

CIRCULAR ECONOMY PRINCIPLES IN THE BUILT ENVIRONMENT: A SYSTEMATIC LITERATURE REVIEW

Idris Soliu¹, Giovanni C. Migliaccio² and Idris Abdulgafar³

1 University of Washington, Seattle, WA, United States. Email: sidris2@uw.edu

2 University of Washington, Seattle, WA, United States. Email: gianciro@uw.edu

3 Abubakar Tafawa Balewa University, Bauchi, Nigeria.

Abstract

The impact of the consumerism economy model on environmental degradation, waste generation, and resource depletion has heightened the attention of industry practitioners, academic scholars, and policymakers toward the adoption of the Circular Economy in the last few decades. Consequently, being a resource-intensive and waste-generating industry, the built environment has embraced the paradigm shift from a take-make-use-dispose approach to emerging economy models to withstand future shocks. While the literature on circular economy concepts, frameworks, and business models is rapidly growing, the empirical evidence regarding the practical implementation of circularity principles is scarce within the built environment. However, transitioning to a circular built environment is unrealizable unless principles of circularity are fully integrated into the building lifecycle. Consequently, the present study investigates the research trajectory of Circular Economy Principles (CEP) within the built environment through a systematic literature review. The study employed the Preferred Reporting Items for Systematic Review and Meta-Analysis framework to conduct a literature search on two prominent databases, Web of Science and Google Scholar, and thematic analysis was conducted to evaluate the research trend and identify the knowledge gap. The review found that significant attention was given to certain circularity principles, while others received less focus over the past decade. Additionally, the study uncovered areas where further exploration is needed because of the existing knowledge gaps identified in the current study. This study sheds light on the evolving landscape of the circular economy within the built environment, underscores the progress made, and concludes with the areas that require further exploration to achieve a circular built environment.

© 2024 The Authors. Published by Budapest University of Technology and Economics & Diamond Congress Ltd.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2024.

Keywords: Built Environment, Circularity, R- principles.

1. Introduction

The impact of the consumerism system of production on environmental degradation, waste generation, and resource depletion has increased the popularity of the Circular Economy among academic scholars, government institutions, and industry practitioners alike in recent times. As a resource-intensive and waste-generating industry, these factors prompted the Built Environment to embrace the transformative change from the conventional take-produce-use-dispose production system to a take-make-use-return model to avoid future disruption. Circular Economy (CE), dubbed as circularity, is a model proposed to disrupt several economic sectors' linear consumption and production systems through material circulation [1]. The model involves keeping material usage in circulation at the highest possible value by restoring waste to the production line through reuse, repair, and recycling, thereby reducing the pressure on limited natural resources [2] and other externalities such as CO₂ emission [3] and loss of biodiversity [4]. According to Luebke and Fiksel [5], the pillars of the CE can be categorized into three main principles: design out of waste and pollution, keeping products and materials in circulation (closed loop), and regeneration of natural systems. These CE paradigms are based on the principles of circularity promoted by the Ellen McArthur Foundation [6]. The fundamental principles of circularity can

be traced back to the 3R approach, including reduce, reuse, and recycle, which are rooted in the European waste pyramid hierarchy [7].

The European waste hierarchy is the foundation of circular economy principles, with prevention considered the highest principle in the pyramid, followed by reuse, recycling, recovery, and landfilling. However, landfilling is not considered a principle contributing to the circular economy [8] and is subsequently excluded from the circularity ladder [7]. Building on these fundamental 3R principles, additional principles were uncovered, which include refuse, rethink, repair, refurbish, remanufacture, repurpose, and recover [9], [10], [11], [12]. However, the most popular among these principles within the built environment are reduce, recycle, and reuse [11]. Further, Kio et al. [13] also uncovered three more relevant principles of circularity in the built environment, including recovery, redesign, and remanufacture, resulting in six principles known as the 6R. Consequently, this set of the most relevant circular economy principles is evaluated in the current study. Despite the awareness and adoption of CE principles in various sectors, their application in the built environment is progressing slowly; this slow progression could be due to a lack of research. There is still no thorough understanding of how the principles can be integrated into the construction project. This is evident from the lack of empirical evidence of the actual implementation of circularity principles in the construction project. However, transitioning from a linear approach to an emerging model is unrealizable unless the principles of circularity are fully integrated into the building lifecycle [14]. To that end, this review examines the recent development of the phenomenon and identifies the knowledge gap using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). This study provides valuable insights into the research trajectory of CE practice over a decade, identifying extensively researched principles and highlighting areas that require attention in future studies to achieve a circular built environment.

