Towards Sustainable Built Environments: Scientometric Insights on Global Barriers to Circular Construction

Gulden Gumusburun Ayalp[1)], Yusuf Berkay Metinal[2*)]

[1)] Department of Architecture, Fine Arts and Architecture Faculty, Hasan Kalyoncu University, Gaziantep, 27010, Turkey, gulden.ayalp@hku.edu.tr; 0000-0002-7989-5569
[2*)] Department of Architecture, Fine Arts and Architecture Faculty, Hasan Kalyoncu University, Gaziantep, 27010, Turkey, yberkay.metinal@hku.edu.tr; 0000-0001-9528-893X

https://doi.org/10.29227/IM-2025-02-02-094

Submission date: *2025-03-26* | Review date: *2025-04-25*

Abstract

The construction sector is a key driver of economic growth and environmental sustainability; however, it remains one of the largest consumers of natural resources and a significant contributor to waste generation. As urbanization accelerates, resource depletion and environmental concerns highlight the urgent need for sustainable solutions. Circular construction (CC) offers a promising approach by promoting resource efficiency, waste reduction, and material reuse. Despite its potential, the transition to CC faces persistent challenges, including entrenched project-based practices, fragmented supply chains, regulatory barriers, and stakeholder resistance. This study systematically investigates these barriers and outlines future directions for overcoming challenges to CC (C2CC). By analyzing global contributions, it identifies influential countries, key journals, leading scholars, and emerging keyword trends within C2CC literature. Using a scientometric approach, this research assesses existing knowledge on C2CC, drawing from the Web of Science (WoS) database, which provides extensive coverage of relevant academic studies. A bibliometric analysis of 199 articles published between 2000 and 2024 was conducted using VOSviewer software to visualize research trends and thematic clusters. Findings reveal six major C2CC themes, emphasizing the critical role of government policies, industry collaboration, innovative material use, circular design principles, digital technologies, and financial incentives. Addressing these challenges requires integrated efforts from policymakers, industry professionals, and researchers. This study contributes to the academic and practical discourse on CC by mapping research trends and highlighting areas for further exploration. The results offer valuable insights for fostering a more sustainable and resource-efficient construction sector.

Keywords: *Barriers, circular construction, scientometric analysis.*

1. Introduction

As a cornerstone of economic activity and a key contributor to environmental pressures, the built environment sector holds strategic significance [1]. Across EU member states, it accounts for nearly 9% of GDP and supports the employment of approximately 18 million individuals [2]. While it plays a vital role in delivering infrastructure and housing, the sector also faces major sustainability challenges—consuming close to half of global raw material resources and 36% of the world's total [3].

Furthermore, it generates 39% of energy-related emissions, exacerbating environmental challenges [4]. As population growth accelerates, the demand for urban development is expected to surpass the construction needs of the past 4000 years [5]. Concurrently, rising raw material costs drive the industry toward resource-efficient approaches such as reuse and recycling [5]. Therefore, shifting toward a circular economy (CE) is essential for achieving sustainability [3].

The CE principles—reduce, reuse, and recycle—are relatively new in the construction sector but hold significant potential for enhancing sustainability by promoting the use of sustainable materials, improving resource recovery, and minimizing waste [6]. Implementing circular economy practices in Europe has the potential to generate economic benefits estimated at €350 billion by the year 2030 [4]. However, due to the project-based nature of construction, integrating CE practices remains complex and necessitates government support to provide clear guidelines [7].

Circular construction (CC) operationalizes CE principles by incorporating strategies such as design for disassembly, material reuse, and recycling, thereby addressing the industry's substantial waste generation [3]. CC promotes a closed-loop system that extends the lifecycle of materials, improving sustainability across the planning, design, and deconstruction phases [8]. Additionally, it fosters resource efficiency, mitigates environmental impact, and enables material exchanges, where waste from one project can be repurposed in another [9].

