E. Nikolaou, T.A. Tsalis, K.I. Vatalis, A framework to integrate circular economy principles into public procurement, Circ. Econ. Sustain. (2022) 279–291, https://doi.org/10.1016/B978-0-12-819817-9.00020-X.
[164] Y.A. Villagrán-Zaccardi, A.T.M. Marsh, M.E. Sosa, C.J. Zega, N. De Belie, S. A. Bernal, Complete re-utilization of waste concretes–Valorisation pathways and research needs, Resour. Conserv. Recycl. 177 (2022) 105955, https://doi.org/10.1016/J.RESCONREC.2021.105955.
[165] L. Ding, T. Wang, P.W. Chan, Forward and reverse logistics for circular economy in construction: A systematic literature review, J. Clean. Prod. 388 (2023) 135981, https://doi.org/10.1016/J.JCLEPRO.2023.135981.
[166] S. Ahmed, J. Majava, K. Aaltonen, Implementation of circular economy in construction projects: a procurement strategy approach, Constr. Innov. (2023), https://doi.org/10.1108/CI-12-2022-0327.
[167] B.I. Oluleye, D.W.M. Chan, T.O. Olawumi, A.B. Saka, Assessment of symmetries and asymmetries on barriers to circular economy adoption in the construction industry towards zero waste: A survey of international experts, Build. Environ. 228 (2023) 109885, https://doi.org/10.1016/J.BUILDENV.2022.109885.
[168] J.F. Azcárate-Aguerre, A.C. den Heijer, M.H. Arkesteijn, L.M. Vergara d'Alençon, T. Klein, Facades-as-a-Service: Systemic managerial, financial, and governance innovation to enable a circular economy for buildings. Lessons learnt from a full-scale pilot project in the Netherlands, Front. Built. Environ. 9 (2023) 1084078, https://doi.org/10.3389/FBUIL.2023.1084078/BIBTEX.
[169] T. Watari, Z. Cao, A.C. Serrenho, J. Cullen, Growing role of concrete in sand and climate crises, iScience 26 (5) (2023) 106782, https://doi.org/10.1016/J.ISCI.2023.106782.
[170] K. Anastasiades, S. Michels, H. Van Wuytswinkel, J. Blom, A. Audenaert, Barriers for the circular reuse of steel in the Belgian construction sector: an industry-wide perspective, 2022, https://doi.org/10.1680/jmapl.21.00044.