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BUILDINGS DESIGNED FOR SYSTEMIC CIRCULARITY: A COMPREHENSIVE REVIEW OF METHODOLOGICAL TAXONOMIES

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ABSTRACT

Circular economy (CE) principles have been appraised as the requisite approach to enhance buildings and construction process to achieve sustainable development. Hence, architects and other construction professionals have been urged to adopt the CE principles in design thinking, supply chain systems, production, operation, and end-of-life activities of buildings. However, as much as CE principles could be seen subjectively to benefit the environment, it is incumbent to determine and document this empirically to propel its seamless adoption and enforcement. Therefore, extant studies have proposed several methods, metrics, and indicators to assess the environmental impact, recovery, technical, cost, systems, and recyclability potentials of buildings designed for total circularity. Nonetheless, the complexity of CE requires that such assessment should consider the integration of different methods that should be able to assess the different dimensions of the lifecycle of a circularly designed building. In this study, a thorough systematic review was conducted to explore the existing means of measurement and propose a comprehensive methodological approach for assessing buildings designed for systemic circularity. The proposed approach should enhance CE methodological development and guide construction professionals and building designers in the effective adoption of CE principles throughout building lifecycles to attain sustainable development.

Keywords: *Circular Economy; Design for Systemic Circularity; Indicators; Methods; Systematic Review.*

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1. INTRODUCTION

The fate of most existing building structures at their end-of-life have been predetermined for landfill due to adopted construction process. The traditional construction process follows a take-make-dispose design thinking approach whereby buildings are not designed with reusability of parts or materials in mind (Hossain et al., 2020). This approach has led to the exorbitant building and demolition waste which the construction industry is currently facing. To circumvent this approach and reduce the negative effects of building across its lifecycle, a new design thinking which embeds circularity and sustainable principles should be upheld (Ellen MacArthur Foundation, 2015; Antwi-Afari et al., 2023).

Extant studies have shaped the direction of contemporary building design thinking to incorporate key sustainable and circularity principles such as adaptability, manufacturability, assembly, reusability, systemic circularity, flexibility, and cost among others (c.f., Moraga et al., 2019; Attia & Al-Obaidy., 2021; De Silva et al., 2023). Hence, there has been an influx of new design strategies and models which helps construction stakeholders to target the sustainability agenda. However, how to evaluate the extent of systemic circularity of a building or component designed through these design thinking approaches needs to be identified. Systemic circularity encompasses the assessment of buildings entire production system and goes beyond the sustainable principles adopted within the design, manufacturing and construction process. Thus, it includes the adopted business models, system conditions and reverse cycles together with the key performance indicators under each of these building blocks (Antwi-Afari, 2023).

To assess buildings designed with sustainable or circular thinking, this study conducted a systematic review of extant literature to identify the existing methods, tools, metrics or indicators. The current study differs from existing review studies (c.f, Antwi-Afari et al., 2022; Oluleye et al., 2023) because of the broad perspective of not limiting the literature search to only one or few sustainability indicators, also, different methods and metrics as far as they fall within the scope of the study were considered in the study. To this end, this study was conducted to evaluate the intellectual core and key methods needed to evaluate buildings design for systemic circularity. The rest of the manuscript is as follows: the next section provides details on the methods adopted for reviewing extant literature. The key findings of the methods, metrics, indicators or tools for assessing buildings' systemic circularity is also presented. Then the discussion of these methods and conclusions and further research sections are also shown.

2. METHODOLOGY

This study adopted a critical review approach to carefully analyse all the extant literature. Based on different review methods in Grant and Booth (2009)'s studies, critical reviews help researchers to identify discrepancies in existing literature and resolve ideas by finding solution rather than merely highlighting gaps. A four-stage approach was used to conduct this critical review. To obtain the papers used for the study, a detailed advanced search was conducted in Scopus with relevant words such as methods, metrics, indicators and building construction and limited to the last decade.

The search string "circular metrics" OR "Circularity Indicator" OR "metric" OR "circular methods" OR "sustainable metrics" OR "Circularity Assessment" AND "building construction". Scopus was chosen as the preferred database because it has a wide range of reach and a powerful data control and quality analytical tools (Oteng et al., 2021). A total of 143 documents were retrieved from the advanced search. Further analysis of the abstract, keywords and the title of the documents led to 99 obtained papers used in the critical review analysis. A thorough content review was done to cut down the papers even further for the content analysis. This led to the use of 17 articles which were considered as appropriate and detailed enough for such purposes. The overall 99 retrieved papers were also classified across predefined criteria such as scope, document type, year, materials used, citation count, and methods adopted.

The 17 articles selected for content analysis were then reviewed and their key findings concerning methods, metrics, indicators and tools for assessing buildings design for systemic circularity were identified and presented. Based on the in-depth content analysis, the key methods, tools, metrics, and indicators for evaluating buildings systemic circularity were discussed and a comprehensive methodological approach which could be adopted to enhance buildings systemic circularity were formulated based on extant literature.

