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TAXONOMY OF CIRCULAR ECONOMY TERMINOLOGIES

Sepani Senaratne[1], Iresha Gamage[2], Shashini Jayakodi[3], and Srinath Perera[4]

ABSTRACT

The construction sector predominantly follows a linear economic model, which necessitates a shift towards embracing the Circular Economy (CE) principles. Even though several CE approaches have been introduced for the construction context, numerous barriers have hindered their implementation. Confusion of CE terminologies with a lack of awareness is identified as one of the main barriers to the successful implementation of CE in the construction industry. Hence, this research focuses on differentiating the CE terminologies based on their academic definitions to establish a consolidated and comprehensive understanding and thereby, aims to develop a taxonomy for CE terminologies for the construction industry. This research adopted qualitative comparative literature analysis research methodology and selected individualising comparison as a suitable comparison method. To carry out the comparison, the academic definitions from Oxford and Cambridge dictionaries were compared with the definitions from CE-related construction articles. Subsequently, the consolidated definitions were established for selected terminologies by differentiating their ideas. Consequently, the hierarchy of the terminologies was identified to develop a CE taxonomy. This research provides significant guidance for CE researchers for appropriate CE terminology usage in their research, while industry practitioners can gain a wider understanding of CE for its successful implementation in the industry.

Keywords: *Circular Economy; Construction Industry; Definitions; Taxonomy; Terminologies.*

1. INTRODUCTION

CE is a trending concept in many industries, which consists of an opposing approach to the prevailing linear economy approach. The linear economy's 'take-make-dispose' approach has been transformed in the circular economy by minimising the 'take' and 'dispose' steps through closed-loop methods such as reusing, recycling, and regeneration (Velenturf & Purnell, 2021). The Ellen MacArthur Foundation (EMF), Wautelet (2018) and Rodríguez et al. (2020) have identified a few different schools of thought that the CE concept has been nourished from.

[1] Associate Professor, Centre for Smart Modern Construction (c4SMC), School of Engineering, Design and Built Environment, Western Sydney University, Australia, s.senaratne@westernsydney.edu.au
[2] Doctoral researcher, c4SMC, School of Engineering, Design and Built Environment, Western Sydney University, Australia, iggamageiresha@gmail.com
[3] Doctoral researcher, c4SMC, School of Engineering, Design and Built Environment, Western Sydney University, Australia, jayakodishashini@gmail.com
[4] Professor, c4SMC, School of Engineering, Design and Built Environment, Western Sydney University, Australia, srinath.perera@westernsydney.edu.au

The first instance of CE appearing in the literature was the study entitled 'The Economics of the Coming Spaceship Earth' by Boulding (1966). In his study, Boulding (1966) explained the idea of the **'spaceman economy'**, comparing Earth with a resource-constrained spaceship, where humans must live and meet their needs within a 'cyclical ecological system'. According to the argument of Stahel (1982), product life extension activities are more labour-intensive than energy intensive. There can be employment opportunities for people, as the product goes in a cycle between the consumer and the manufacturer in which energy can be substituted by manpower. This argument is the basis for a '**performance economy'** which can be considered as another school of thought associated with CE. CE was also influenced by the concept of **'industrial ecology'**, where waste from one industrial activity is incorporated as raw materials for another industrial activity, which ultimately results in reducing adverse effects on the environment through industrial activities (Frosch & Gallopoulos, 1989). The concept of **'regenerative design'** which was initialised by Lyle (1996) is also considered as a baseline concept for CE. According to the author, it simply means altering the current linear output flows with cyclical flows. Another concept that supports CE is **biomimicry**. The underlying concept of biomimicry has placed a higher value on nature than other concepts. It promotes the idea that humans can observe patterns and strategies of nature to find answers to manmade challenges in a better way, as nature has already dealt successfully with many problems people are handling now (Benyus, 1997). Lovins et al. (1999) proposed another concept related to CE as '**natural capitalism'** which is a system that allows companies to meet customer needs and improve profits, while also providing solutions to conflicts of interest between business and the environment. A well-known concept that heavily influenced CE is **'Cradle to Cradle (C2C)'**. The C2C concept explains the way of designing products considering both metabolic types, biological aspects and engineering, to keep the value of materials and ingredients at the highest possible level for the next cycle of use. According to Rodríguez et al. (2020), the latest concept called **'blue economy'** is the concept that has created the highest influence on CE so far. The blue economy suggests an innovative business model that facilitates local communities to come up with competitive products and services targeting different markets from what they have while encouraging social well-being and environmentally friendly lifestyle (Rodríguez et al., 2020).

