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Circular Economy Principle Review: From Barriers to Assessment in Construction Projects

Zahraa Saleh Jawad *, **Meervat R. Altaie**

Department of Civil Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq

ABSTRACT

The construction industry is a major contributor to resource depletion, environmental degradation, waste production, and greenhouse emissions, which makes it necessary to adopt alternative development models. The Circular Economy (CE) has become one of the potential strategies of resource conservation, waste reduction, and environmental equilibrium restoration. This paper aims to provide a systematic literature review of the CE principles by analyzing research papers and articles in scientific journals and some university theses, encompassing the R-Principles (Reduce, Recycle, Reuse, Refuse, Rethink, Repair, Repurpose, Remanufacture, And Recovery), together with principles related to design and production, use and consumption, management and policies, as well as innovation and technology principles. Moreover, examines barriers to the implementation of CE and indicators of assessment. The results show that the adoption of CE in the construction industry is multidimensional and comprises eight broad categories, namely: Political, Economic and Market, Social and Cultural, Technical, Technological, Informational, Administrative, and Environmental Barriers. In addition, the review highlights fragmentation and inconsistency in existing circularity indicators across economic, environmental, and social dimensions. Collectively, the analyzed literature indicates that even though a variety of principles of a Circular Economy can be found, there is still a limited implementation due to the ongoing structural barriers and disjointed approaches to evaluation. The literature review identifies a recurring discrepancy between the theory of the Circular Economy and its practical implementation in the construction industry.

Keywords: Circular economy, Circular principles, Barrier, Indicators, R-Principles.

1. INTRODUCTION

The construction industry is the largest consumer of natural resources globally, consuming approximately 50% of total resource consumption and 36% of global energy use; furthermore, contributing nearly 40% of global carbon emissions **(Núñez-Cacho et al., 2018; Firoozi and Firoozi, 2022; Ahmed, 2023)**. Due to the adoption of traditional linear

*Corresponding author
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economic models based on extraction, production, consumption, and disposal, which have intensified resource depletion, waste generation, and greenhouse gas emissions **(Guerra and Leite, 2021; Zhao et al., 2025)**. As a result, global sustainability initiatives have been subject to increasing scrutiny and ongoing monitoring in recent times in this sector **(Mfon and Bassey, 2023)**. By preserving resources within closed-loop supply chains, CE principles prioritize waste reduction, material reuse, emission mitigation, and the regeneration of natural systems **(Ghufran et al., 2022; Hegedűs and Longauer, 2023).** This leads to the Circular Economy (CE) becoming a practical and creative substitute for the linear economic model in the construction industry **(Hossain et al. 2020)**. According to **(Gamage et al., 2024)** these principles can be used along all phases of a construction project, from planning, design, construction, operation, maintenance, and end-of-life phase, this promotes sustainable development outcomes by separating economic growth from resource consumption, additionally CE improve social and economic value **(Rahla et al., 2021; Liu et al., 2021),** as shown in **Fig. 1**.