CC also drives social, technological, and organizational innovations within construction projects. It redefines project practices to prioritize material recovery, extending product life, and ensuring recovery at end-of-life stages. Despite its potential for advancing CE, CC introduces new challenges in project execution due to increased complexity [10]. This shift, however, introduces uncertainties, complexities, and risks in project delivery [10], making it a focal point for academic research. Studies have explored various aspects of CC, including its role in managing construction and demolition waste (CDWM) [9] and the development of conceptual models and frameworks for integrating CE into construction through case studies [11]. Additionally, studies have addressed the adoption of CE practices in the construction sector [12] and identified key indicators of CC [13]. Meanwhile, another line of research has examined barriers to CC, particularly those related to stakeholders [14,15].

Many studies focus on CC and waste management; however, there is a need to address barriers to CC holistically. The current study addresses this gap by conducting a scientometric analysis to examine key research themes, existing gaps, and future directions for overcoming challenges to CC (C2CC). This research presents the first comprehensive global analysis of C2CC, offering insights

into emerging trends and guiding future investigations. Its findings will assist researchers and policymakers in integrating CE principles within the construction sector, supporting policy development aligned with CE objectives.

2. Literature Review

The construction sector depends extensively on finite resource inputs, and their unsustainable consumption plays a major role in accelerating depletion rates [14]. As a response, the CE has gained prominence as a sustainable approach to reducing the industry's environmental impact [10]. Researchers have examined the key obstacles to CE adoption in construction and explored strategies for transitioning toward CC [3,7]. Simultaneously, studies have investigated integrating emerging technologies such as AI, blockchain, IoT, and Construction 4.0 to enhance CC implementation [16]. The role of Building Information Modeling (BIM) has also been highlighted, emphasizing its capacity to support circularity through sustainable material selection and management [17]. Beyond BIM, other studies examine CE aspects such as CE dimensions [18], and circularity indicators [19].

Regional approaches vary, with developed countries like the Netherlands, UK, Australia, and Japan emphasizing CE awareness while developing nations focus on addressing barriers to CE [20]. Various methodologies, including online surveys, factor analysis, and Monte Carlo simulations, advance CC research [21]. Mixed-method approaches, such as semi-structured interviews and case studies, provide additional insights [22]. Despite these advancements, CC research remains nascent, and comprehensive reviews are needed to address research gaps [16].

Quantitative and mixed-method reviews, such as systematic and bibliometric analyses, have mapped the current body of literature, identifying key trends and gaps [13]. This study employs a comprehensive methodology to synthesize diverse perspectives, uncovering interrelated trends and establishing a cohesive foundation for future research on C2CC. This research provides a multidimensional perspective that fosters a more integrated approach for ongoing and future studies by bridging fragmented insights.

3. Research Methodology

To address the aims of this research and guide the inquiry process, the authors employed a literature mapping technique to investigate the C2CC body of work. This approach offers a structured way to examine and visually represent a particular scholarly domain [23], highlighting the spatial connections between subject areas, research themes, and contributing scholars [23]. It is particularly useful in uncovering trends and knowledge structures within extensive bibliographic datasets, revealing insights that traditional analytical approaches might overlook [24]. The current study adopted a three-step methodology, consisting of bibliometric retrieval, scientometric evaluation, and qualitative synthesis [25].

3.1 Bibliometric Search

The initial data collection phase involved choosing the Web of Science (WoS) core collection, which is well regarded for its data quality and superior citation tracking compared to Scopus. A keyword-based search was conducted in WoS within the "ALL FIELDS" category using the following query: ("circular economy" OR "circular econom*" OR "circularity") AND ("construction industry" OR "construction") AND ("barrier") NOT ("infrastructure" OR "road"). Specific filters, such as document type and language, were applied, resulting in 47,613 records as of August 2024. Sources such as conference proceedings, books, and book chapters were not included due to their generally lower levels of peer-review rigor [25].

