A CRITICAL REVIEW ON DEFINITIONS OF CIRCULAR ECONOMY IN THE BUILT ENVIRONMENT

M.Gowsiga[1*], T. Ramachandra[1], P. Sridarran[1], N Thurairajah[2]
[1]University of Moratuwa, Moratuwa, Sri Lanka.
[2]Northumbria University, Newcastle, United Kigdom.
**Correspondence E-mail: gowsigam@uom.lk, TP: +94770703102*

Abstract: Currently, the circular economy (CE) concept is receiving encouraging attention among scholars and practitioners as a convenient solution to moving away from the linear economy concept without neglecting the goals of sustainable development. However, adaption of circular economy concept in the built environment is challenging due to its nature. In addition, the built environment plays a crucial part in this transition since it consumes a lot of resources, which results in massive waste, greenhouse gas emissions, environmental effects, and also exerts great pressure on natural resources. Although several studies reviewed the term circular economy, there is still a lack of conceptual clarity and missing an accepted definition of circular economy. Hence, this study aims to propose a definition of circular economy from the built environment perspective. A systematic literature review was carried out using Preferred Reporting Items for Systematic Reviews (PRISMA) as the analysis tool, a total of 24 papers were analysed. Rasmussen's Abstraction Hierarchy (AH) framework was used to analyse the summarised eleven definitions. The study has proposed a definition for circular economy in the built environment where CE is viewed in terms of the key questions of where, why, what, and how towards providing a clear and comprehensive understanding of the CE concept.
Keywords: Abstraction Hierarchy (AH); Built Environment; Circular Economy (CE); Definition; Literature Review; Preferred Reporting Items for Systematic Reviews (PRISMA)

1. Introduction

Globally, the demand for resources is increasing year by year, given the world's resource constraints (Smol et al., 2016). Organisation for Economic Cooperation and Development [OECD] (2018) estimated that material use per person per day will increase by 12 kg from 2011 to 2050 as living standards keep rising. The built environment contributes significantly to resource consumption and solid waste generation, which leads to the scarcity of certain prevalent materials (like steel and copper), as well as greenhouse gas emissions and other environmental impacts (Rios & Grau, 2020). Further, buildings account for almost 40% of resource use and waste production, and nearly 33% of GHG emissions globally (Bolier, 2018). Therefore, CE is crucial in the built environment to address the aforementioned effects of the industry (Benachio, et al., 2020). To strengthen this, Osobajo et al. (2020) assert that the adaption of CE in the built environment is necessary to achieve a resource-efficient society. However, it is still a theoretical concept and is yet to be fully adopted by the economy (Ellen MacArthur Foundation [EMF], 2012). Many different definitions and interpretations of the concept are available in the literature, which indicate that there is no commonly accepted definition of CE (Mangers et al., 2021). For instance, the definitions of Kirchherr et al. (2017) and Akhimien et al. (2020) indicated that CE includes only reducing, reusing, recycling, and recovering materials and do not include other R-imperatives (e.g., refuse, refurbish). Further, Benachio et al. (2020) mentioned that CE is about loops rather than R-frameworks (e.g., reduce, reuse). The micro, meso, and macro levels of the ecosystem were discussed by some authors including Kirchherr et al. (2017), Prieto-Sandoval et al. (2018), and Nobre and Tavares (2020), however other authors such as Korhonen et al. (2018) and Suarez-Eiroa et al. (2019), chose to disregard those levels. Likely, the stages of the building life cycle were covered by Benachio et al. (2020), but not by Akhimien et al. (2020). The definition of Alhawari (2021) essentially fits the organisation, etc. This results in a lack of understanding of how to efficiently adopt CE for the built environment (Eberhardt, et al., 2019). Moreover, the ambiguous understanding of the concept may lead to the ultimate collapse of the concept, or force it to remain in a deadlock due to permanent conceptual contention (Mangers et al., 2021). Hence, this study aims to investigate definitions of CE and propose a clear and comprehensive definition for CE for the built environment. The remainder of the paper is organised as follows. Section 2 discusses the study methodology while section 3 presents the literature findings, analysis, and the proposed definition of CE for the built environment. Finally, section 4 presents the conclusions of this study.