2. Methods

This study uses the PRISMA framework to investigate current research trends about Circular Economy Principles (CEP) within the built environment. Specifically, the study aims to focus on the critical 6R principles within the built environment and exclude articles that delve into discussions of other CE concepts such as policy frameworks, barriers and enablers, technology, measurement and assessment, stakeholder participation, and business models, as these aspects have been addressed by various authors [15], [16], [17]. Accordingly, the present study adhered to specific criteria for the article selection process. Initially, preference was given to peer-reviewed articles available in open-access databases to enhance the replicability and transparency of the study. This ensured that other researchers could access and verify our findings, thus contributing to the overall robustness of the investigation [18]. In addition, the temporal scope of article inclusion is from 2013 to 2023. This timeframe was deliberately chosen to encompass the critical early stages of development in the built environment, coinciding with the initiatives and advancements undertaken by influential circular economy promoter nations, such as China, Japan, and various European countries [19]. Thirdly, the chosen manuscripts must be authored in English. This condition was instituted to foster broader accessibility by acknowledging the widespread recognition of English as a universally accepted language [20]. Furthermore, it is a requirement that the words 'circula*', 'principles', 'R princ*', must be present in the title, abstract, or keyword of the article. However, this condition may lead to the exclusion of some relevant articles; this criterion ensures that only articles related to the principles of circularity in the built environment are selected, thereby eliminating redundant manuscripts in the selection process. These decisions simplified the data collection process which is derived from using 'circular* economy principles', 'built environment', 'circularity principles', 'R principle', 'reduc*', 'recyc*', 'reus*', 'recove*', 'redesign*', and 'remanufactur*' as a requirement for exclusion.

A literature search was conducted on two prominent online scientific databases: the Web of Science (WoS) core collection and Google Scholar. This strategy was adopted to ensure a vast pool of scholarly contributions to the literature search. Google Scholar was chosen based on its distinction as one of the largest repositories of peer-reviewed literature [21]. On the other hand, Web of Science was selected because of its large coverage of indexed journals with high-impact factors in the Journal Citation Report [22]. The first search was conducted on the WoS database on August 2, 2023, and on Google Scholar on August 6, 2023. A follow-up search was carried out on November 12, 2023. This ensures that articles

published in the last quarter of the year were also captured in the review. The search Boolean terms used were (“Circular Economy” OR “Circular*” OR “Circular Economy Principles” OR “R Principles”) AND (“Built Environment” OR Construction OR Building). Specifically, a filter was applied to the WoS database to include the ‘topic’ category, which encompasses the author, abstract, and keywords. However, consideration was given only to the article title, abstract, and keywords related to the criteria for selection. The results were exported as RIS and CSV files for analysis, and data were manually extracted from Google Scholar and crosschecked to ensure that appropriate data were obtained.

3. Results

The rigorous selection criteria for this study resulted in the identification of a cumulative total of 291 articles, with 226 sourced from the Web of Science and an additional 65 extracted from Google Scholar. The PRISMA guidelines incorporate a checklist and a flow diagram to succinctly outline the study selection process, including identification, screening, eligibility, and inclusion, as shown in Figure 1. The first phase of the bibliometric analysis focuses on quantifying annual publication trends within the selected literature. The examination of publication trends revealed that a modest number of 4 articles were published in 2013, and this figure experienced a gradual increase until 2016. Notably, a significant turning point occurred in 2017, marked by an exponential growth in publications related to the circular economy in the built environment. This surge reflected a threefold increase compared to publications in 2013, as indicated in Figure 2. This noticeable uptick in scholarly output aligns with the global emphasis on circularity, a trend actively embraced by numerous nations during that period [23].

Regarding the publication region, Europe emerged as the predominant contributor to the geographical distribution of publications, with approximately 61% of the publications originating from the region, as shown in Figure 3. This is not surprising considering that Europe is at the frontline in implementing circular economy principles in various sectors of the economy, justifying the abundance of articles originating from the region. Closely followed are contributions from Asia, Australia, the Americas. Africa occupies the lower end of the spectrum in terms of publication output. This delineation highlights diverse global participation in disseminating research on this subject matter, with Europe notably leading in scholarly contributions.