3. FINDINGS

The year trends of the selected documents revealed that majority of the articles on methods for assessing the circularity of buildings were published in 2023 with more than two-thirds published after 2020 (Fig. 1). This matches the influx and popularity which circular economy (CE) was obtaining during and after the Covid-19 era. The need to rethink existing systems, achieve resilience and enhance innovation in the construction industry (CI) post-pandemic era increases the attention of researchers considering how to measure the improvements made to the circularity of buildings along its lifecycles.

The cited sources citation shows that of the selected documents, at least 23 received 0-20 number of citations on average. While more than 50 articles received more thana 20 citations but less than 41 citations. Hence on average, we can infer from the analysis that at least more than half of CE metrics, methods or measurement studies in the last decade had at least receive 40 citations. This shows the influence, relevance and impact of this research to the built environment and the scientific community. Hence, a more important reason to continue to research in this area to push the frontiers of knowledge in the key methods for assessing building circularity to reduce poor measurement and gauge the improvement done in building circularity correctly.

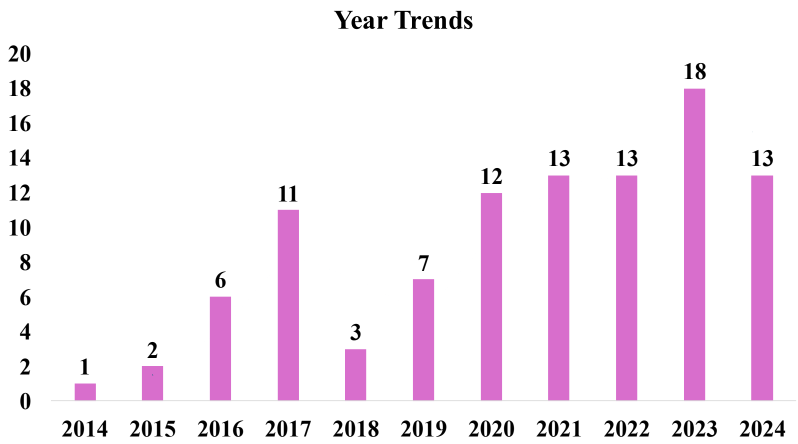

Figure 1: Year trends of CE methods for assessing buildings circularity

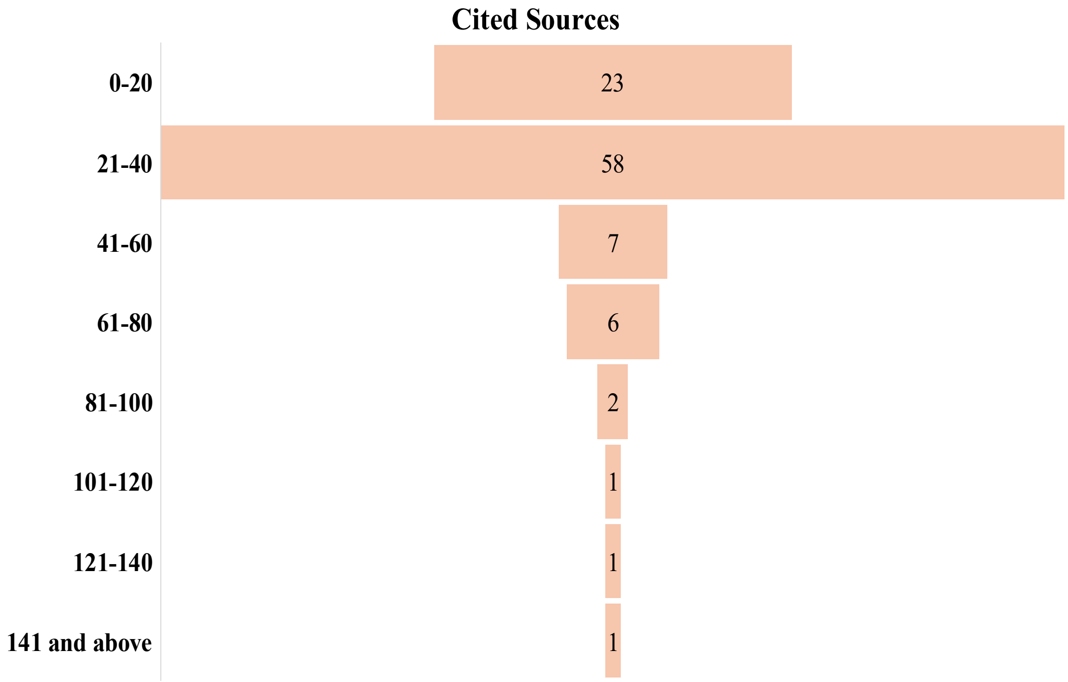

Figure 2: Cited source co-citation of selected articles

The selected documents used for the study were mainly peer-reviewed published journal articles from Scopus. This formed about 77% of the total number of articles with about 14% being peer-reviewed conferences. Since this study was looking at methods used for assessing building circularity, the key focus was on analytical articles with few very good review articles considered which formed about 6% of the selected articles. Book chapters were only 3% of the selected articles for this study.