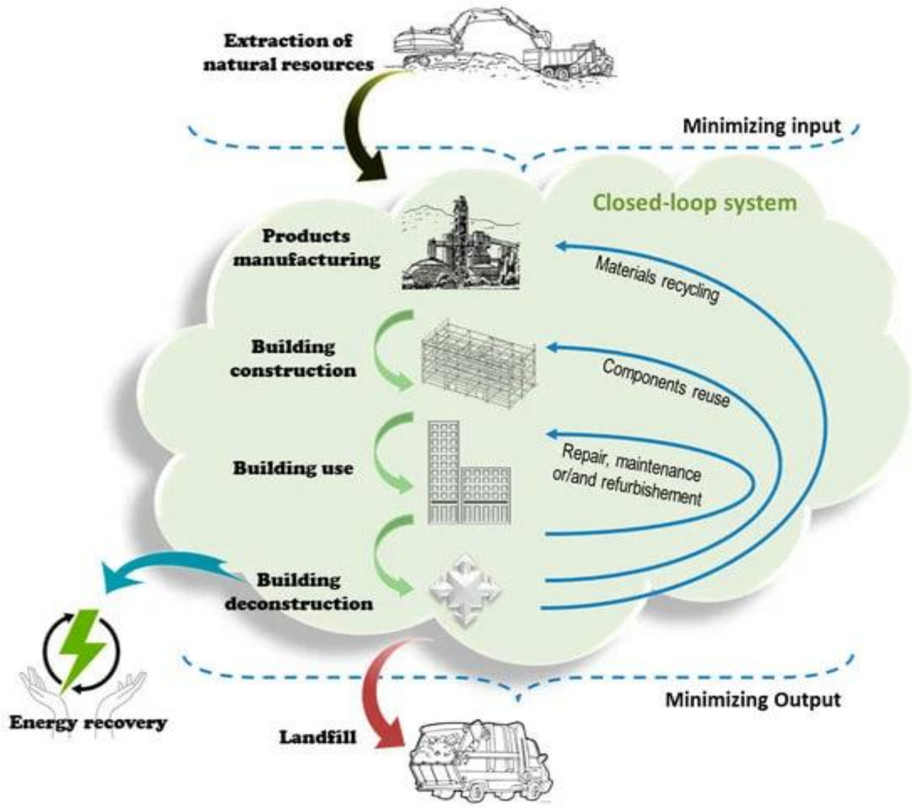

Figure 1. Closed Construction Loops **(Rahla et al., 2021).**

Although circular construction is receiving more attention recently, implementation remains slow due to industry resistance to change, limited digital transformation, and persistent technical and institutional barriers **(Wuni, 2022; Ababio and Lu, 2023; Thirumal et al., 2024; Sheen, 2025)**. In parallel, **(Jayakodi et al., 2024)** observed that systematic adoption is constrained by the lack of comprehensive frameworks to assess environmental, economic, and social circular performance. As a result, this study adopts a systematic literature review of Circular Economy principles, implementation barriers, and evaluation indicators in construction projects. Even though influenced by regional contextual variations, the assessment offers a comprehensive viewpoint and suggests avenues for further investigation.

2. CONCEPTUAL FOUNDATIONS OF THE CIRCULAR ECONOMY (CE)

Before the 1990s, the Circular Economy (CE) was known as a "Closed-Loop Economy" that challenged the dominant linear paradigm of extraction, production, use, and disposal **(Tuladhar et al., 2022).** The paradigm has since expanded to include resource management, systemic planning, and societal well-being **(Murray et al., 2017)**. According to **(Kirchherr et al., 2017)**, CE is an economic system that is based on business models that replace the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production, distribution, and consumption processes. To achieve sustainable development, which entails fostering social justice, economic prosperity, and environmental quality for the benefit of present and future generations, it operates at the macro level (city, region, nation, and beyond), meso level (eco-industrial parks), and micro level (products, businesses, consumers). Additionally, the Ellen MacArthur Foundation, which described CE as an economic system intended to minimize resource depletion, extend the lifespan of materials and components, and maximize value recovery across the supply chain, gave the concept international traction in the early 2000s **(Gong and Whelton, 2019)**.

3. METHODOLOGY

This paper applies the systematic literature review methodology to generalize the knowledge regarding the principles of CE, barriers to its implementation, and parameters to evaluate it in the construction sector. A significant amount of peer-reviewed literature was gathered from well-known databases such as Google Scholar, Web of Science, and Scopus; some university theses were also consulted. In addition, some sources were obtained from the university library by using specific keywords such as (Circular Economy, Circular projects, Circular Cities, Waste and demolition management, energy efficiency in construction projects, Circular Economy framework, etc.). To describe the current trends, the review concentrated on the literature published in the years 2015-2025, with selected literature published in the past years being used to provide a conceptual background. The chosen articles were sorted into three analytical categories, which were principles of the CE, barriers to its implementation, and indicators of its evaluation. A thematic analysis was conducted to integrate similar findings and identify recurring patterns in the literature as shown in **Fig. 2**. Selected global examples reported in previous studies were included to illustrate how circular economy concepts have been discussed in real-world contexts.

Figure 2. Systematic Review Methodology.

4. CIRCULAR ECONOMY PRINCIPLES

The principles of the Circular Economy (CE) are the basis for achieving the goal and vision of sustainability **(Walker et al., 2022)**. Implementing these principles is a necessary step toward moving away from the traditional linear economy, which relies on the model of extraction, then manufacturing, followed by demolition and waste **(Chennak et al., 2024; Gamage et al., 2024)**. **Fig. 3** illustrates how CE principles can be integrated throughout the building life cycle **(Bajare et al., 2025)**. It highlights how the stages of design, construction, operation, refurbishment, and demolition can all collaborate to support resource efficiency, waste reduction, and value retention in the built environment. The CE principles drawn from literature and compiled into this closed loop create an interlinked network, where the effectiveness of one relies on the others.