Subsequent screening of titles, abstracts, and keywords narrowed the dataset to 5,968 relevant articles. Studies were included if they focused on C2CC, were peer-reviewed, and indexed in SCI-E, SSCI, or AHCI. Publications in languages other than English were excluded. After applying these criteria, 199 articles were selected and exported as CSV files for scientometric analysis.

3.2 Scientometric Analysis

A bibliometric analysis employs quantitative techniques to systematically examine research publications on a chosen topic, using mathematical methods [26]. This method allows for examining unique characteristics of publications, uncovering interrelationships within scientific discussions. To investigate C2CC, the authors utilized VOSviewer's text-mining capabilities to assess bibliometric relationships through specific results. The analysis, focused on five key areas, was conducted on the assembled dataset: (1) publication counts by country, (2) publication distribution by document source, (3) publication frequency by author, (4) keyword co-occurrence patterns, and (5) emerging trends via overlay visualization.

4. Findings and Discussion

4.1 Publications by Country

Table 1 provides a detailed overview of the 13 leading countries in the C2CC domain, with more than eight articles contributing to it.

Tab. 1. Number of C2CC Related Publications by Country.

Country	Documents	Citations	Total Link Strength
Australia	32	775	176
People's Republic of China	30	1867	170
England	29	1414	245
Netherlands	16	742	82
Italy	11	837	110
Brazil	10	648	40
India	9	125	31
Portugal	8	292	20

Table 1 highlights Australia, China, and England as the leading contributors to the literature, each producing over 20 publications.

4.2 Publications per Document Source

Sources play a critical role in understanding the journal landscape, their influence and impact, and the evolving trends in academic publishing. In this research, 61 journals are represented within the 199 analyzed articles. Table 2 highlights the nine most influential journals containing five or more articles. The top three journals contribute to one-third of the total publications. Sustainability ranks

first, contributing 34 articles (17.0%) and reflecting a strong emphasis on publishing C2CC-related research. It is followed by the Journal of Cleaner Production (14.5%), Buildings (7.5%), the Journal of Building Engineering (4.5%), and Sustainable Production and Consumption (4.0%), in descending order of representation.

Tab. 2. Number of Publications per Source.

Source	Documents	Citations	Total Link Strength
Sustainability	34	460	33
Journal of Cleaner Production	29	3057	87
Buildings	15	186	21
Journal of Building Engineering	9	499	22
Sustainable Production and Consumption	8	226	29
Smart and Sustainable Built Environment	7	99	34
Building and Environment	5	111	11
Construction Innovation-England	5	49	17
Resources Conservation and Recyclıng	5	573	38

4.3 Publications per Author

An authorship network analysis was performed using VOSviewer to map collaborations among researchers focused on C2CC. The 199 documents analyzed feature 605 authors affiliated with 284 institutions, including primary and co-authors. Setting a minimum threshold of five publications per author, twelve authors met the criteria for inclusion. Table 4 lists the most influential authors in this research area, highlighting those with the most publications and citations. The most prolific contributors identified include Weisheng Lu, Ibrahim Yahaya Wuni, Ferhat Karaca, and Aidana Tleuken, each with six publications and citation counts of 415, 138, 76, 76, and 602, respectively, demonstrating their impact in the C2CC field.

Tab. 3. Number of Documents per Author.

Author	Documents	Institution	Country	Citations	Total Link Strength
Weisheng Lu	6	University of Hong Kong (HKU)	Hong Kong	415	17
Ibrahim Yahaya Wuni	6	King Fahd University of Petroleum and Minerals	Saudi Arabia	138	9
Ferhat Karaca	6	Nazarbayev University	Kazakhstan	76	8
Aidana Tleuken	6	University of Twente	Netherlands	76	8
Sergio Fernando Tavares	5	Universidade Federal do Paraná	Brazil	602	0
Prince Antwi-Afari	5	University of Adelaide	Australia	375	4
Rabia Charef	5	Lancaster University	UK	216	1