The concept of CE is still evolving and incorporates elements from the other schools of thought mentioned earlier. Furthermore, the multi-disciplinary nature of the CE concept makes it difficult to come up with a solid definition for CE (Kirchherr et al., 2017). The most employed definition is given by EMF (Geissdoerfer et al., 2017), which defines CE as an industrial system that is *'restorative or regenerative by intention and design'* (Ellen MacArthur Foundation, 2012). Elaborating further, Geissdoerfer et al. (2017) highlighted that within such a regenerative system resource intake, waste, emission and energy outflows are controlled by slowing, closing and narrowing loops.

Notable attention has been given towards the CE concept in recent decades. Multiple government and non-government organisations have further investigated the CE concept and developed several CE principles and CE frameworks to facilitate the implementation of the concept. EMF has developed three principles to wrap up the basic idea of CE and to direct how CE would be implemented within different contexts. EMF's three CE principles are; (i) Conserve and improve natural capital through better management of scarce resources and sustainable energy flows; (ii) Improve the use of resources through

circulating those at the highest value at all times in both technical and biological cycles; and, (iii) Substitute system through designs which eliminates negative outwardness (EMF, 2012). As a result of EMF's continuous efforts in the development of the CE concept, the 'ReSOLVE' framework was developed jointly with Arup, which has defined six action areas i.e. (i) regenerate, (ii) share, (iii) optimise, (iv) loop, (v) virtualise, and (vi) exchange, that can consider in transitioning towards CE. The British Standard Institute (BSI) has also developed six CE principles and published a guideline for CE named BS 8001:2017, which is recognised as the first guideline related to CE. The six principles defined in BS 8001:2017 are; i) Systems thinking; ii) Stewardship; iii) Transparency; iv) Collaboration; v) Innovation; and vi) Value optimisation. According to BSI (2017), these principles would assist organisations and governments in their decision-making. Furthermore, Papageorgiou et al. (2021) have carried out a study on available CE principles in the literature and found that 'R' principles have gained wide attention among different types of CE principles. There are many variants of R- principles available in the literature ranging from 3Rs to 10Rs since different authors have expanded the basic 3Rs with new attributes based on their perceptions.

Given the significant depletion of resources, wastage, and ecological footprint associated with the construction industry, the transition to the CE model has become a top priority (Munaro et al., 2020; Senaratne et al., 2021; Jayakodi et al., 2023). However, the construction industry is notoriously resistant to change, and its complexity creates unprecedented barriers to CE adoption (Buyle et al., 2019; Ossio et al., 2023). Consequently, the transition to CE in the construction sector is complex and necessitates a comprehensive effort to acquire the necessary knowledge for implementation in the industry (Illankoon & Vithanage, 2023). As a result, studies that facilitate the transformation towards the circular built environment have been in a rapid progression within the last few years and remarkable attention has been given to practical implementation and assessment.

In the circular economy, the 'take-make-dispose' approach is minimised through closed-loop methods such as reusing, recycling, and regeneration (Velenturf & Purnell, 2021). Furthermore, there are commonly used terminologies in assessing CE implementation as 'dimensions', 'indicators', 'indices', 'measures' and 'metrics' (Corona et al., 2019; de Oliveira et al., 2021; Khadim et al., 2022). Bocken et al. (2016) and Ababio and Lu (2022) identified that most CE-associated terminologies have been used differently by researchers in the construction context. The underlying cause of this confusion is that CE is still an evolving idea, which lacks precise boundaries. Ababio and Lu (2022) identified this confusion of terminologies as a barrier to the successful implementation of CE in the construction industry and suggested that further research should be conducted to overcome this barrier. Consequently, this study aims to propose a taxonomy for CE terminologies for the construction industry. Accordingly, each term is discussed separately considering their dictionary definition and how those have been applied for CE implementation within the construction industry to derive a consolidated definition for each term and to develop a hierarchical taxonomy. The upcoming sections of this paper describe the research methodology, and research findings followed up with a proposed taxonomy and finally conclusions and recommendations.