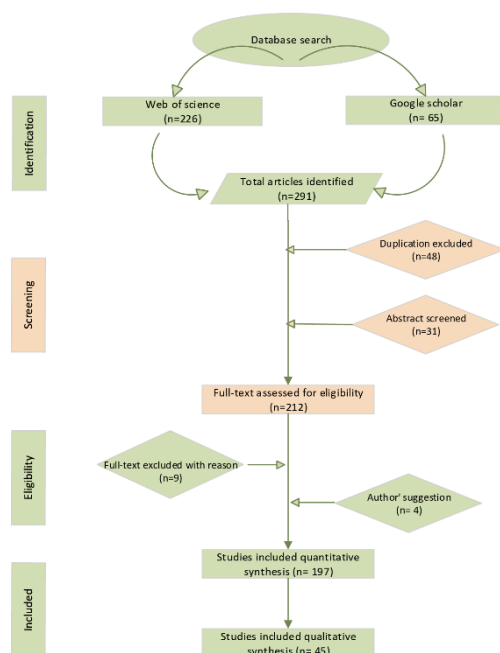


Fig. 1. Articles selection process.

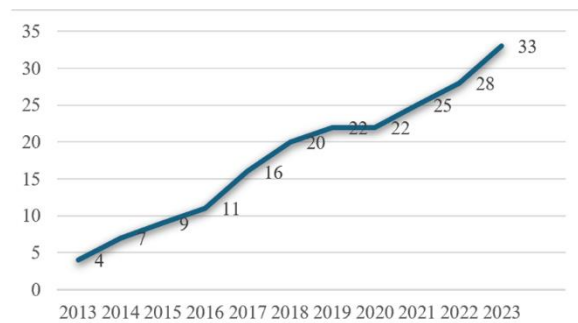


Fig. 2. Publication per year

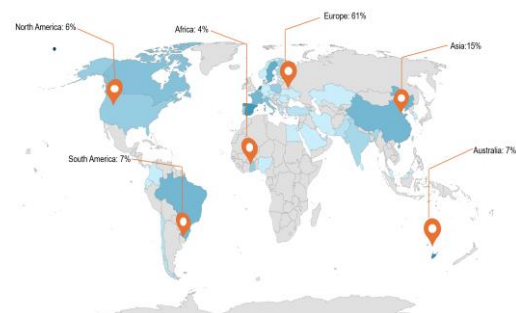


Fig. 3. Region of Publication

Furthermore, a thorough examination was conducted to assess the distribution of identified articles across various publication outlets. The findings revealed a noteworthy prevalence of articles in the "Journal of Cleaner Production," which emerged as the primary outlet and featured 16% of the articles identified. "Built Environment Project and Asset Management" and "Sustainability," followed closely behind, with 15% and 9% of the articles, respectively. The subsequent three outlets with significant article counts were "Building," "Engineering Construction and Architecture Management," and the Journal of Construction Engineering and Management.

4. Discussion of Findings

4.1. Bibliometrics Analysis

The bibliometrics analysis revealed a significant surge in studies on the circular economy within the built environment, particularly evident over the past decade. This temporal span witnessed a remarkable doubling in publications compared to the base year 2013, signifying a notable and sustained growth trajectory in scholarly contributions to CE domains. The noticeable surge in attention in this field presents a unique opportunity to convene scholars with the shared objective of advancing research in the CE within the built environment. The increasing number of publications and scholarly contributions underscores the growing significance of interest in this evolving domain. It is noteworthy that a substantial portion of these publications emanate from two distinguished journals, both classified as Q1 in the Scimago Journal Rank (SJR): the "Journal of Cleaner Production" and "Built Environment Projects and Asset Management." This observation indicates the active involvement of leading knowledge hubs in the context of built environment research. The prominence of these journals reaffirms their role as key disseminators of knowledge and catalysts in scholarly discourse, further emphasizing the centrality of the CE in shaping the future of the built environment.