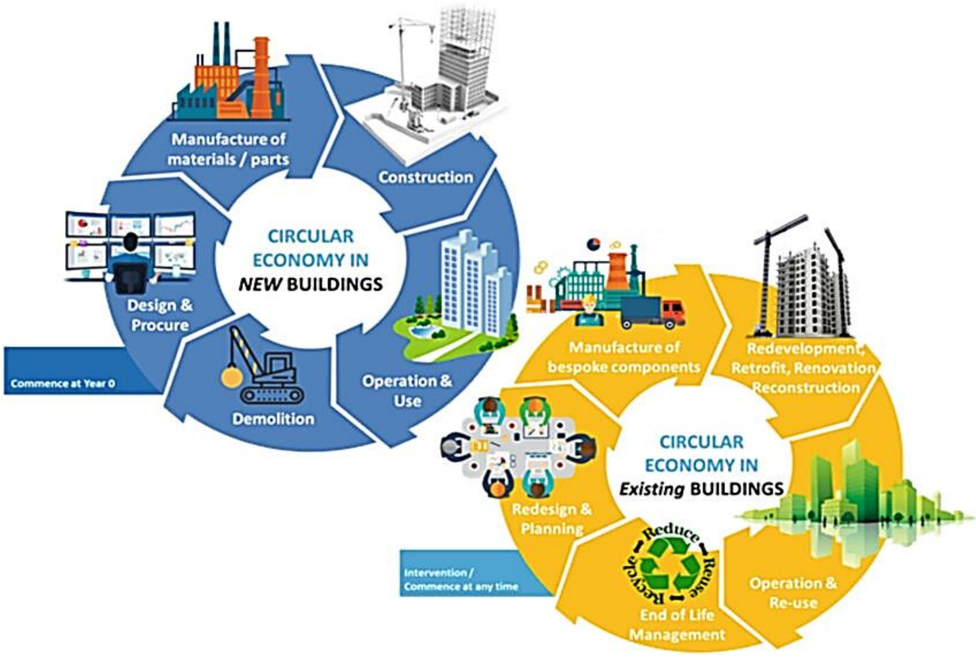

Figure 3. Circular Economy Principles. **(Bajare et al., 2025)**

To provide a clear analytical framework and minimize conceptual overlap, the researcher-developed taxonomy takes into consideration the interconnected and mutually reinforcing interactions between the suggested groups. Five CE principles (R-Principles, Design and Production, Consumption and Use, Management and Policy, as well as Innovation and Technology principles) are considered the key to attaining circularity in construction projects.

4.1 R-Principles

The R-principles represent the central foundation of the Circular Economy. It aims to change the relationship between resource consumption and the natural environment beyond recycling or waste reduction alone, and to promote long-term sustainability. The literature shows many different practices as presented in **Table 1**; it is evident that circular initiatives always emphasize a core set of behaviors that are effective in advancing the circular economy and are realistically accessible.

According to **(Abdolmaleki et al., 2025)**, reduce, reuse, recycle, and recover are the most commonly described CE practices. Moreover, some research endeavors have emphasized practices that are not as prevalent, including repair, remanufacture, refuse, and rethinking and repurposing **(Garusinghe et al., 2023)**. However, by adopting these specialized approaches, the CE can be achieved in construction projects and ensure the sustainability of buildings and their services.

Table 1. R- Principles from the Literature Review

No.	Principles	Definiens	References
1	Reduce	Aims to reduce the environmental, economic, and social impacts of construction operations and demolition waste, and reduce material demand and waste generation.	**(Tomaszewska, 2020; Rahla et al., 2021; Guerra et al., 2021; Shooshtarian et al., 2022; Abdul et al., 2022; Hauashdh et al., 2022; Ogunmakinde et al., 2022; Purchase et al., 2022; Garusinghe et al., 2023; Munaro and John, 2024; Abdolmaleki et al., 2025)**
2	Recycle	It aims to recycle construction and demolition waste materials and reintroduce them into the construction supply chain as an alternative to raw materials.	**(Guerra and Leite, 2021; Medina and Fu, 2021; Rahla et al., 2021; Abdul et al., 2022; Purchase et al., 2022; Garusinghe et al., 2023; Abdolmaleki et al., 2025; Balasbaneh et al., 2025)**
3	Reuse	It aims to reuse building components and parts that require little or no processing, to reduce construction costs, reduce pollution and material waste, and support the circular economy.	**(Gaballo et al., 2021; Medina and Fu, 2021; Abdul et al., 2022; Purchase et al., 2022; Garusinghe et al., 2023; Munaro et al., 2024; Abdolmaleki et al., 2025)**
4	Refuse	A methodology for changing traditional practices aims to reject designs, practices, and construction processes that lead to waste and pollution and replace them with practices that support the circular economy.	**(Rahla et al., 2021; Garusinghe et al., 2023)**
5	Rethinking	It aims to reshape construction and consumption practices in line with the concept of a circular economy, such as adopting a new construction approach and renting instead of owning.	**(Rahla et al., 2021; Garusinghe et al., 2023)**
6	Repair/ Refurbish	It aims to improve the use of resources and buildings through continuous maintenance and extending the lifespan of buildings, thus reducing the need for new buildings.	**(Gaballo et al., 2021; Medina and Fu, 2021; Rahla et al., 2021; Garusinghe et al., 2023)**
7	Repurposing	It aims to reuse buildings and vacant spaces without the need for treatment, which helps avoid demolition and increased waste.	**(Rahla et al., 2021; Garusinghe et al., 2023)**
8	Remanufacture	Reincorporate materials or components that require minor processing into new building components.	**(Rahla et al., 2021; Garusinghe et al., 2023; Gough et al., 2024)**
9	Recovery	Refers to material, carbon, and energy recovery from construction waste.	**(Rahla et al., 2021; Abdul et al., 2022; Purchase et al., 2022; Mandi, 2023; Garusinghe et al., 2023; Munaro et al., 2024; Abdolmaleki et al., 2025)**