2. METHODOLOGY

The above-mentioned aim of this research leads to two key objectives i.e., (i) to establish consolidated definitions for CE terminologies, and (ii) to identify the hierarchy of the selected terminologies to develop a CE taxonomy for the construction industry. This research adopts a qualitative comparative literature analysis research methodology to achieve the aim of the research. A comparative study is a method that analyses phenomena and then puts them together to find the points of differentiation and similarity (Miri & Shahrokh, 2019). According to Esser and Vliegenthart (2017), comparative research focuses on understanding how the surrounding context influences communication outcomes, emphasising the explanatory significance of the environment and its role in shaping communication phenomena across diverse settings. According to Pickvance (2001), there are four types of comparative analysis: i.e., (i) individualising comparison, (ii) universalising comparison, (iii) variation-finding comparison, and (iv) encompassing comparison. Among the identified types, this research is more focused on individualising comparison as it compares a small number of definitions to grasp the peculiarities of each definition. The research process followed in the current study is depicted in Figure 1.

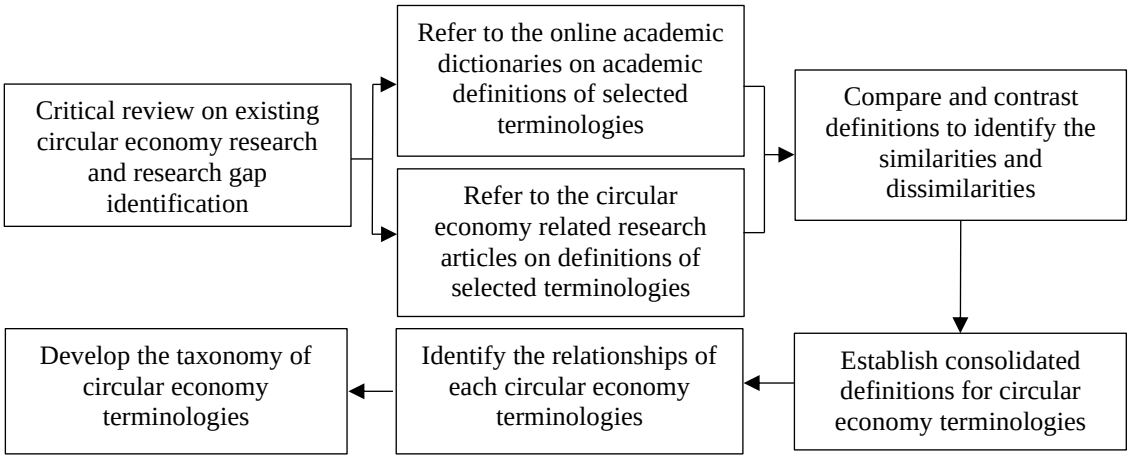

Figure 1: Research process

To achieve the first objective, the study referred to online academic dictionaries (Oxford and Cambridge) to find the general academic definition of selected CE terminologies. Online specialised free dictionaries aid everybody in need of information while facilitating immediate responses (Caruso et al., 2011). Authors further defined dictionaries as the best terminological resources. Subsequently, the research articles published in construction industry-specific CE literature were critically reviewed to identify the definitions of the selected terminologies in the CE context. In the instances that definitions were not available, it was mainly focused on the examples and background explanations of the selected CE terminologies to set the definition scope.

Then, the identified definitions were compared to identify the similarities and dissimilarities of the definitions to establish consolidated definitions for selected CE terminologies. After the establishment of the consolidated definitions for CE terminologies, the relationships of terminologies were mapped to identify and establish

the hierarchy of the terminologies to achieve the second objective. Based on the identified relationship between the terminologies, a CE taxonomy was developed.