4.2. Circularity Principles in The Built Environment

Within this category of articles, a body of literature is dedicated to investigating the practical application of the Circular Economy Principle within the built environment. The identified CEP encompasses a comprehensive spectrum, including reuse, reduce, remanufacturing, redesign, recycling, and recovery. This category of articles delves into the details of how these principles can be strategically employed within the built environment to extract actionable insights that can inform and enhance construction practices.

According to the review, reuse is one of the most researched principles of circularity. The literature described reuse as the most ecologically desirable strategy because it requires no energy expenditure on recycling or producing new materials or products. This research domain includes ten articles that predominantly focus on the re-utilization of materials in the construction industry. This set of articles can be further categorized into three distinct groups: Micro-, Meso-, and Macro-levels. The Micro-level category encompasses studies that have examined techniques for repurposing materials [24-25]. The Meso-level studies address the implementation of reutilization across entire buildings rather than solely focusing on specific materials or components, [e.g., [26], [27], [28]] and the Macro-level encompasses articles that investigate the reuse of materials for the built environment. For instance, Geldermans [29] examined the essential conditions that materials must satisfy for re-utilization in construction projects. Similarly, Dongez et al. [30] investigate the benefit of reutilization of building elements in a construction project to facilitate the circular transition in the built environment. The substantial number of articles in this domain provides evidence for noteworthy endeavours toward implementing reusable materials in the built environment. This observation reflects a concerted effort by diverse scholars globally, signalling the widespread recognition of the importance of incorporating CEP, particularly the adoption of reusable materials in constructing and developing built spaces.

Reduce focuses on minimizing the energy input, material usage, waste generation, and emissions of toxic gases during both the manufacturing and post-manufacturing processes [9], [31]. The category of articles in this domain underscores the observation that most of the identified practices for implementing CEP in the built environment are primarily directed toward reducing waste generated at a building's end-

of-life stage and enhancing the management of resources throughout its existence. Interestingly, these two outcomes closely parallel the ultimate objectives of Lean Construction, which seek to eliminate waste throughout the construction process and enhance the overall process efficiency. This intersection of factors promises to yield positive outcomes, rendering it a domain that merits further exploration and in-depth study in subsequent research. Given the confluence of these elements, there is a rich opportunity for scholars and researchers to delve into this realm, unravel its complexities, and contribute to a more nuanced understanding through rigorous investigation.

The literature search results revealed a limited number of studies that focused on remanufacturing concerning the built environment, with two articles credited to this domain. For instance, Kovacic et al. [32] proposed a Building Material Passport (BMP) for buildings with diverse alternatives to assess the ecological implications of concrete and timber. The authors revealed that concrete has a higher recycling potential than timber. Similarly, Munaro and Tavares [33] formulated a BMP as part of their study focusing on the wood-frame system in the Brazilian construction industry. The authors identified a challenge owing to the absence of a requirement for Environmental Product Declarations (EPDs) in the country. This underscores the necessity for manufacturers of building materials to generate EPDs for their products to establish a foundation for viable BMP creation. A constrained volume of publications within the remanufacturing domain is imperative for advancing research in this area. This suggests an existing gap or underrepresentation in scholarly discourse, emphasizing the need to boost research efforts and expand the knowledge base in this field.

Redesign is a widely discussed theme across diverse research domains, with six articles focusing on crafting tools and enhancing the understanding of the essential changes necessary to enable the seamless transition of circular economy practices during the architectural design phase. Akinade et al. [34] and Lima et al. [35] explored the integration of this principle in the early stages of the design process through collaboration with Building Information Modelling (BIM) tools. The authors remarked that the process can store various forms of information within its digital model, establishing an important instrument for integrating circular economic principles into the built environment. Kyrö et al. [36] and Suleman et al. [37] investigated the application of CE in the early design phase to facilitate the integration of redesigns in construction projects. This aspect was central to the discourse of [38] who suggested that projects adhering to CEP encompass distinct phases within the design stage, characterized by decision points and planning methodologies. This research domain stresses the need to integrate CEP during the earliest phases of construction projects. The concept involves incorporating BIM tools to assess different materials' impact on a building's reuse potential. However, redesign extends beyond incorporating BIM tools alone; it consists of designing structures for disassembly that allow more materials and components to be reused at the end of a building's lifecycle.