4.2 Design and Production Principles

Design Circularity refers to selecting simple designs and materials that allow for reuse **(Kamas et al., 2019)**, ease of maintenance and use, with the ability to be improved and revised **(Machado and Morioka, 2021)** extends the building's lifespan by utilizing modern technologies and materials that promote environmental sustainability **(Rajab and Breesam, 2025)**, and reduces waste **(Rao et al., 2025)**, and carbon footprint **(Andabaka, 2024)**, significantly impacting the social, economic, and environmental aspects of the building **(Babbitt et al., 2021)**. Circular design concepts are fragmented in the literature, but they can be summarized in two basic principles: Design for Deconstruction (DFD) and Design for Adaptation (DFA). These are the umbrella terms for all others, such as design for flexibility, design for sustainability, design for change, design without waste, and design for recycling and reuse **(Andabaka, 2024; Figueirôa et al., 2024)**, and modular design **(Monetti, 2025)**. In addition, circular design should consider water and energy efficiency throughout the building's life cycle **(Rahla et al., 2021)**, and also includes the reincorporation of recycled materials into the design, considering the safety of use **(Rani et al., 2025; Shooshtarian et al., 2025)**. Furthermore, utilize alternative and sustainable building materials like wood **(Abdolmaleki et al., 2025; Passarelli, 2024)**, mushrooms **(Barta et al., 2024; Gough et al., 2024)**, or bio-concrete **(Araujo et al., 2025)**, and use non-toxic and environmentally safe materials **(Johansson et al., 2020)**. Although literature showed that the most common practice is designed for deconstruction, most studies have examined these practices from a theoretical perspective rather than from practical application. Furthermore, most of these practices have focused on technical and engineering aspects and neglected social and economic aspects, where user acceptance and the market value of recycled materials play a fundamental role in implementing circular design.

4.3 Consumption and Use Principles

Consumption and use principles are a strategic model of maximizing resource efficiency throughout the building life cycle by preserving values, extending lifespan, and minimizing waste **(Munaro and John, 2024)**, and keeping materials within a closed cycle **(Ghufran et al., 2022)**. In addition, considering products as services rather than ownership, such as renting lighting and lamps instead of owning them. This encourages the producer to produce sustainable products with lower maintenance costs, and also contributes to reducing economic costs and waste for the consumer **(Lingegård, 2020)**. In addition leasing equipment and facilities promotes shared consumption and reduces waste in materials and energy **(Henriques et al., 2023)**. However, CE research has predominantly focused on design and production innovations, but the dynamics of use and consumption have gotten very little attention, especially those that focus on product-as-a-service models. Studies often overlook customer behavior, sharing culture, and decreasing consumption. This emphasizes how crucial it is to address consumer involvement in circularity, making this gap crucial.

4.4 Management and Policy Principles

The fundamental pillar for CE practices in construction projects is the legislative principles. They consist of the legal and institutional framework for implementing circular practices at both the international and local levels. Therefore, transform the construction sector from a traditional linear model to a circular model through laws, legislation, administrative oversight of implementation, and legal accountability for violations and negligence. through integrating forward and reverse flows to minimize waste and enhance recycling. These principles support the development of more efficient circular designs, thereby contributing to the achievement of Sustainable Development Goals (SDGs) **(Butt et al., 2024)**. In addition, utilizing public facilities, such as waste companies, to support the circular economy **(Karaca and Tleuken, 2024)**, and promoting industrial integration **(Yu et al., 2021)** among stakeholders through collaborative networks and digital platforms to reduce consumption, recycling, and resource use **(Cecchin et al., 2020)**, and incorporating the CE philosophy into construction project management **(Obradović et al., 2024)**. Moreover, transforming cities into environmentally and economically renewable and adaptive systems, encouraging urban living laboratories, and establishing an appropriate setting for testing and putting circular practices and solutions into practice **(Appendino et al., 2021; Benedetti et al., 2022)**. These principles are predominantly theoretical and lack practical mechanisms, standardized indicators, or governance frameworks. It needs more attention to transform principles into workable plans that take into account regional circumstances.