4.4 Keyword Co-occurrence Clusters

Keyword co-occurrence analysis identifies clusters of research topics within the C2CC field, emphasizing the most significant themes. The resulting clusters represent distinct categories, themes, and directions in the research. Using VOSviewer, a network of 509 keywords was analyzed, applying a minimum occurrence threshold of four, which yielded 32. Through clustering, six keyword groups emerged, visualized in Figure 1. This network includes 187 links with a total link strength of 581. In Figure 1, node size indicates keyword frequency, with larger nodes representing more frequently occurring keywords, while line thickness reflects the strength of keyword relationships—the thicker the line, the stronger the relationship [27]. Keywords were organized into similar research topics, as shown in Figure 1. VOSviewer's proximity-based visualization places keywords from related research areas closer together, with connecting lines indicating interrelations, allowing for intuitive interpretation. Cluster 1 (red) involves keywords related to Integrative Digital and Sustainable Design Challenges in CC, such as "blockchain," "building information modeling," "built environment," "circular economy," "circularity indicators," and "sustainability." Cluster 2 (blue) involves keywords related to Barriers in Reducing Construction Waste for Circular Development, such as "circular construction," "construction waste," "sustainable development," and "systematic literature review." Cluster 3 (green) involves keywords related to Optimizing Business Models for Resource Efficiency and Waste Reduction in Construction, such as "business model," "resource efficiency," and "reuse." Cluster 4 (yellow) focuses on Enhancing Waste Management Indicators in Construction and Demolition Projects, such as "construction and demolition waste," "waste management," and "indicators." Cluster 5 (purple) includes keywords related to Overcoming Digital Barriers in the Construction Industry, such as "barriers" and "digital technologies." Cluster 6 (light blue) includes keywords related to Integrating Life Cycle Assessment into Construction Project Management, such as life cycle assessment, management, and project management.