The scope of selected articles helped to identify the focus of these articles. It was seen that most of the articles on CE measurement for building circularity looked at the materials level. Thus, concrete, steel, plastics etc. which formed 28.28% of all the selected articles. Case-specific articles were mainly studies which looked at different case scenarios of materials, buildings or projects. This formed 21.21% of all the selected articles. Component level such as slabs, floors, roofs etc. formed 13.13% of all the articles used in the critical review while 7.07% and 5.05% of the articles were focused on national or corporate level looking at circularity of buildings from business models and policies impact on decision making.

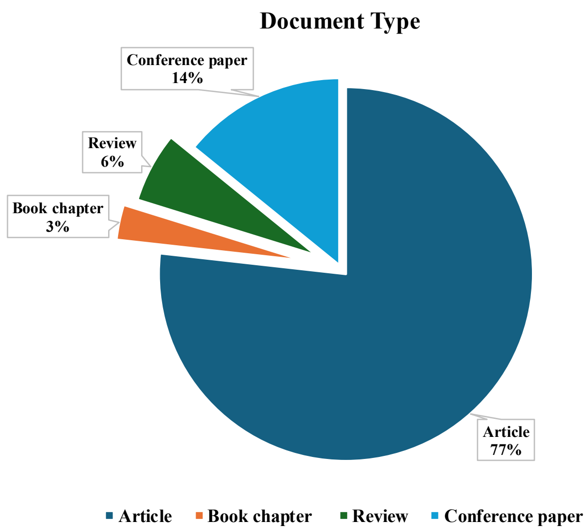

Figure 3: Document types of selected articles

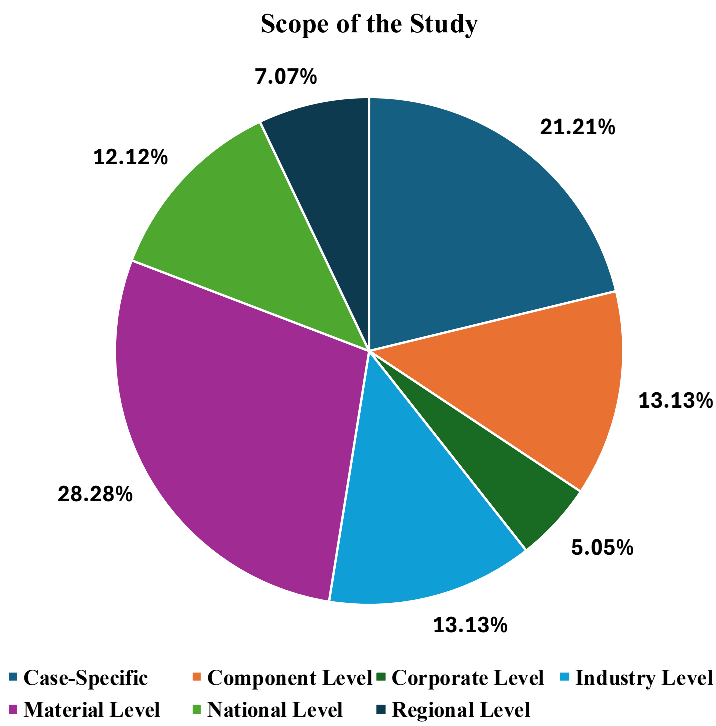

Figure 4: Scope of selected articles

The next analysis of the review was to consider the materials used for the analysis. About nine of the studies did not specify any kind of materials or did not provide any material usage details at all. These were mainly corporate or policy related studies which focused on improving existing building business models to be circular. Eight of the articles focused on wood and its derivates such as cross laminated timber, sawn timber, glue laminated timber and their usage for kitchen modules or other parts of buildings. Different kinds of materials were all considered in the extant literature. For example, steel (nine studies), concrete (nine studies), Paper (three studies), composite materials which encompass a reinforced concrete, engineered wood products and fibre-reinforced polymers among others formed about 12 of the selected articles. Also, about nine of the studies looked at waste during construction and demolition of circular buildings and how the circularity at that phase is measured.