4.5 Innovation and Technology Principles

In the construction industry, innovation and technology integration are thought to be the main forces behind the CE. They provide practical tools and mechanisms that facilitate CE practices and move them from theory to application. Combined with scientific innovations, social and behavioral change make the Implementation of CE in the construction sector feasible **(Borrero and Yousafzai, 2025; Suchek et al., 2021)**. Adopting robotics and artificial intelligence **(Youssouf and Berghout, 2025)** in all stages of construction for more accurate planning and implementation, to reduce resource waste **(Ghobadi and Sepasgozar, 2025)**. Moreover, applying digital simulations **(Pehlken et al., 2024; Chen and Huang, 2020)** and digital product passports **(Langley et al., 2023)** can improve product lifecycles and predict resource loss before it occurs. Furthermore, using modern construction technologies, such as 3D printing, can reduce material loss **(Khan et al., 2023)**, and establishing digital platforms for exchanging information and resources between companies and individuals **(Wan, 2025)**. As shown, applying these principles can contribute to reducing the negative environmental, social, and economic impacts of the construction industry. Furthermore, these techniques open up new growth prospects and make the industry more resilient, enabling it to keep up with other global sectors and be sustainable.

5. BARRIERS OF THE CIRCULAR ECONOMY IN CONSTRUCTION PROJECTS

CE practices are referred to in various ways in literature, such as principles, strategies, approaches, or aspects. This led to their actual application being constrained by a lack of standardization and inconsistent terminology in the existing literature, even though circular practices are crucial for guiding the construction sector toward a circular economy. **(Gamage et al., 2024)** refers to the need for uniform terminology for more effective implementation.

In addition, the literature showed transition from a linear to CE faces many barriers and difficulties. These vary according to the project type and its location. However, they often appear in recurrent patterns. **(Gasparri et al., 2023)** identified seven categories of CE barriers, namely economic, environmental, technological, social, governmental, methodological, and sectoral. Similarly, **(Munaro and Tavares, 2023)** classified it into five main categories, including economic, informational, institutional, political, and technological factors, and highlighted the key stakeholders associated with each category. Likewise, **(Charef et al., 2021)** categorized them into six dimensions: regulatory, economic, technical, social, political, and environmental. In the same context, five major groups by **(Ababio and Lu, 2023)** encompass conceptual and theoretical misunderstandings, political and legislative barriers, social and cultural barriers, financial and economic constraints, and technological challenges. While **(Thirumal et al., 2024)** classified barriers into nine areas: organizational, infrastructure, regulatory, standardization, investment, nature of the construction industry, technological, stakeholder, and data-related barriers. These classifications vary in terms of the number of categories and labeling, but taken as a whole, they reveal that legislative and policy constraints, economic and market-related issues, socio-cultural factors, technical and technological limitations, and conceptual or knowledge-related gaps consistently underpin CE challenges. Rather than a fundamental dispute on the nature of the barriers, this diversity in classification reflects disparities in research breadth, sectoral focus, and geographic setting. For a more comprehensive comprehension of the nature of the barriers impeding the circular economy's implementation, this study grouped and categorized the barriers identified in the literature into eight main categories, as described below:

5.1 Political Barriers

One of the biggest barriers to the construction industry's embrace of the CE is political and regulatory. The shift to CE will necessitate the binding of government legislation to use circular materials and methods **(Pedroso and Tavares 2024)**. Nevertheless, the current policies are all rather fragmented and focus more on recycling and waste management than on offering a fully integrated approach that incorporates the full-circle principles **(Giorgi et al., 2022; Purchase et al., 2022)**. Lack of national waste policies, political reluctance, and insufficient financial incentives also serve as additional deterrents forcing businesses and investors to practice circularity **(Debrah et al., 2022; AlJaber et al., 2023)**. Other obstacles are insufficient funding mechanisms for recycled materials, the absence of official statistics on reusable resources, the absence of governmental control, and the lack of legislative support for the digital transformation **(Munaro and Tavares, 2023; Santos et al., 2024; Pedroso and Tavares, 2024)**. This discrepancy between fragmented political regulations and practical realities underscores the urgent need for cohesive governance structures, legally binding legislation, and incentive programs that support constructive circular transformation in the construction industry.

5.2 Economic and Market Barriers

It is considered the second most significant barrier to implementing CE principles in construction projects. Substantial initial costs are associated with circular practices, such as investments in sustainable design, obtaining certifications **(AlJaber et al., 2023; Munaro and Tavares, 2023; Pedroso and Tavares, 2024; Santos et al., 2024)**. Another barriers stems from the accessibility and low costs of traditional raw materials, which decreases the economic motivation to use recycled resources **(Charef et al., 2021; Munaro and Tavares,**

2023), this subsequently makes it challenging to create a competitive market for recycled materials due to the considerable financial burdens associated with dismantling, separating, processing, and transporting construction and demolition waste **(Charef et al., 2021; Mignacca and Locatelli, 2021; AlJaber et al., 2023; Munaro and Tavares, 2023)**, along with the absence of demonstration projects that highlight the advantages of CE **(Tavares and Pedroso, 2024)**, uncertainty about the economic viability and financial returns of CE practices **(Pedroso and Tavares, 2024)**, and the absence of clear economic benefits over traditional methods **(Charef et al., 2021; Pedroso and Tavares, 2024)**, and due to the elevated operational and maintenance expenses **(Munaro and Tavares, 2023)**, the increasing costs associated with technologies for recycled materials **(Munaro and Tavares, 2023)** in addition, market instability and the varying lifecycles of buildings, confidence in recycled materials diminishes **(Sun et al., 2025)**, therefore focuses on short-term profits **(Charef et al., 2021)**.