2. Research Methodology

A systematic literature review was conducted to achieve the aim of this study as it enables mapping, assessing, and synthesising literature to develop knowledge in a field (Tranfield, et al., 2003). A PICO framework is helpful to design and report a systematic review (Luijendijk, 2021) where P refers to patient or population, I refer to intervention or indicator, while C and O refer to comparison or control, and outcome respectively (Leonardo, 2018). Accordingly, the PICO framework was used to formulate the well-formulated question which is "What are the definitions available for CE in the built environment?". In addition, the wildcard characters "*" and "?" and the Boolean operators "AND" and "OR" were utilised to develop the search string. Moreover, quotation marks were used to get the exact term when searching. Finally, the final search string was developed as follows:

(built?environment OR building? OR construction? OR "building design?" OR "building operation" OR "building maintenance" OR "facilit* management" OR "building life?cycle" OR sustainability OR "sustainable development?" OR "sustainable building?" OR "adaptable design?" OR "architectural design?" OR "construction and demolition waste" OR whole?life?cycle) AND ("circular economy" OR circularity OR "circular concept") AND (definition? OR meaning? OR explanation? OR clarification? OR description?).*

The number of eligibility and exclusion criteria was determined to further refine the literature selection. Primarily, a systematic search of the scholarly literature was done using the TITLE-ABS-KEY (title, abstract, and keywords) field as the search field. Next, concerning literature types, only peer-reviewed journal articles were selected. Moreover, a period of the last 6 years has been selected (between 2016 and 2022) to ensure the contemporary nature of the research. As the research question was to explore a clear and comprehensive definition for CE, articles which focused on CE, and built environment areas were selected.

In terms of databases, Web of Science, Scopus, and Science Direct were selected for literature searches as those databases comprise high-ranking and indexed scholarly journals. In addition, Google scholar was also used to identify any other remaining articles which satisfied the research question of this study. Finally, all the records generated through the above process were imported to the Mendeley software for screening and systematic analysis.

The systematic review was directed by the PRISMA Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PRISMA is often utilised within the environmental management field. The systematic review has largely been recognised as an effective, more complete, repeatable, and less biased type of literature review that can successfully lead to evidence-based conclusions (Koutsos, et al., 2019). Accordingly, Figure 1 illustrates PRISMA 2020 flow diagram developed for this study.

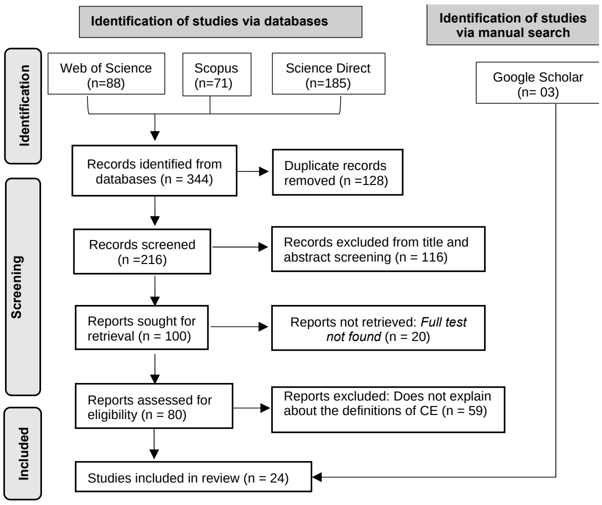

Figure 1: PRISMA flow diagram

This study adopted Rasmussen's Abstraction Hierarchy (AH) framework to examine CE definitions to propose a definition for CE in the built environment. The basic idea of an AH is to provide a stable modeling framework for complex socio-technical systems and it is useful because it can show a static, scaled perspective of a dynamic system and records the "means-ends" interactions between the different components (Jones, 2017). It is a knowledge representation-based framework and there are various advantages of using this, such as it is based on a description of the system rather than a system, and a clear partition between the system model and reasoning mechanism (Bisantz & Vicente, 1994). Although this was designed for engineering sectors, its ideas of it were widely used in various other fields too (Lind, 1999). This mean-ends AH, explains how physical resources and system operations can be organised into five layers, each of which defines the means for the next upper level and the ends that are achieved utilising objects on the level below as the means (Lind, 1999). It can be also conceptualised as "why, what, and how" connections between entities at different levels. This hierarchy enables each level to describe the work domain from a different perspective. Between adjacent levels, the middle level represents the structure of the work domain (what), while the level above explains the purpose (why) and the level below describes the means (how) (Lau, et al., 2008). The means-ends links between levels of the AH framework are shown in Table 1.

Table 1: Five Levels of AH Framework [Data extracted from Lau et al. (2008) and Patriarca et al. (2017)]

Levels of AH	Description	
Functional purpose (FP)	The intended functional effect of the system on its environment	Why?
Abstract function (AF)	The overall function of a system, which is represented by a generalised causal network, reflects the intended operational state	What? Why?
Generalised function (GF)	Generalised processes of the system that reflects the behavioural structure	How? What? Why?
Physical function (PF)	Specific processes related to sets of interacting components and their properties, which can be determined by their typical functions	How? What?
Physical form (P)	The physical description of specific objects in the system in purely physical terms	How?