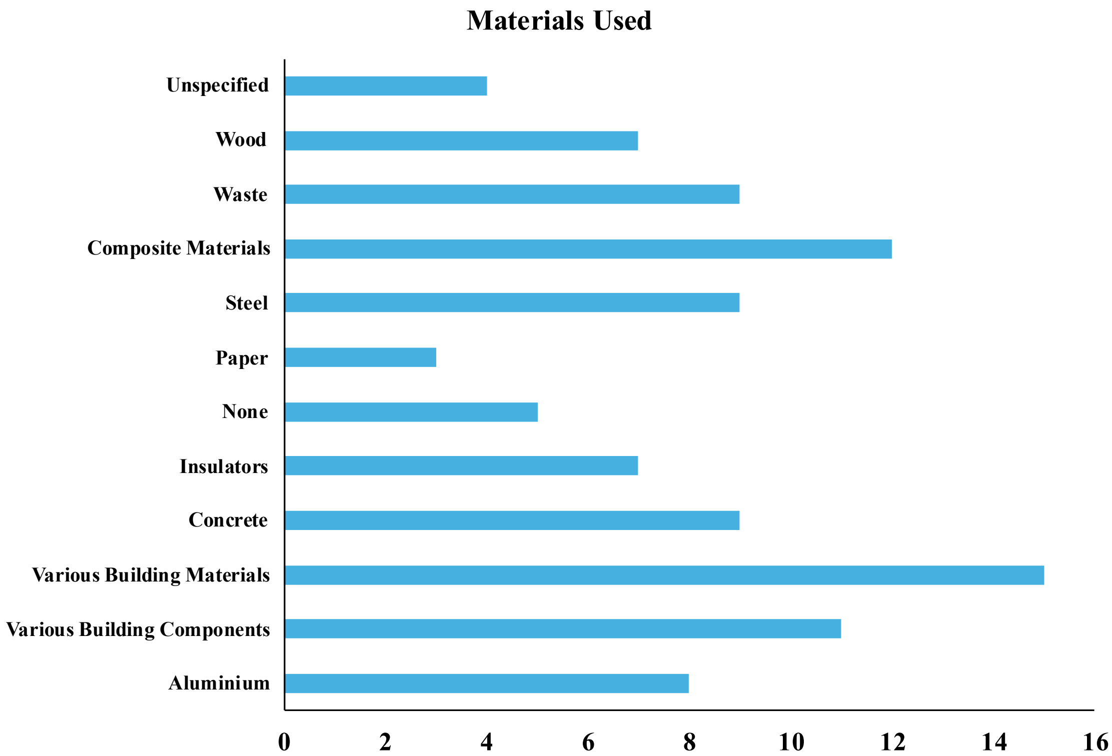

Figure 5: Materials assessed in the methods of selected articles

The last analysis in this section was to evaluate the methods adopted in extant literature for measuring the circularity of buildings. Aside from review articles which used document analysis (about five studies), the rest of the articles used some kind of method to assess the impact of materials along the environment, social, economic, technical, and systems dimensions. Most studies used only one type of method for analysis. For instance, lifecycle assessment (LCA) only was used to determine the embodied carbon impacts of materials, while building information modelling (BIM), LCA and multi-criteria decision-making methods (MCDM) were used to assess the decision-making models of circular designed buildings among others. The use of different methods enabled extant studies to evaluate the sustainability and circularity of different materials, decisions, processes and strategies of circularly designed buildings, materials, components and design guidelines for CE attainment in buildings.

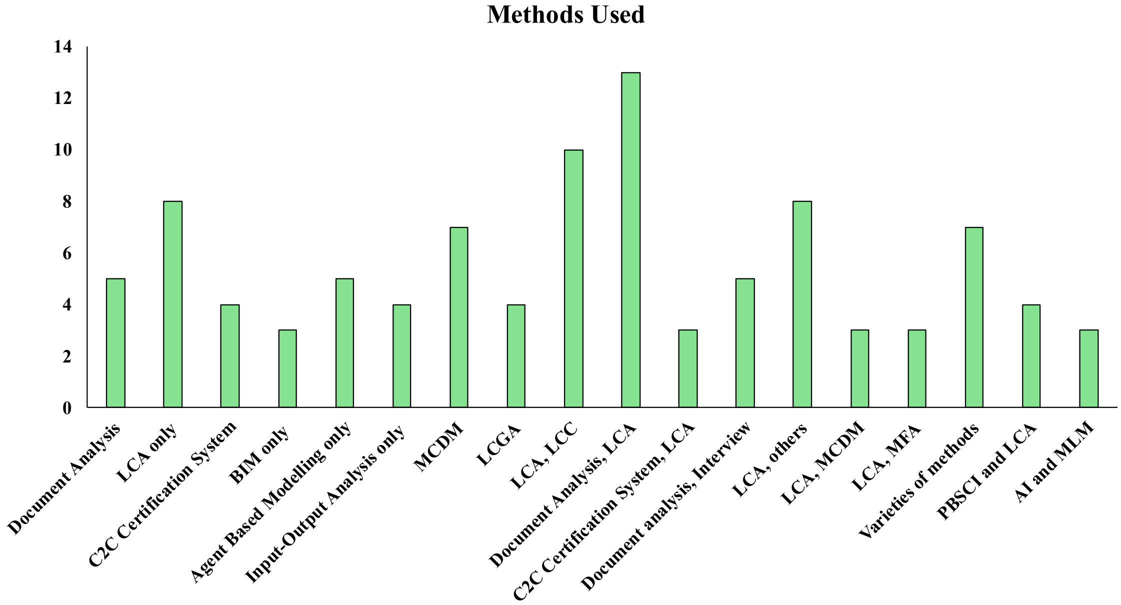

Figure 6: Methods used in the selected articles

4. DISCUSSIONS AND IMPLICATIONS

Different methods, metrics, and indicators have been adopted in extant literature to assess the circularity potentials of activities involved the in the lifecycle of building construction or circularly designed buildings. In this study, the key 17 articles used for content analysis were evaluated and the adopted methods, metrics and indicators used classified across the environmental, social, economic, technical, business and legislative dimensions.