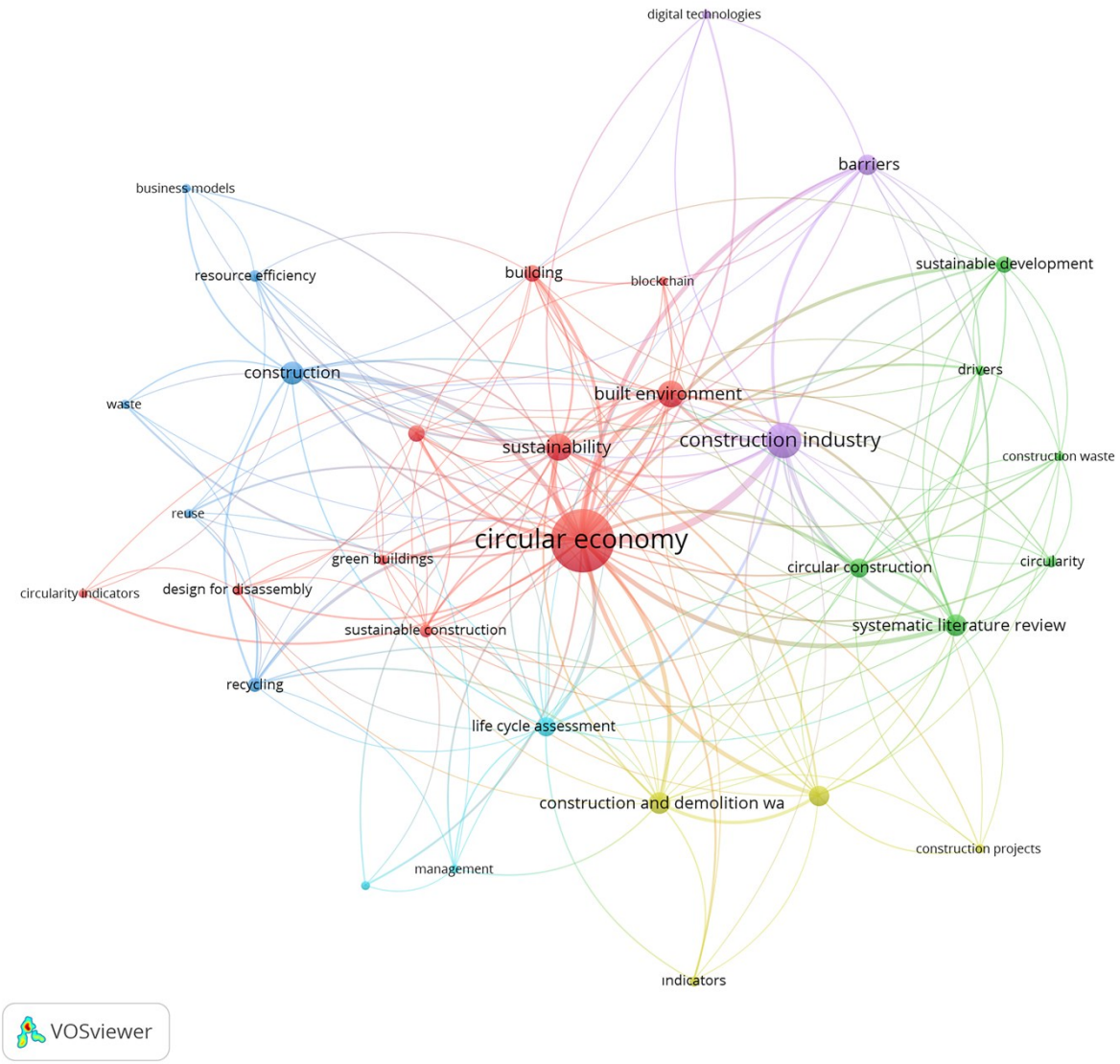

Fig. 1. Keyword co-occurrence analysis.

Table 4 displays the most common terms extracted from the 199 analyzed documents using keyword co-occurrence analysis. A minimum threshold of four co-occurrences was applied. "Circular economy" was the most frequent keyword, appearing 163 times, followed by "construction industry" (51) and "sustainability" (29).

Tab. 4. Keywords Occurrences and Total Link Strength.

Keyword	Occurrences	Total Link Strength
Circular Economy	163	298
Construction Industry	51	117
Sustainability	29	77
Built Environment	28	70
Construction	22	49
Systematic Literature Review	20	56
Construction and Demolition Waste	19	47
Waste Management	18	45
Barriers	18	43
Life Cycle Assessment	15	39
Circular Construction	15	32
Building	12	27
Sustainable Development	12	25

4.5 Annual Tendencies of Research Topics

Figure 4 illustrates a thematic overlay map generated via VOSviewer, depicting how pandemic-driven research topics evolved between 2021 and 2023. The visualized clusters indicate a notable rise in research output in 2021, particularly on topics related to the built environment and sustainable development within the scope of C2CC. More specific issues were addressed in 2022, including circular economy, barriers, life cycle assessment, construction and demolition waste, and systematic literature review. From 2023 onward, keywords such as circular construction, business models, and digital technologies have become more popular (Figure 2).