3. ANALYSIS AND DISCUSSION

This section discusses terminologies that frequently appeared in CE-related literature in the construction context. Accordingly, definitions of the CE concept, CE principle, CE framework, CE strategy, CE practice and CE assessment-related terminologies are compared to derive a new definition for each. Meanwhile, occasional misuse of CE terminologies in literature is critically discussed here under three subheadings and an acceptable hierarchy has been proposed.

Oxford Dictionary defines a 'concept' as "an idea that is connected with something existing in thought but not having a physical reality and often relates to something new". Section 1 of the current study describes the evolution of the CE concept in a detailed manner concerning all prior concepts that impacted shaping the CE concept. During the discussion in Section 1, it was observed that there is no contradiction in the dictionary meaning of the term 'concept' and how it appears in the CE-related literature. On the other hand, it was noted that the definition given by EMF is widely used to define the 'circular economy'. Thus, combining both dictionary definitions of the term 'concept' and EMF's definition of CE, the current study defines the 'CE concept' as *"an idea about a system that is restorative or regenerative by intention and design".* CE concept is broader and at the highest level, which should be studied further and narrowed down until real implementation is possible. The upcoming sections will discuss the terminologies that are commonly used when implementing the CE concept in the construction context.

3.1 CIRCULAR ECONOMY PRINCIPLES AND FRAMEWORKS

Along with the development of the CE concept, different entities and individuals have developed CE principles and frameworks, which have been briefly discussed in Section 1. The two terminologies have been utilised interchangeably on some occasions to refer to the same information in the literature. For instance, Papageorgiou et al. (2021) propose 'R's as CE principles, whereas some authors define those as CE frameworks (Chizaryfard et al., 2020). According to the Cambridge Dictionary, a 'principle' is "a basic idea or rule that explains or controls how something happens or works" and a 'framework' is "a system of rules, ideas, or beliefs that is used to plan or decide something". The dictionary definitions depict that the principles are established to inform and shape concepts whereas, frameworks can be a set of principles rolled together along with relationships and probable actions, which aid in planning something. Within the CE context, CE principles shape the CE concept providing the foundation for CE implementation. Thus, a CE principle can be defined as "*a fundamental rule or belief on which CE implementation is based"*. The CE principles developed by the EMF can be identified as examples, which comply with the characteristics of the derived definition. Besides, a CE framework can be defined *as "a system which is developed from CE principles and outlines a set of ideas to facilitate CE implementation within a particular context"*. The 'ReSOLVE' framework described in Section 1 is an example of a CE framework at a higher level. During practical implementation, different entities such as organizations, institutes, and the government may develop more detailed frameworks based on high-level frameworks to meet their specific requirements. For instance, Iyer-Raniga (2019) has customised the ReSOLVE framework considering the emerging markets in the

construction industry. Furthermore, it can be noted that the 'R's do not comply with the definition of CE principles, as Rs help adopt CE rather than rule the concept. Since Rs exhibit the characteristics of a CE framework, it is appropriate to name them as frameworks.

3.2 CIRCULAR ECONOMY STRATEGIES AND PRACTICES

Circular economy strategies and practices are vital for the transition towards CE in the construction industry (Guerra et al., 2021). These two terminologies have been used interchangeably in CE literature to indicate the same content (Gamage et al., 2024). For instance, design for disassembling building components is indicated as a 'practice' (Adams et al., 2017; Benachio et al., 2020; Ishan et al., 2023) and as a 'strategy' (Ghobadi & Sepasgozar, 2023; Lee et al., 2023). Besides, the same fact has been identified as a CE principle by Cheshire (2019). However, as per the derived definitions in Section 3.1, the term 'principle' is at a high level in the hierarchy of CE-related terminologies, thus, it is not appropriate to use the term 'principle' to refer to aspects such as 'design for disassembling building components.' According to the Oxford Dictionary, 'strategy' means "a plan, scheme, or course of action designed to achieve an overall aim" and 'practice' means "an activity or action considered as being the realisation of a theory". Quoted definitions exhibit a clear difference between these two terminologies. Strategies are more from the managerial level, and they refer to an overall plan to achieve CE, which may contain practices as part of it. According to van Bueren et al. (2019), strategies refer to the theoretical picture, whereas practices refer to the practical picture of CE implementation. Moreover, van Bueren et al. (2019) identified the lack of existing standard practices as a barrier to adopting circular strategies in construction. From the construction industry's point of view, a strategy can be formed by the government, relevant institutions, or top management of the construction organisations, whereas a practice can occur in a construction project context. A strategy implemented by an organisation can be achieved through multiple practices at the project level and applying practices may differ according to the project context. Thus, a CE strategy should be in a higher place than a CE practice within the construction context.