3. Circular Economy Definitions from the Perspective of Built Environment

Of the 24 studies reviewed, 11 studies have proposed (or have their own) a set of revised definitions for CE, by taking into existing definitions and CE applicable contexts, principles, etc. Hence, these revised definitions were considered further in this study and details are summarised in Table 2.

Table 2: Details of the selected 11 definitions

No	Source	Perspective	Method adopted
1	Kirchherr et al (2017, p.224)	Systems perspective	Systematic analysis of 114 definitions
2	Korhonen et al. (2018, p.547).	Production and consumption system	Systematic review of 12 definitions including EMF’s
3	Prieto-Sandoval et al. (2018, p.610)	Consensus view of the basic notions	Content analysis of the CE terms - more than 12 explicit definitions
4	Suarez-Eiroa et al. (2019, p.958)	Sustainable development	68 scientific papers, several books, and reports
5	Desing et al. (2020, p.8)	Resource-based and systemic view (Normative)	First showing the development and foundations of the normative assumptions on which, it is built and then identifies the physical and environmental principles and limitations that have to be taken into account and how they translate to CE.
6	Geissdoerfer et al. (2020, p.3)	Dynamic system (Going circular)	Revisited the 114 definitions of Kirchherr et al (2017)

7	Nobre and Tavares (2021, p.10)	Single and comprehensive	6 documented definitions of CE (top 5 cited authors' documented definitions and EMF report) and the answers of 44 worldwide CE PhD-level specialists' researchers. Content analysis using a code framework was used for the analysis
8	De Angelis (2021, p.10)	Management	22 definitions of the CE were selected through a systematic review
9	Alhawari et al. (2021, p.14).	Organisational	18 well-recommended or key definitions of CE were investigated
10	Akhimien et al. (2020, p.18)	Building	Systematic review - 64 articles were analysed under the 7 strategies
11	Benachio et al. (2020, p.5)	Construction Industry	Systematic review – 45 articles and considered the building life cycle stages

The question "What is a circular economy (CE)?" does not have a straightforward answer due to the complexity of the concepts it incorporates. It is also defined in a variety of contradictory ways and it is always evolving and being redefined (Bucknall, 2020). However, these different definitions of CE share the basic concept of 'decoupling of natural resource extraction and use from the economic output, having increased resource efficiency as a major outcome" (Mavropoulos & Nilsen, 2020). Moreover, Nobre and Tavares (2021) highlighted that upon recent studies and definitions analysis, along with scientists' inputs, authors could find a common-sense definition that allows identification and separation of the definition itself (the "what") from its surrounding principles, concepts and enablers (the "how"), where it is applicable (the "where") and the purpose or reason for the action (the "why"). Therefore, the AH framework was selected as the analysis tool for this study. Table 4 summarises the answers to the questions about what each domain represents, while the level above explains why and the level below explains how for each identified CE definition. In addition, table 3 elaborates the AH framework analysis comprehensively.

Table 4: Summary of AH framework of the CE definitions

AH Levels	Description
Functional purpose (FP)	Sustainable development, resource efficiency, regenerative production-consumption, ecologically effective economic system that works within planetary limits, highest utility value for customers and society
Abstract function (AF)	Replace the 'end-of-life', longevity, effective and efficient utilisation of ecosystem, economic, and product cycles, maintains and rebuilds natural capital, zero waste and pollution throughout materials lifecycles, minimising entropy production, slow cycles
Generalised function (GF)	Easily changeable building configuration, closing loops/system for all the related resource flows, regenerating cycle, extending, intensifying, and dematerialising resource loops, applying materials cycles (reduce, alternative reuse, recycle, recovery, safe disposal), renewable and cascade-type energy flows
Physical function (PF)	Strategic programming, organisational planning processes, leaning on design and education, renewable energy and materials, innovation (business model, regulation, society legislate, policy and production & consumption system) multiple, cooperative, and simultaneous innovations and technology, digitalisation, servitisation, sharing, develop cooperation among stakeholders, long-lasting product design, repair, maintain, reuse, recycle, remanufacture, refurbish
Physical form (P)	Resources, materials, energy, product, component, natural capital, goods, and services