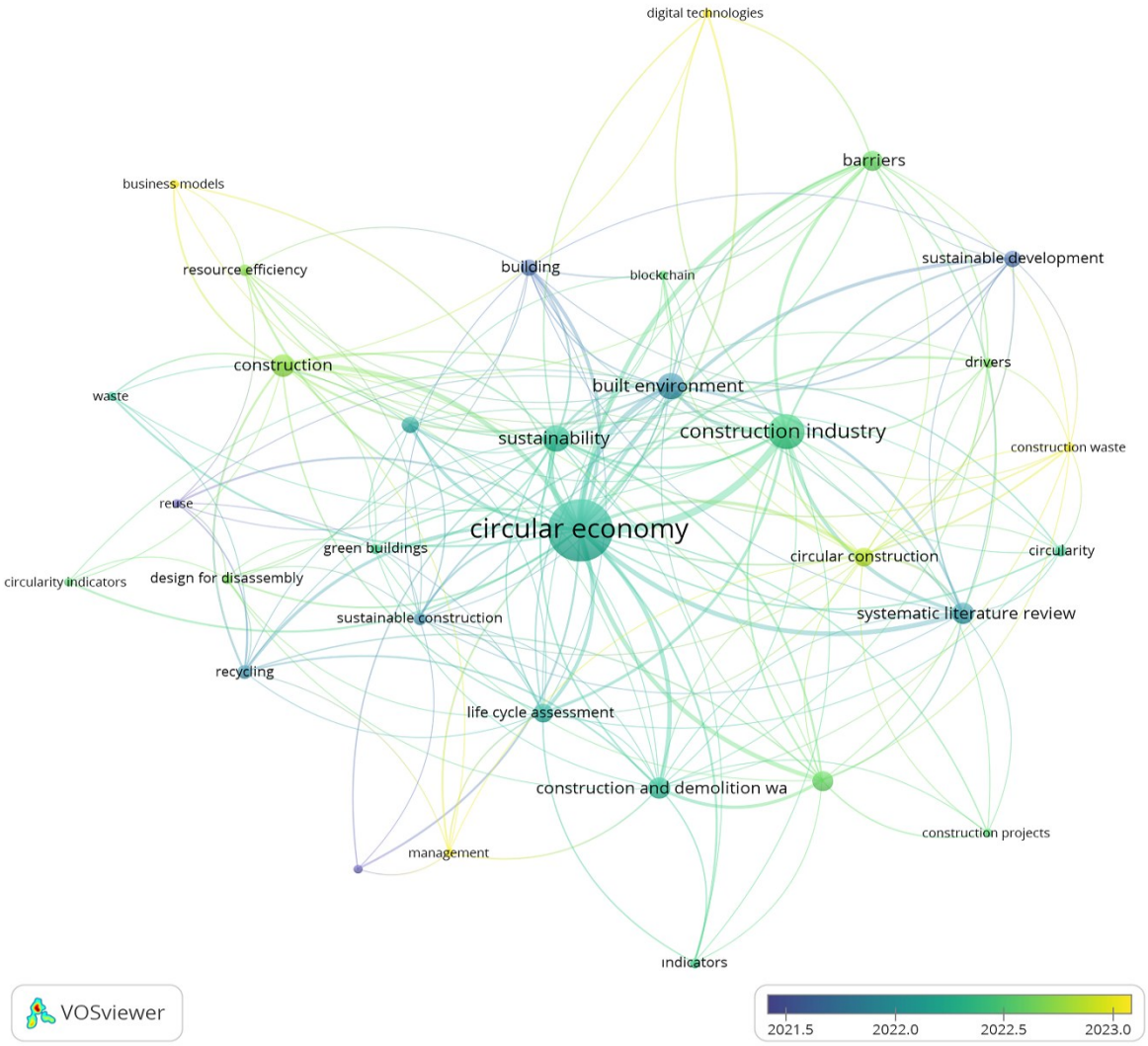

Fig. 2. Overlay visualization of research topics.

5. Conclusions and Further Research

This research provides a scientometric perspective on the academic development of C2CC, utilizing a reliable and comprehensive collection of 199 scholarly publications spanning the years 2017 to 2024.

The main findings are outlined below:

(1) Australia, China, and England are leading contributors, reflecting an international interest in C2CC practices, particularly in regions experiencing rapid urban development and facing urgent sustainability challenges. The high contributions from these countries suggest a regional prioritization of CC in policy, academia, and industry, potentially driven by governmental sustainability agendas and resource scarcity.

(2) The dominance of journals like Sustainability, Journal of Cleaner Production, and Buildings points to a solid academic foundation in environmental sustainability and sustainable design. These sources highlight C2CC as a multidisciplinary field integrating environmental science, engineering, and architecture. The concentration of articles within a few journals suggests that a focused core of academic communities drives innovation and dissemination, likely creating a solid basis for further research collaborations.