5.3 Social and Cultural Barriers

One of the most elongated barriers to the application of the principles of the CE to construction projects is the barriers associated with the socio-cultural issues. According to **(AlJaber et al., 2023)**, there has been no community acceptance of the recycled building materials, and this has led to less expansion of recycled building materials in the market, along with less credibility due to the misconceptions that surround building materials in terms of safety, durability, and quality. Moreover, the general population lacks knowledge about the benefits and significance of circular construction methods because of the lack of educational and awareness campaigns and the absence of expertise in the sphere of CE **(Debrah et al., 2022; Omer et al., 2025).** Moreover, easier acceptance of traditional forms of building practices and cultural reluctance to adopt new ones, thus resulting in the inadmissibility of circular materials **(Charef et al., 2021; Scipioni et al., 2021; Ababio and Lu, 2023)**. Consequently, the views of the stakeholders, their level of knowledge, and the acceptance of the techniques of the CE in the construction industry are highly influenced by sociocultural problems.

5.4 Technical Barriers

According to **(Babbitt et al., 2021; AlJaber et al., 2023)**, most of the current constructions were not initially planned to be deconstructed or reused, and this created a problem with circular end-of-life practices. In addition, the complexity of architectural and structural systems, non-detachable joints, and the use of multi-material composites make dismantling and material recovery especially challenging **(Charef et al., 2021; AlJaber et al., 2023).** The unique designs, long lifecycles of buildings, and the frequent changes throughout the life cycle of a building complicate reuse strategy **(Charef et al., 2021)**. In addition, component recovery is limited because of poor and inadequate maintenance **(Mignacca and Locatelli, 2021)**. Moreover, there is a lack of qualified personnel and expertise in CE practices **(Charef et al., 2021; Debrah et al., 2022)**. Contamination of buildings, such as chemicals, dangerous materials, war damage, and pollution from Inadequate waste management**,** led to a lower value of the materials **(Charef et al., 2021; Mignacca and Locatelli, 2021; AlJaber et al., 2023; Sagan and Mach, 2025)** and reduced their potential for reuse. As stated by **(AlJaber et al., 2023),** a lack of storage space, constraints on building sites, complicated and dispersed nature of supply chains, inadequate facilities for recovery **(Charef et al., 2021; Smol et al., 2021)**, as well as the absence of standardized indicators for assessing material circularity **(Morel et al., 2021),** raise the risks associated with deconstruction and complicate the circular transition. Addressing these gaps requires a comprehensive framework and practical pathway that are urgently needed to support companies of all scales and locations to overcome these issues and reduce uncertainty in CE implementation **(Purchase et al., 2022)**.

5.5 Technological Barriers

Although with global progress in digitization, artificial intelligence (AI), and 3D printing, a considerable gap remains in the use of these tools for circular construction practices. Furthermore, waste reduction and resource efficiency are supported by digital technology and analytical assessment techniques like Building Information Modeling (BIM) and Life Cycle Assessment (LCA). However, their wider deployment is limited by high prices, a lack of interoperability, and a lack of application expertise **(Hasibuan et al., 2025).** According to **(Tavares and Pedroso, 2024),** the majority of public and private governments and businesses lack the necessary technology infrastructure and integrated digital platforms to monitor structures over their whole life, from design to demolition and reuse. **(Santos et al., 2024)** referred to incorporating CE principles into projects and supply chains, which is made more challenging by the lack of reliable information management systems and material exchange platforms among stakeholders. Because of antiquated recycling technology **(Ghufran et al., 2022; Purchase et al., 2022),** the usage of reclaimed materials lowers their importance and quality. Additionally, Insufficient innovation in bio-inspired smart materials, modular design, and remanufacturing methods **(Gasparri et al., 2023)**. These barriers show how market, legal, digital, and research limitations are interdependent and impact the adoption of circular processes.