Table 3: The AH framework of summarised CE Definitions

	Kirchherr et al, (2017).	**Korhonen et al., (2018).**	**Prieto-Sandoval, et al., (2018)**	**Suárez-Eiroa et al., (2019).**	**Akhimien, et al., (2020)**	**Benachio, et al., (2020,)**
FP	Sustainable development (implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations)	Sustainable development	Sustainable development	Regenerative production-consumption system	Resource efficiency	Reduce the use of new natural resources
AF	Replace the 'end-of-life'	Reduce the linear material and energy throughput flows in the societal production-consumption systems	Prevent the depletion of resources	Maintain resource extraction and wastes generation rates and emissions under suitable values for planetary boundaries	Longevity (Long life)	Keep the materials as long as possible in a close loop
GF	Reduce, alternative reuse, recycle, & recovery of materials in production, distribution, & consumption processes	Applying materials cycles (e.g., Recycle), renewable and cascade-type energy flows to the linear system	Close energy and materials loops	Closing the system, reducing its size and maintaining the resource's value as long as possible within the system	Easily changeable building configuration, reduce, reuse, recycle	The use of practices (in all stages of the life cycle of a building)
PF	Novel business models, responsible consumers	High-value material cycles alongside more traditional recycling and develop cooperation among producers, consumers, & other societal actors	Cyclical and regenerative environmental innovations in the way society legislate, produces and consumes	Leaning on design and education	Strategic programming	N/A
P	Materials	Material and energy	Resources (Material & Energy)	Resources	Buildings	Materials (building materials)

Table 3: AH framework of summarized CE Definitions (Continued)

	Desing et al., (2020)	Geissdoerfer et al., (2020).	Alhawari et al., (2021).	De Angelis, (2021)	Nobre and Tavares, (2021)
FP	Consider all the variables of the system earth to maintain its viability for human beings (long-term economic prosperity, social well-being, manages the sustainably available resources and optimises their utilisation within the physical limits and planetary boundaries)	N/A	Highest utility value for customers and society	N/A	N/A
AF	Minimising entropy production, slow cycles, resource and energy efficiency	Minimise resource input and waste, emission, and energy leakages	Effective and efficient utilisation of ecosystem, economic, and product cycles	Maintains and rebuilds natural capital	Zero waste and pollution throughout materials lifecycles applied to all ecosystems involved
GF	Minimum raw material extraction, ensuring the safe disposal and spread of unavoidable trash in the environment	Cycling, extending, intensifying, and dematerialising material and energy loops	Closing loops for all the related resource flows	Ecologically effective economic system that works within planetary limits	Materials (end life) return to industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle
PF	Renewable energy and materials, technology, business model innovation	Digitalisation servitisation, sharing, long-lasting product design, repair, maintain, reuse, recycle Remanufacture, refurbish	Organisational planning processes (creating, delivering)	Multiple, cooperative, and simultaneous innovations at different scales in the wider socio-economic context (Innovations at different scales such as regulation, policy and production & consumption systems, and Innovative business models)	Use clean and renewable energy sources, efficient consumption of resources, ensure the correct system for long-term operation responsible consumers (Sustainability nested concept is fully utilised)
P	Goods and services (all the variables of the Earth)	Material and energy	Product, material, component	Natural capital (Resource)	Resources (materials and energy)

In addition to table 4, six (06) out of the eleven descriptions identified CE as a system, while another study definition suggested it as a model. However, 04 out of 11 definitions have not recognised the CE either as a system or a model. Five of those six definitions have referred CE to as an “economic system”, while one study suggested that CE refers to a "regenerative production-consumption system”. Further, certain literary works have described CE as a “regenerative system” (Donatia et al., 2020; Manninen et al. (2018). However, the term regenerative means to improve a system especially by making it more active or successful (Cambridge dictionary, 2022) whereas according to the Oxford English Dictionary, to be regenerated is to be ‘re-born; brought again into existence; formed a new’ (Thane, 2018). Accordingly, it is related to especially after something has been damaged or lost. CE is not only restoring or making improvements to damaged or spoiled issues. Other than that, although, all three levels (micro, meso, and macro) of an economic system are crucial to achieving sustainable development, only four of the eleven articles described these three levels. According to Pomponi and Moncaster (2017), the three levels of the built environment are macro-level (eco-parks or cities), meso-level (buildings), and micro-level (building components or manufactured products).

The top level of the AH framework is the functional purpose and six of the eleven definitions said that the aim of CE is sustainable development with three expressing it explicitly and the others stating differently. Sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987, p.43). Desing et al. (2020) stated it without using the same terminology but almost with the same meaning of sustainable development. To support this, Ulucak et al. (2019) mentioned that the ultimate goal of sustainable development is to reduce environmental risks while maintaining economic growth within ecological restrictions.