Much of the article is dedicated to exploring the recycling domain, encompassing approximately ten scholarly works accredited to this field. Within this body of literature, a predominant focus emerges, wherein most authors investigate methodologies for closing the material loop at the end of a building's lifecycle. The central theme revolves around the examination of sustainable practices and strategies that contribute to the circularity of materials, ensuring their continued use and minimizing waste after the building reaches the end of its operational life. The significant number of articles attributed to this domain implies that recycling is one of the most extensively researched CE principles in ongoing discourse. This observation is reinforced by the findings of [11], [39], who emphasized that recycling remains the most extensively studied practice for non-disposal methods within the built environment. However, most of the articles in this domain focused on using recycled material in a secondary loop. The review uncovered a scarcity of studies on multiple recycling loops for building materials. This underscores a critical gap the current study identified. Exploring this gap in future studies will enhance multiple recycling loops.

The systematic literature review results highlighted five studies that specifically concentrated on material recovery. These studies highlight that material recovery is significant for transitioning towards a circular building environment. This importance arises because the built environment consumes substantial quantities of natural resources, and buildings are often not designed with recovery in mind, ultimately leading to their disposal in landfills. However, to establish an effective circular building system, it is

imperative to incorporate recovery into building components through replacement and maintenance from the end of their service life. A considerable percentage of construction and demolition waste is downcycled at the end of a building's service life because of the limited awareness among practitioners, coupled with the fact that buildings are often not designed with recovery in mind. This underscores the potential of recovery to address the issue of resource scarcity within built environments. This noticeable gap in the existing body of literature highlights a significant opportunity for future material recovery in the built environment.

5. Conclusion

This study sets out to unpack the developmental research trajectory of CEP in the built environment. By adopting a PRISMA framework to conduct a literature search of relevant articles on two prominent databases, the Web of Science and Google Scholar databases, covering ten years, the study identified 45 articles for this review. The articles were selected based on a bibliometric network analysis that identified the six most frequently referenced principles of circularity related to the built environment: reuse, reduce, remanufacture, redesign, recycle, and recover. The investigation revealed that, among the principles of circularity evaluated, reuse, recycling, and reduce appear to have been extensively explored in previous studies, signifying a robust body of literature and research in these areas. However, findings also uncovered redesign, recovery, and remanufacturing as principles with less focus in the last decade, suggesting a notable gap in existing scholarly discourse. This discrepancy in research emphasis highlights an opportunity for further exploration and in-depth investigation of the under-explored principles of circularity. Addressing this gap will contribute significantly to a more comprehensive understanding of this circularity concept, its practical applications, and the potential for achieving a circularized built environment. Notably, this review solely relied on WoS and Google Scholar for literature, overlooking other relevant databases. This limitation highlights the need for future research to consider these factors while investigating similar studies.

Acknowledgments

We want to thank the Valle Scholarships and Scandinavian Program for supporting Idris Soliu in studying abroad, and we would also like to thank the Howard Wright Endowed Chair Fund for supporting his attendance at this conference.