4.1 ENVIRONMENTAL DIMENSIONS

To assess the environmental impacts of materials, processes or buildings designed to attain circularity, extant literatures have used indicators such as waste intensity indicators, longevity indicators, water intensity indicators, embodied carbon, embodied energy, resource output rate and resource duration indicators for environmental impact assessments (Franklin-Johnson et al., 2016; Romnee et al., 2019). Other methods such as LCA which look at assessing the environmental impact of materials across different midpoint and endpoint categories have been used to evaluate the environmental impact of plastic waste and end-of-life waste management (Hossain et al., 2021). To make decisions concerning circular buildings, Carvalho et al. (2021) used LCA and other methods to quantify the highest environmental impact performance among several different scenarios. LCA was also used together with input-output analysis to assess the cradle to grave embodied carbon and embodied energy of residential buildings designed to attain sustainability. The adoption of a hybrid form of LCA provided an improved means of quantifying buildings' material emissions (Zhan et al., 2018).

4.2 ECONOMIC DIMENSIONS

To assess the economic impact of buildings or materials designed for circularity, extant studies such as Magrini et al. (2021) and Malabi et al. (2021) adopted life cycle costing, material flow cost accounting, net present value, cost benefit analysis and life cycle sustainability assessment to assess circular waste and circular building components.

Indicators mostly used in examining the economic impacts of circularly designed buildings or materials includes investment cost indicator, cost of energy consumption, cost substitutive goods, sustainability financial incentives, transportation cost among others. Braakman (2019) adopted lifecycle cost (LCC) to assess the building circularity levels of a standard one-family house using design-oriented scenarios. The usage of LCC showed that increasing circularity of these buildings may not have substantial effect on its lifecycle cost, but as circularity increases, the LCC increases to almost double the initial cost. This provided an array to gauge circularity improvements to cost-effects of attaining circularity in buildings. Jansen et al. (2020) also proposed a circular economy LCC model for building components which helped to provide decisions on the most economic, but circular kitchen module to adopt taking into consideration product lifespan, interest rates and expected value retention percentages of the module.

4.3 SOCIAL DIMENSIONS

To evaluate the social dimensions of buildings designed for circularity, extant studies have used several indicators such as social fairness of building designs, health and safety during construction and stakeholder awareness among others as some of the key indicators. (c.f., Braungart et al., 2007; Toxopeus et al., 2015). Key methods or metrics adopted to measure the social aspects of circularity measurements include managerial indicators, organizational indicators, social circularity indicators, social life cycle assessment and cradle to cradle (C2C) assessment (c.f., Niero et al., 2017; Antwi-Afari et al., 2022). Fatourehchi & Zarghami (2020) adopted a social sustainability assessment framework to include social indicators in the measurement of sustainable residential buildings in Iran. The study identified that some key determinants of meeting the social aspects of a sustainable or circular building includes workplace health and safety, performance and flexibility at the workplace.

4.4 TECHNICAL DIMENSIONS

When assessing the technical dimensions of products designed for circularity, extant studies such as Geldermans (2016) Adams et al. (2017) and Alamarew et al. (2020) have proposed or used indicators such as material separability rate, usage level of recycled products, viable take back schemes, technological indicators and technical feasibility for examining the technical aspects of circularly designed materials or buildings. For metrics or methods, disassembly time and cost, end-of-life indices and predictive building circularity indicator (PBCI) have been used. For instance, Geldermans (2016) argued that to embrace full circularity measurement, technical, temporal, and social implications need to be calculated together with the economic and social impacts in formulating decisions.

4.5 BUSINESS DIMENSIONS

Circularity measurement encompasses consideration of the requisite business model enacted to enhance the reusability of building’s materials or components across several lifecycles. Hence, measuring the circularity potentials of a product should include the business dimensions as well. Thus, whether the product (materials or building) has a reusability/recyclability plan and a circular business model to enhance its usage during the first cycle and reusability in subsequent lifecycles. Indicators such as supply chain indicators, and methods such as Agent Based modelling, system dynamics, multi-criteria decision-making methods among others have been proposed in extant literature to be considering some of the business dimensions of CE measurement (c.f., Adams et al., 2017; Alamerew et al., 2020; Rossi et al., 2020).