5.6 Administrative Barriers

These barriers are a reflection of underlying issues with company administrative cultures, such as uneven data and performance frameworks, and a poor integration of CE principles such as the absence of collaborative platforms and information-sharing systems among businesses and stakeholders **(Santos et al., 2024),** which restricts the capacity to recycle materials and reintegrate them into supply chains **(AlJaber et al., 2023; Sun et al., 2025)**. In addition, the ineffectiveness of waste management staff and procedures leads to a continued dependence on conventional linear practices like demolition and disposal **(Charef et al., 2021; Debrah et al., 2022)**. Moreover, organizations do not prioritize circular initiatives, disregarding them in favor of short-term financial goals **(Klein et al., 2022).** This encourages separate efforts rather than working toward cooperative solutions, which results in poor industrial integration, fragmented long-term support, and challenges with value chain participant coordination **(Smol et al., 2021; Pedroso and Tavares, 2024)**.

5.7 Informational Barriers

(Tavares and Pedroso, 2024) identify that the lack of efficiency in the data management system, together with poor data quality, availability, and data documentation of building

materials, also makes informed decision-making and lifecycle assessment very difficult. Additionally, the lack of funding, practical tools, applied research, and knowledge of CE practices restricted the creation and adoption of CE initiatives, especially in developing nations **(Charef et al., 2021; Munaro and Tavares, 2023; Santos et al., 2024)**.
Along with the absence of information regarding deconstruction **(Munaro and Tavares, 2023)**, there is insufficient information sharing between stakeholders, whether through institutional cooperation channels or digital platforms, which makes it more difficult to create efficient networks for materials recycling and reuse **(Munaro and Tavares, 2023)**. As describe these barriers are made worse by the restricted availability and transparency of technical data about recycled construction components, which highlights how disjointed the current information systems are. Consequently, this fragmentation makes it more difficult to make well-informed decisions and limits the successful implementation of CE practices.

5.8 Environmental Barriers

Available literature lacks empirical data on the environmental risks of CE in construction since the environmental barriers are commonly seen as part of the bigger sustainability agenda, but not as the direct circular constraints, less attention is paid to environmental issues and is often confined to the end-of-life measures, including the management of construction and demolition waste (CDW) and reverse logistics constraints **(Charef et al., 2021)**. Such a limited perspective overlooks the role of climate instability, pollution, and dependence on non-renewable materials in undermining circular practices by reducing resource availability and raising costs **(Amoah and Smith, 2024)**. The conventional construction processes pollute materials further and make this recycling and reuse more difficult **(Atta and Bakhoum, 2024)**. Moreover, institutional and academic settings have no established environmental management programs that undermine monitoring and evaluation frameworks **(Munaro and Tavares, 2023)**. Environmental barriers should be considered in future studies as a core dimension of circular transition and focus on the mitigation and recovery process.

6. PERFORMANCE INDICATORS OF CIRCULAR ECONOMY IN CONSTRUCTION PROJECTS

Many important circularity indicators in construction projects are available in the literature. Although it has significant importance, studies have demonstrated a deficiency in these indicators and standards **(Abadi et al., 2021)**. These indicators encompass economic, environmental, and social directions to measure circularity. Nevertheless, the lack of a single global framework and the diversity of indicators make it difficult to compare results or generalize successful experiences.

6.1 Economic Indicators

Research emphasizes traditional financial measures such as Return On Investment (ROI) **(Horzela-Miś and Semrau, 2025)**, payback period, levelized power cost, Life-Cycle Cost Assessment (LCCA) **(Spreafico, 2022; Deshmukh and Yadav, 2025)**, and Cost-Benefit Analysis (CBA) **(Basile et al., 2024)**. Indicators pertaining to materials, such as the Material Circularity Indicator (MCI) and the modular buildings' end-of-life value, are also crucial **(Incelli et al., 2023; De Silva et al., 2023)**. In addition, long-term maintenance expenses are essential to maintaining circular performance **(Sofronievska et al., 2024)**. Even if there are many signs, fragmentation results from a lack of standardization and prioritization. In an integrated assessment system, effective frameworks must strike a balance between cost-effectiveness, innovation, resilience, and circularity.

6.2 Environmental Indicators

An examination of the literature shows that environmental indicators for circularity mainly focus on energy performance and carbon-related measures, like embodied energy, embodied carbon, and greenhouse gas emissions, which are the focus of most studies **(Sofronievska et al., 2024; Shanbhag and Dixit, 2025; Xu et al., 2025)**, as well as water efficiency **(González et al., 2021)**, waste minimization **(Mandičák et al., 2024)**, and the incorporation of renewable energy is comparatively less addressed **(Piñones et al., 2023).** This demonstrated how climate change mitigation and carbon neutrality goals are prioritized globally. Moreover, metrics of building performance such as thermal comfort, U-value, and indoor environmental quality are discussed in fragmentary form **(Deshmukh and Yadav, 2025).** In addition, advanced operational strategies like BIM-based management, electromobility, and preventive maintenance are surfacing **(Piñones et al., 2023).** A comprehensive assessment of circularity requires broader frameworks that include water, waste, and emissions indicators. Environmental assessments might become jumbled and overlook important facets of circularity in the constructed environment, without these harmony indicators.