References

- [1] R. Merli, M. Preziosi, and A. Acampora, "How do scholars approach the circular economy? A systematic literature review," *Journal of Cleaner Production*, vol. 178. Elsevier Ltd, pp. 703–722, Mar. 20, 2018. doi: 10.1016/j.jclepro.2017.12.112.
- [2] "Founding Partners of the Ellen MacArthur Foundation 2013 CIRCULAR ECONOMY TOWARDS THE Economic and business rationale for an accelerated transition."
- [3] E. Ingemarsdotter, E. Jamsin, G. Kortuem, and R. Balkenende, "Circular strategies enabled by the internet of things-a framework and analysis of current practice," *Sustainability (Switzerland)*, vol. 11, no. 20, Oct. 2019, doi: 10.3390/su11205689.
- [4] K. Demestichas and E. Daskalakis, "Information and communication technology solutions for the circular economy," *Sustainability (Switzerland)*, vol. 12, no. 18. MDPI, pp. 1–19, Sep. 02, 2020. doi: 10.3390/su12187272.
- [5] C. Luebke and A. Fellow, "The Circular Economy in the Built Environment," 2016.
- [6] S. Çetin, V. Gruis, and A. Straub, "Digitalization for a circular economy in the building industry: Multiple-case study of Dutch social housing organizations," *Resources, Conservation and Recycling Advances*, vol. 15, Nov. 2022, doi: 10.1016/j.rcradv.2022.200110.
- [7] L. Stumpf, J. P. Schöggel, and R. J. Baumgartner, "Climbing up the circularity ladder? – A mixed-methods analysis of circular economy in business practice," *J Clean Prod*, vol. 316, Sep. 2021, doi: 10.1016/j.jclepro.2021.128158.
- [8] T. Domenech and B. Bahn-Walkowiak, "Transition Towards a Resource Efficient Circular Economy in Europe: Policy Lessons From the EU and the Member States," *Ecological Economics*, vol. 155, pp. 7–19, Jan. 2019, doi: 10.1016/j.ecolecon.2017.11.001.
- [9] D. Cheshire, *Building revolutions : applying the circular economy to the built environment*.
- [10] G. Foster, "Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts," *Resour Conserv Recycl*, vol. 152, Jan. 2020, doi: 10.1016/j.resconrec.2019.104507.
- [11] P. Ghisellini, C. Cialani, and S. Ulgiati, "A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems," *J Clean Prod*, vol. 114, pp. 11–32, Feb. 2016, doi: 10.1016/j.jclepro.2015.09.007.