4.6 LEGISLATIVE DIMENSIONS

To achieve systemic (total) circularity, a circularly designed product should also exhibit some key legislative dimensions such as responsible communication, meeting the required standards and performance solutions/minimum criteria of quality. Indicators such as strategy and policy indicators and methods such system dynamics, multi-criteria decision-making methods among others have been identified in extant literature to help in the evaluation of the legislative dimension of circularity (Magrini et al., 2021).

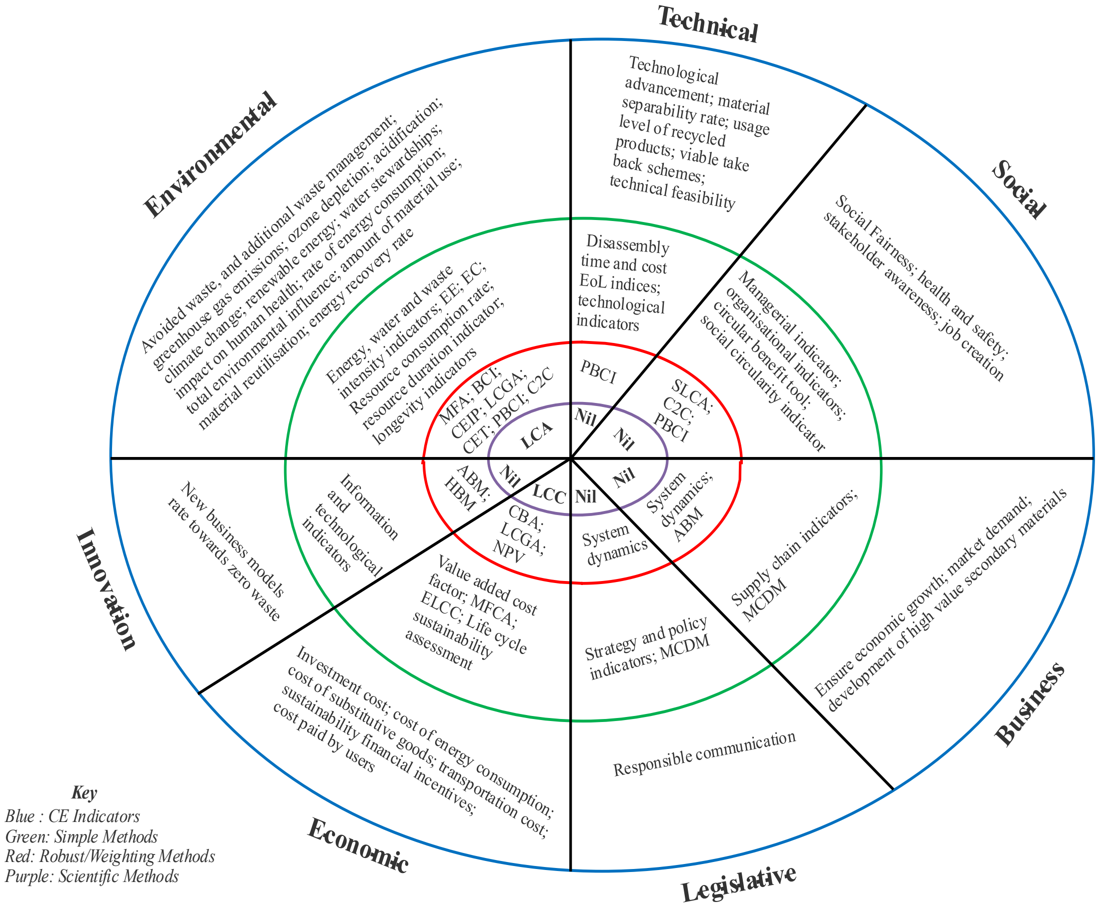

Fig. 7. Indicators, methods and metrics for circularity assessment. Adapted from Antwi-Afari et al. (2022)

4.7 AN INTEGRATED METHOD FOR ASSESSING BUILDING'S CIRCULARITY

To assess that a building or material has attain a total/systemic circularity, different impact dimensions should be evaluated such as the building's environmental, social, economic, business, technical, innovation and legislative dimensions. However, deducing from existing methods (Fig. 7) shows that none of the methods alone would be enough to assess the key dimensions of building's circularity. For example, LCA can give a clear indication of the building's environmental impact but its usage for assessing technical, cost and social dimensions is limited. LCC can also help in the economic quantification of different materials but its usage for environmental impact and social impact is constrained. Multi-Criteria Decision-making methods could be used to evaluate some business and legislative aspects of product lifecycle systems, but its usage for environmental or economic impact assessment is inadequate.

Since total circularity of buildings will not only consider its environmental, economic or social impacts, but also its technical, systems and legislative considerations of the product lifecycle, there is the need to develop a robust assessment tool which will consider the requisite dimensions for a detailed assessment of the building's circularity. However, there is a problem with methods compatibility when integrating them as such some must still be assessed separately and infused into the integrated method calculation along the process or considered during the final decision-making process. This study proposes that, LCA, C2C and PBCI should be integrated into a methodological framework by combining their system boundaries, strength and indicators to assess the environmental, social, technical, business and legislative dimensions of circularly designed buildings.