Further, resource efficiency plays an important role in the SDGs (e.g., SDG 8: achieve sustainable economic growth and SDG 12: ensure sustainable consumption and production) and it is one of the prime indicators to monitor the progress of these SDGs as well (Flachenecker & Rentschler, 2019). Furthermore, sustainable development uses resource efficiency to minimise the negative impact on the environment by being waste-free (Anastas & Zimmerman, 2003). Accordingly, resource-efficient is a part of sustainable development and the "highest utility value for customers and society" can be considered the social aspect of sustainable development as well. The other is the "regenerative production-consumption system," which can be thought of as one of the things that CE promotes, which is the 12^{th} SDG (responsible consumption and production) (Nikolaou et al., 2021). Further, a few pieces of evidence to show the relationship between CE and sustainable development, such as Homrich et al. (2018) found that CE is a new strategy (path) for promoting sustainable development, and Millar et al. (2019) mentioned that CE is to practice sustainable development and also a detailed approach to sustainable development. Ogunmakinde et al. (2021) stated that CE could be the perfect path to achieving sustainable development. Thus, the aim of CE can be concluded as achieving sustainable development.

The next level of the AH framework is abstract function and all the identified elements at this level have positive correlations among them. This demonstrates the circular nature of the system which is the objective of achieving the aim of sustainable development. It can be summarised as “substituting the end-of-life concept”. For example, “replace the end-of-life”, “longevity”, and “slow cycles” are similar and which is about extending the life of materials/products. Accordingly, the end-of-life can be eliminated by substituting the extended life of materials/products. The next one is ‘zero waste and pollution throughout materials lifecycles' If there is no waste at the end, it is evident that the end-of-life concept is replaced.

Then the third level is generalised function; this says how to practically attain the objective and can be represented in two ways, such as loops and R-imperatives (different R words). Firstly, there are three different types of loops: closing, narrowing, and slowing loops (Akhimien et al., 2020; Gallego-Schmid et al., 2020). Additionally, some refer to the regenerative loop as the 4th loop (Cetin et al., 2021). The other one is R-imperatives (different Rs). Many studies have already researched this and defined the R framework with 9Rs (Potting, et al., 2017), 10Rs (Sarfraz, et al., 2020), and 11Rs (Cimen, 2021). Moreover, all R words can be included within any one of the four loops. For example, slowing resource loops entails prolonging and intensifying the use of products to retain their value over time, whereas closing resource loops facilitates upcycling to restore or create new value from used materials (Bocken et al., 2016). Finally, narrowing resource loops implies eco-efficient solutions that reduce resource intensity and environmental impacts per unit of product or service (Mendoza et al., 2019).

The other one is physical functions which are the strategies used to achieve the loops or R-imperatives. These strategies are changing with the levels of the ecosystem, advancement of technologies, etc. For example, prefabrication is one of the strategies for reducing building materials and elements (Akanbi et al., 2019); design for durability and design for adaptability belongs to the slowing loop (Jansen et al., 2020); long-lasting and high-quality materials and components are included in reselling (Kosanovic et al., 2021); etc.

The final level is the fundamental of CE implementations, which could be the product, components, resources, materials, energy, services, waste, water, etc. Thus, this is changed by other factors in the system (for example, sector, level of society, etc.).

Based on the exploration and discussion, a working definition of the concept of CE from the perspective of the built environment is proposed by integrating i) aim of CE ii) the CE objective, iii) the CE loop or R-imperatives, iv) the CE strategies and resources. The CE is defined as an economic system that aims to facilitate sustainable development by substituting the end-of-life concept, using various R-imperatives (or resource loops) at all three levels (micro, meso, macro) of the built environment, and employs effective strategies for the use of resources through whole life cycle of the system.

4. Conclusion

This research has aimed to explains the concept of CE in the built environment using AH framework where the concept is defined in terms of four query terms: where, why, what, and how. Firstly, the three levels of CE application such as macro (city, region, nation, and beyond), meso (buildings, eco-industrial parks), and micro (consumers, products, companies) was identified. Next, the purpose (why) of CE requirement was explained as a concept to facilitate sustainable development. In terms of question of what does CE do, the study concluded that it substitutes the end-of-life concept while the question of how CE achieves the aim was explained using various R-imperatives or resource loops. Furthermore, CE is a broad concept, many scholars have defined it differently in sectors and from different perspectives. However, authors believe that this paper provides a reference for easy understanding of the CE. Despite the fact that there are already two studies that define CE in relation to the built environment, they do not provide satisfactory answers for all four query terms. Reducing, reusing, and recycling were mentioned by Akhimien et al. (2020), but not other R-imperatives like renovation, refurbishing, etc. In addtion, resource efficiency remains as the purpose. Just one loop (close loop) is described in the Benachio et al. (2020) definition, the other three resource loops are not covered and the question of how is not received a thorough response.

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