- [12] A. Moscati, P. Johansson, R. Kebede, A. Pula, and A. Törngren, "Information Exchange between Construction and Manufacturing Industries to Achieve Circular Economy: A Literature Review and Interviews with Swedish Experts," *Buildings*, vol. 13, no. 3, Mar. 2023, doi: 10.3390/buildings13030633.
- [13] P. N. Kio, C. J. Anumba, and A. K. Ali, "Circular Economy Trends - Potential Role of Emerging Technologies," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics, 2022. doi: 10.1088/1755-1315/1101/6/062005.
- [14] N. G. Akhimien, E. Latif, and S. S. Hou, "Application of circular economy principles in buildings: A systematic review," *Journal of Building Engineering*, vol. 38. Elsevier Ltd, Jun. 01, 2021. doi: 10.1016/j.jobe.2020.102041.
- [15] M. R. Munaro and S. F. Tavares, "A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective," *Cleaner and Responsible Consumption*, vol. 8, Mar. 2023, doi: 10.1016/j.clrc.2023.100107.
- [16] F. Pomponi and A. Moncaster, "Circular economy for the built environment: A research framework," *J Clean Prod*, vol. 143, pp. 710–718, Feb. 2017, doi: 10.1016/j.jclepro.2016.12.055.
- [17] P. Rosa, C. Sassanelli, A. Urbinati, D. Chiaroni, and S. Terzi, "Assessing relations between Circular Economy and Industry 4.0: a systematic literature review," *Int J Prod Res*, vol. 58, no. 6, pp. 1662–1687, Mar. 2020, doi: 10.1080/00207543.2019.1680896.
- [18] G. L. F. Benachio, M. do C. D. Freitas, and S. F. Tavares, "Circular economy in the construction industry: A systematic literature review," *Journal of Cleaner Production*, vol. 260. Elsevier Ltd, Jul. 01, 2020. doi: 10.1016/j.jclepro.2020.121046.
- [19] 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*, vol. 392, Mar. 2023, doi: 10.1016/j.jclepro.2023.136201.
- [20] T. A. D. K. Jayasanka, A. Darko, D. J. Edwards, A. P. C. Chan, and F. Jalaei, "Automating building environmental assessment: A systematic review and future research directions," *Environ Impact Assess Rev*, vol. 106, p. 107465, May 2024, doi: 10.1016/j.eiar.2024.107465.
- [21] N. Machado and S. N. Morioka, "Contributions of modularity to the circular economy: A systematic review of literature," *Journal of Building Engineering*, vol. 44. Elsevier Ltd, Dec. 01, 2021. doi: 10.1016/j.jobe.2021.103322.
- [22] E. Cagno, A. Neri, M. Negri, C. A. Bassani, T. Lampertico, and A. Carvalho, "The Role of Digital Technologies in Operationalizing the Circular Economy Transition: A Systematic Literature Review," 2021, doi: 10.3390/app11.
- [23] R. Medaglia, B. Rukanova, and Z. Zhang, "Digital government and the circular economy transition: An analytical framework and a research agenda," *Gov Inf Q*, vol. 41, no. 1, p. 101904, Mar. 2024, doi: 10.1016/j.giq.2023.101904.
- [24] K. Anastasiades, J. Blom, M. Buyle, and A. Audenaert, "Translating the circular economy to bridge construction: Lessons learnt from a critical literature review," *Renewable and Sustainable Energy Reviews*, vol. 117. Elsevier Ltd, Jan. 01, 2020. doi: 10.1016/j.rser.2019.109522.
- [25] B. Sanchez and C. Haas, "A novel selective disassembly sequence planning method for adaptive reuse of buildings," *J Clean Prod*, vol. 183, pp. 998–1010, May 2018, doi: 10.1016/j.jclepro.2018.02.201.
- [26] M. Barreiro-Gen and R. Lozano, "How circular is the circular economy? Analysing the implementation of circular economy in organisations," *Bus Strategy Environ*, vol. 29, no. 8, pp. 3484–3494, Dec. 2020, doi: 10.1002/bse.2590.
- [27] H. S. Kristensen and M. A. Mosgaard, "A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability?," *Journal of Cleaner Production*, vol. 243. Elsevier Ltd, Jan. 10, 2020. doi: 10.1016/j.jclepro.2019.118531.
- [28] G. C. Nobre and E. Tavares, "The quest for a circular economy final definition: A scientific perspective," *J Clean Prod*, vol. 314, Sep. 2021, doi: 10.1016/j.jclepro.2021.127973.
- [29] R. J. Geldermans, "Design for Change and Circularity - Accommodating Circular Material & Product Flows in Construction," in *Energy Procedia*, Elsevier Ltd, 2016, pp. 301–311. doi: 10.1016/j.egypro.2016.09.153.
- [30] N. Dongez, K. Manisa, and S. Basdogan, "Tendency to Circular Economy: Reuse of Architectural Elements," *Enquiry*, vol. 18, no. 2, pp. 73–93, 2021, doi: 10.17831/enqarcc.v18i2.1089.
- [31] I. S. Jawahir and R. Bradley, "Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing," in *Procedia CIRP*, Elsevier B.V., 2016, pp. 103–108. doi: 10.1016/j.procir.2016.01.067.
- [32] I. Kovacic, M. Honic, and M. Sreckovic, "Digital Platform for Circular Economy in AEC Industry," 2020.
- [33] M. R. Munaro, S. F. Tavares, and L. Bragança, "Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment," *Journal of Cleaner Production*, vol. 260. Elsevier Ltd, Jul. 01, 2020. doi: 10.1016/j.jclepro.2020.121134.
- [34] O. Akinade *et al.*, "Design for deconstruction using a circular economy approach: barriers and strategies for improvement," *Production Planning and Control*, vol. 31, no. 10, pp. 829–840, Jul. 2020, doi: 10.1080/09537287.2019.1695006.
- [35] P. R. B. de Lima, C. de S. Rodrigues, and J. M. Post, "Integration of BIM and design for deconstruction to improve circular economy of buildings," *Journal of Building Engineering*, vol. 80, Dec. 2023, doi: 10.1016/j.jobe.2023.108015.
- [36] R. Kyrö, T. Jylhä, and A. Peltokorpi, "Embodying circularity through usable relocatable modular buildings," *Facilities*, vol. 37, no. 1–2, pp. 75–90, Jan. 2019, doi: 10.1108/F-12-2017-0129.
- [37] T. Suleman, I. Ezema, and P. Aderonmu, "Challenges of circular design adoption in the Nigerian built environment: An empirical study," *Clean Eng Technol*, vol. 17, Dec. 2023, doi: 10.1016/j.clet.2023.100686.
- [38] B. Sanchez, C. Rausch, and C. Haas, "Deconstruction programming for adaptive reuse of buildings," *Autom Constr*, vol. 107, Nov. 2019, doi: 10.1016/j.autcon.2019.102921.
- [39] W. Lu, Z. Peng, C. Webster, and L. Wu, "Developing a construction waste material 'passport' for cross-jurisdictional trading," *J Clean Prod*, vol. 414, Aug. 2023, doi: 10.1016/j.jclepro.2023.137509.