To propose this integrated framework, LCA midpoint and endpoint indicators should be merged with that of C2C indicators and strengthened with an improved PBCI calculation to reduce the limitations of circularity assessments. Therefore, with LCA-C2C-PBSCI method, assessing the systemic circularity of buildings would consider the environmental, technical, social, business, legislation and innovation dimensions. Economic impacts could be added to the decision-making process using LCC or other economic impact indicators/methods and MCDM could also be used to help in the selection of the optimal circular scenario based on the assessed examples.

5. CONCLUSIONS

Assessing systemic circularity in building construction is critical for advancing sustainable practices and effectively integrating circular economy principles into the construction sector. Although numerous methods exist to evaluate circularity, a comprehensive, integrated approach that addresses multiple dimensions simultaneously remains underexplored. Existing research primarily focuses on isolated dimensions such as environmental impacts or economic assessments, neglecting a holistic view necessary for systemic circularity. Addressing this gap, the current study systematically reviewed existing methods, metrics, indicators, and tools utilized across environmental, economic, social, technical, business, and legislative dimensions.

A critical review methodology was adopted, analysing selected literature from the Scopus database. After rigorous screening, 17 relevant studies were subjected to detailed content analysis to identify prevalent methods and indicators. Key findings reveal that predominant methodologies employed include LCA, LCC, MCDM, C2C, and PBCI. Indicators commonly applied include embodied carbon, resource efficiency, cost-benefit analyses, social fairness, material separability, supply chain considerations, and policy compliance.

These findings highlight the fragmented but complementary nature of current approaches. To overcome the identified fragmentation and enhance practical circularity assessments, this study proposes an integrated methodological framework combining LCA, C2C, and PBCI (LCA-C2C-PBSCI). This framework merges environmental, technical, social, business, and legislative dimensions, enabling stakeholders to make informed, multidimensional decisions regarding building circularity. Practically, adopting this integrated approach can significantly streamline evaluations, promote consistent practices, and facilitate broader implementation of circular principles in the construction industry.

Nevertheless, this study has limitations. The restriction of the literature search to the Scopus database potentially excludes relevant research indexed elsewhere. Additionally, the relatively small sample size may limit generalizability, and the broad scope adopted could overlook detailed nuances within specific dimensions. Future research directions should address these limitations by expanding database searches and validating the proposed integrated framework through empirical studies and practical case applications across various contexts. Developing standardized sets of indicators and tools is also recommended to facilitate comparability and consistency. Further exploration of underrepresented dimensions such as social and legislative aspects will enhance the holistic understanding and effectiveness of systemic circularity assessments.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017, February). Circular economy in construction: Current awareness, challenges and enablers. In Proceedings of the institution of civil engineers-Waste and resource management (Vol. 170, No. 1, pp. 15-24). Thomas Telford Ltd. https://doi.org/10.1680/jwarm.16.00011

Alamerew, Y. A., Kambanou, M. L., Sakao, T., & Brissaud, D. (2020). A multi-criteria evaluation method of product-level circularity strategies. Sustainability, 12(12), 5129. https://doi.org/10.3390/su12125129

Antwi-afari, P. (2023). Developing a best practice model for attaining systemic circularity in product system design in the construction industry. [Doctoral dissertation, The University of Hong Kong]. HKU Theses Online. https://hub.hku.hk/handle/10722/332180

Antwi-Afari, P., Ng, S. T., & Chen, J. (2022). Developing an integrative method and design guidelines for achieving systemic circularity in the construction industry. Journal of Cleaner Production, 354, 131752. https://doi.org/10.1016/j.jclepro.2022.131752

Antwi-Afari, P., Ng, S. T., Chen, J., Oluleye, B. I., Antwi-Afari, M. F., & Ababio, B. K. (2023). Enhancing life cycle assessment for circular economy measurement of different case scenarios of modular steel slab. Building and Environment, 239, 110411. https://doi.org/10.1016/j.buildenv.2023.110411

Attia, S., & Al-Obaidy, M. (2021, March). Design criteria for circular buildings. In Crossing boundaries. https://hdl.handle.net/2268/258348

Braakman, L. (2019). Assessing life cycle costs over increasing building circularity levels [Master's thesis, University of Twente]. UT-Thesis Repository. https://essay.utwente.nl/79183/

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: Creating healthy emissions–a strategy for eco-effective product and system design. Journal of cleaner production, 15(13-14), 1337-1348. https://doi.org/10.1016/j.jclepro.2006.08.003

Carvalho, J. P., Villaschi, F. S., & Bragança, L. (2021). Assessing life cycle environmental and economic impacts of building construction solutions with BIM. Sustainability, 13(16), 8914. https://doi.org/10.3390/su13168914