(3) The identification of productive authors like Weisheng Lu and Ibrahim Yahaya Wuni, with extensive networks, indicates leading voices shaping this research domain. Their collaborative networks enhance cross-institutional and international collaboration, which is critical for addressing global challenges in circularity and construction. These influential authors likely set research priorities and methodologies that guide the field's development.

(4) To explore the conceptual foundation of the C2CC domain, a keyword co-occurrence mapping was conducted, aiming to uncover its essential thematic elements and ultimately highlighting six key challenges: (i) Cluster 1 centers on Digital and Sustainable Design Challenges, emphasizing technologies like blockchain and BIM, which are pivotal for tracking material lifecycles and supporting sustainable practices. The intense focus on digital tools highlights the reliance on technological innovation to enable circularity. (ii) Cluster 2 addresses Barriers to Reducing Construction Waste, underscoring challenges in transitioning to waste-minimizing practices. This reflects an ongoing need to refine waste management strategies. (iii) Cluster 3 focuses on Optimizing Business Models, indicating that economic factors play a significant role in advancing circularity in construction, with strategies around resource efficiency and reuse. (iv) Cluster 4 emphasizes Waste Management Indicators, showing a trend toward developing metrics to assess better and manage demolition waste. (v) Cluster 5 explores Overcoming Digital Barriers, reflecting an understanding that while digital technologies are essential, barriers to their adoption persist. (vi) Cluster 6 highlights the integration of Life Cycle Assessment (LCA), showing an interest in holistic environmental impact evaluation as part of project management practices.

(5) The keyword shift since the pandemic reflects a growing emphasis on sustainable development within the built environment.

From 2021 to 2023, there is a clear progression from foundational topics in sustainability and the built environment towards specific challenges such as life cycle assessment, business models, and digital integration. This evolution signals an increasing maturity in the field, with research moving towards operationalizing circular practices and addressing implementation barriers.

This analysis highlights the rich, multidimensional nature of C2CC research, from theoretical explorations of sustainability and digital technologies to practical applications in waste reduction and lifecycle management. Moving forward, bridging gaps between technological potential and real-world application remains essential, as does fostering interdisciplinary and cross-border collaboration. The ongoing trend toward integrating digital tools and sustainability measures into the lifecycle of construction projects suggests that C2CC will increasingly influence future construction standards, with a clear trajectory toward more resilient and circular built environments.