6.3 Social Indicators

The social components of the evaluation of the CE are still not completely integrated and are only partially covered. Several studies focused on citizen participation and social cohesion **(Piñones et al., 2023)**. Others emphasized cooperation, CE data management, stakeholder awareness and training, and innovative business models **(Abadi and Moore, 2022)**. Additional research focused on job creation **(Bosone et al., 2021)**, user satisfaction, and quality of life **(Oberfrancová and Wollensak, 2021)**, projects added value that is both social and economic **(González et al., 2021)**. Because of the narrow range of current social indicators, scholars point to significant gaps in measuring the social dimension, ignoring crucial elements related to societal effects and human well-being.

7. CONCLUSIONS

This paper shows that the CE principles in construction projects go well beyond waste reduction and recycling; they also include design strategies, consumption models, innovation-driven methods, and governance principles. However, there is still a disparity in the acceptance and development of these principles, with some methods being widely accepted while others get little real-world attention. Additionally, the review identifies eight major groups of barriers that continue to constrain systematic implementation, alongside a fragmented landscape of circularity indicators that lack integration across environmental, economic, and social dimensions. Collectively, those findings demonstrate that the problem is not the lack of circular concepts, but the difficult task of aligning principles, institutional conditions, and measurement systems within a consistent framework. This indicates an ongoing lack of connection between theoretical and practical development and indicates

that future studies should be focused on enhancing the integration, comparability, and clarity of the assessment-based frameworks of circularity.
In addition, in this peer-reviewed academic papers were the main source of the review, and several university theses and institutional materials were also consulted. The analysis does not provide an exhaustive review of all practice-oriented papers, which might include more useful information. Additionally, the various political and geographical circumstances of the examples being studied restrict the generalizability. Cross-study comparison was also complicated by the absence of a standardized set of indicators. Finally, neither primary nor field-based research was done; instead, the study's focus was restricted to secondary literature.

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Credit Authorship Contribution Statement

Zahraa Saleh Jawad took part in the process of collecting and analyzing the relevant literature, as well as in the process of creating the initial draft of the research. Mervat R. Al-Taie provided academic supervision, final review, and guidance throughout the research paper preparation stages.

Declaration of Competing Interest

The researchers declare that they have no financial or personal conflict of interest that could influence the subject matter or results of this research.

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مراجعة مبادئ الاقتصاد الدائري: من العوائق إلى التقييم في مشاريع البناء

زهراء صالح جواد*، ميرفت الطائي

قسم الهندسة المدنية، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

يُعدّ قطاع البناء والتشييد مساهماً رئيسياً في استنزاف الموارد، وتدهور البيئة، وإنتاج النفايات، وانبعاثات غازات الاحتباس الحراري، مما يستدعي تبني نماذج تنموية بديلة. وقد أصبح الاقتصاد الدائري أحد الاستراتيجيات الواعدة للحفاظ على الموارد، والحد من النفايات، واستعادة التوازن البيئي. تسعى هذه الورقة البحثية إلى إجراء مراجعة منهجية لمفهوم الاقتصاد الدائري في قطاع البناء والتشييد. تتناول المراجعة مبادئ "التقليل، وإعادة الاستخدام، وإعادة التدوير، والرفض، وإعادة التفكير، والإصلاح، وإعادة التوظيف، وإعادة التصنيع، والاسترداد"، بالإضافة إلى المبادئ المتعلقة بالتصميم والإنتاج، والاستخدام والاستهلاك، والإدارة والسياسات، والابتكار والتكنولوجيا. كما تبحث في معوقات تطبيق الاقتصاد الدائري ومؤشرات تقييمه. تُظهر النتائج أن تبني الاقتصاد الدائري في قطاع البناء والتشييد متعدد الأبعاد، ويشمل ثماني فئات رئيسية، هي: المعوقات السياسية، والاقتصادية والسوقية، والاجتماعية والثقافية، والتقنية، والتكنولوجية، والمعلوماتية، والإدارية، والبيئية. بالإضافة إلى ذلك، يُبرز هذا الاستعراض التشتت وعدم الاتساق في مؤشرات الاقتصاد الدائري الحالية عبر الأبعاد الاقتصادية والبيئية والاجتماعية. وتشير الدراسات المُحللة مجتمعةً إلى أنه على الرغم من وجود مبادئ متنوعة للاقتصاد الدائري، إلا أن تطبيقها لا يزال محدودًا بسبب العوائق الهيكلية المستمرة واختلاف مناهج التقييم. ويُظهر التحليل وجود فجوة كبيرة بين النظرية الدائرية وتطبيقها الفعلي في قطاع البناء.

الكلمات المفتاحية: الاقتصاد الدائري، المبادئ، العوائق، مؤشرات الدائرية، مبادئ R.