De Silva, S., Samarakoon, S. S. M., & Haq, M. A. A. (2023). Use of circular economy practices during the renovation of old buildings in developing countries. Sustainable Futures, 6, 100135. https://doi.org/10.1016/j.sftr.2023.100135

Ellen MacArthur Foundation. (2015). Towards a circular economy: Business rationale for an accelerated transition. https://content.ellenmacarthurfoundation.org/m/4384c08da576329c/original/Towards-a-circular-economy-Business-rationale-for-an-accelerated-transition.pdf

Fatourehchi, D., & Zarghami, E. (2020). Social sustainability assessment framework for managing sustainable construction in residential buildings. Journal of Building Engineering, 32, 101761. https://doi.org/10.1016/j.jobe.2020.101761

Franklin-Johnson, E., Figge, F., & Canning, L. (2016). Resource duration as a managerial indicator for Circular Economy performance. Journal of Cleaner Production, 133, 589-598. https://doi.org/10.1016/j.jclepro.2016.05.023

Geldermans, R. J. (2016). Design for change and circularity–Accommodating circular material & product flows in construction. Energy procedia, 96, 301-311. https://doi.org/10.1016/j.egypro.2016.09.153

Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. Health Information & Libraries Journal, 26(2), 91-108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Hossain, M. U., Ng, S. T., Antwi-Afari, P., & Amor, B. (2020). Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. Renewable and Sustainable Energy Reviews, 130, 109948. https://doi.org/10.1016/j.rser.2020.109948

Hossain, M. U., Ng, S. T., Dong, Y., & Amor, B. (2021). Strategies for mitigating plastic wastes management problem: A lifecycle assessment study in Hong Kong. Waste management, 131, 412-422. https://doi.org/10.1016/j.wasman.2021.06.030

Jansen, B. W., van Stijn, A., Gruis, V., & van Bortel, G. (2020). A circular economy life cycle costing model (CE-LCC) for building components. Resources, Conservation and Recycling, 161, 104857. https://doi.org/10.1016/j.resconrec.2020.104857

Magrini, C., Degli Esposti, A., De Marco, E., & Bonoli, A. (2021). A framework for sustainability assessment and prioritisation of urban waste prevention measures. Science of the Total Environment, 776, 145773. https://doi.org/10.1016/j.scitotenv.2021.145773

Malabi E. L. C., van Stijn, A., Kristensen S. L., Birkved, M., & Birgisdottir, H. (2021). Environmental design guidelines for circular building components: The case of the circular building structure. Sustainability, 13(10), 5621. https://doi.org/10.3390/su13105621

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., De Meester, S., & Dewulf, J. (2019). Circular economy indicators: What do they measure?. Resources, Conservation and Recycling, 146, 452-461. https://doi.org/10.1016/j.resconrec.2019.03.045

Niero, M., Hauschild, M. Z., Hoffmeyer, S. B., & Olsen, S. I. (2017). Combining eco-efficiency and eco-effectiveness for continuous loop beverage packaging systems: Lessons from the Carlsberg Circular Community. Journal of Industrial Ecology, 21(3), 742-753. https://doi.org/10.1111/jiec.12554

Oluleye, B. I., Chan, D. W., & Antwi-Afari, P. (2023). Adopting Artificial Intelligence for enhancing the implementation of systemic circularity in the construction industry: A critical review. Sustainable Production and Consumption, 35, 509-524. https://doi.org/10.1016/j.spc.2022.12.002

Oteng, D., Zuo, J., & Sharifi, E. (2021). A scientometric review of trends in solar photovoltaic waste management research. Solar Energy, 224, 545-562. https://doi.org/10.1016/j.solener.2021.06.036

Romnée, A., Vandervaeren, C., Breda, O., & De Temmerman, N. (2019, February). A greenhouse that reduces greenhouse effect: how to create a circular activity with construction waste?. In IOP Conference Series: Earth and Environmental Science (Vol. 225, p. 012035). IOP Publishing. https://doi.org/10.1088/1755-1315/225/1/012035

Rossi, E., Bertassini, A. C., Ferreira, C.D.S., do Amaral, W. A. N., & Ometto, A. R. (2020). Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases. Journal of Cleaner Production, 247, 119137. https://doi.org/10.1016/j.jclepro.2019.119137

Toxopeus, M. E., De Koeijer, B. L. A., & Meij, A. G. G. H. (2015). Cradle to cradle: Effective vision vs. efficient practice?. Procedia CIRP, 29, 384-389. https://doi.org/10.1016/j.procir.2015.02.068

Zhan, J., Liu, W., Wu, F., Li, Z., & Wang, C. (2018). Life cycle energy consumption and greenhouse gas emissions of urban residential buildings in Guangzhou city. Journal of cleaner production, 194, 318-326. https://doi.org/10.1016/j.jclepro.2018.05.124