References

1. J. Zuo and Z. Y. Zhao, "Green building research-current status and future agenda: A review", Renew. Sust. Energ. 30, 271–81 (2014).
2. X. Zhao, J. Zuo, G. Wu and C. Huang, "A bibliometric review of green building research 2000–2016", Archit. Sci. Rev. 62, 74–88 (2019).
3. M. R. Munaro and S. F. Tavares, "A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective", Clean. Responsible Consum. 8, 1-14 (2023).
4. A. Allouhi, Y. El Fouih, T. Kousksou, A. Jamil, Y. Zeraouli and Y. Mourad, "Energy consumption and efficiency in buildings: Current status and future trends", J. Clean. Prod. 109, 118–30 (2015).
5. L. C. M. Eberhardt, H. Birgisdottir and M. Birkved, "Potential of Circular Economy in Sustainable Buildings", IOP Conference Series: Materials Science and Engineering 471, 1-12 (2019).
6. L. A. Akanbi, L. O. Oyedele, O. O. Akinade, A. O. Ajayi, M. D. Delgado, M. Bilal, and S. A Bello, "Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator", Resour. Conserv. Recycl. 129, 175–86 (2018).
7. M. U. Hossain, S. T. Ng, P. Antwi-Afari and B. Amor, "Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction", Renew. Sustain. Energy Rev. 130, 1-15 (2020).
8. I. Y. Wuni and G. Q Shen, "Developing critical success factors for integrating circular economy into modular construction projects in Hong Kong", Sustain. Prod. Consum. 29, 574–87 (2022).
9. Q. Chen, H. Feng and B. Garcia de Soto, "Revamping construction supply chain processes with circular economy strategies: A systematic literature review", J. Clean. Prod. 335, 1-16 (2022).
10. M. Donner, A. Verniquet, J. Broeze, K. Kayser and H. De Vries, "Critical success and risk factors for circular business models valorising agricultural waste and by-products", Resour. Conserv. Recycl. 165, 1-11 (2021).
11. O. Ho, U. Iyer-Raniga, C. Sadykova, M. Balasooriya, K. Sylva, M. Dissanayaka, K. Sukwanchai, I. Pal, A. Bhatia, D. Jain and S. Sivapalan, "A conceptual model for integrating circular economy in the built environment: An analysis of literature and local-based case studies", J. Clean. Prod. 449, 1-16 (2024).
12. T. Zuofa, E. G. Ochieng and I. Ode-Ichakpa, "An evaluation of determinants influencing the adoption of circular economy principles in Nigerian construction SMEs", Build. Res. Inf. 51(1), 69–84 (2023).
13. P. Antwi-Afari, S. T. Ng and M. U. Hossain, "A review of the circularity gap in the construction industry through scientometric analysis", J. Clean. Prod. 298, (2021).
14. A. M. Hassan, Y. T. Negash and F. Hanum, "An assessment of barriers to digital transformation in circular Construction: An application of stakeholder theory", Ain Shams Eng. J. 15(7), (2024).
15. A. H. Trevisan, A. Lobo, D. Guzzo and L.A. de V. Gomes, "Mascarenhas J. Barriers to employing digital technologies for a circular economy: A multi-level perspective", J. Environ. Manage. 332, (2023).
16. B. I. Oluleye, Chan D. W. M., Olawumi T. O. and Saka A. B. "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).
17. M. Behún and A. Behúnová, "Advanced Innovation Technology of BIM in a Circular Economy", Appl. Sci. (Switz.) 13(13), (2023).
18. F. Pomponi and A. Moncaster, "Circular economy for the built environment: A research framework", J. Clean. Prod. 143, 710–718 (2017).
19. K. Anastasiades, J. Blom and A. Audenaert, "Circular Construction Indicator: Assessing Circularity in the Design, Construction, and End-of-Life Phase", Recycling 8(2) (2023).
20. K. Koc, S. Durdyev, A. Tleuken, O. Ekmekcioglu, J. Mbachu and F. Karaca, "Critical success factors for construction industry transition to circular economy: developing countries' perspectives", Eng. Constr. Archit. Manag. 31(12), 4955-4974 (2023).
21. P. Mhatre, V. V. Gedam, S. Unnikrishnan and R. D. Raut, "Circular economy adoption barriers in built environment- a case of emerging economy", J. Clean. Prod. 392, (2023).
22. E. Leising, J. Quist and N. Bocken, "Circular Economy in the building sector: Three cases and a collaboration tool", J. Clean. Prod. 176, 976–989 (2018).
23. C. Chen, "Science Mapping: A Systematic Review of the Literature", J. Data Inf. Sci. 2(2), (2017).
24. M. F. Antwi-Afari, H. Li, A. H. S. Chan, J. Seo, S. Anwer, H. Mi, Z. Wu and A. Y. L. Wong, "A science mapping-based review of work-related musculoskeletal disorders among construction workers", J. Safety Res. 85, 114–28 (2023).
25. J. Shi and M. F. Antwi-Afari, "Organizational leadership and employee well-being in the construction industry: a bibliometric and scientometric review", J. Eng. Des. Technol., (2023).
26. Y. Yu, Y. Li, Z. Zhang, Z. Gu, H. Zhong, Q. Zha, L. Yang, C. Zhu and E. Chen, "A bibliometric analysis using VOSviewer of publications on COVID-19", Ann. Transl. Med. 8(13), 816–816 (2020).
27. N. Jan van Eck and L. Waltman, Manual for VOSviewer version 1.6.16. (Universiteit Leiden, Leiden, 2020), 1-53.