New definitions were derived considering the need for a clear distinction between the two terminologies in the construction industry to avoid confusion and overcome theoretical obstacles in CE implementation. Accordingly, a CE strategy can be defined as "*a plan to achieve a circular economy-related goal established in the construction industry*", while a CE practice can be defined "*as an activity that contributes to the implementation of a CE strategy in the construction industry*". Various CE principals and frameworks discussed in Section 1 could help in setting CE-related goals within a specific context. For example, a construction organisation would set a CE-related goal to reduce the natural material extraction for manufacturing construction materials by a certain percentage within the next five years. To achieve that goal, 'the use of second-hand materials/components in construction projects' can be considered as a strategy, whereas activities such as 'assessing the reusability of the materials in existing buildings', 'continuing preventive maintenance throughout the operation phase', 'disassembling building components at the end of life' and, 'designing new buildings with reusable materials and components' can be identified as practices to successfully realise the aforementioned strategy at the project level.

3.3 CIRCULAR ECONOMY INDICATORS AND RELATED TERMINOLOGIES

CE practices can be assessed using CE indicators. The terminologies such as 'indicators', 'dimensions', 'measures', 'metrics', 'index', or 'indices' have been often used in the literature, when referring to 'CE indicators' (Khadim et al. 2022). This variety of terminologies used to refer to CE indicators creates ambiguity. However, a deeper analysis of the relevant literature revealed that all these variations refer to the same phenomenon, which is to assess the progress toward achieving CE goals (de Oliveira et al., 2021). Although these terminologies refer to a similar phenomenon, each has a different definition.

CE indicators can be used to assess the CE adoption of any entity (Ellen MacArthur Foundation, 2015). An indicator is "a quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect changes connected to an intervention, or to help assess the performance of a development actor" (Organisation for Economic Co-operation and Development 2014, p 13). According to the Oxford dictionary, an indicator refers to "something that shows what a situation is like or how it is changing". For instance, González et al. (2021) have defined five CE indicators to assess the CE implementation of a construction project, i.e., (i) energy, (ii) material, (iii) water, (iv) social value, and (v) economic value. This explains that CE implementation of a construction project has been divided into five factors to simplify CE assessment to monitor the CE transition of the construction project. CE indicators can provide a standardised language to simplify information exchange and understanding and ease this transition (Verberne, 2016). Besides, Nuñez-Cacho et al. (2018a) identified material, water, waste, energy and 3R as CE dimensions. According to the Cambridge Dictionary, "a dimension is a measurement of something in a particular direction". Smith and Thomas (2021) explain that economy, environment, and society are three dimensions of CE in the construction context. Furthermore, Martinho (2021) elaborated that sustainability analysis, from a circular perspective, should also consider several dimensions such as environmental, economic, social and technical. Based on the preceding definitions and examples, a clear distinction can be established between CE indicators and CE dimensions, which will help to avoid the conflict between the two terminologies and establish a consolidated definition. Hence, "*a CE dimension represents a key measurable cluster/pillar, which contributes to the transition towards a more sustainable and circular built environment*". The definition of CE indicator can be derived as "*a factor used to measure the CE adoption and transition of some construction entity*". For instance, in a construction project, material, waste, energy and emission indicators are considered under the environmental dimension.

According to the Cambridge dictionary, "a measure refers to a way of achieving something, or a method for dealing with a situation", while "a metric referred to using or relating to a system of measurement that uses metres, centimetres, litres, etc". The study conducted by Torgautov et al. (2022) on the CE performance assessment of construction companies elaborated on 52 CE measures. Some of them are Construction and Demolition Waste (CDW) transportation costs, landfilling fees, administrative costs of CDW management, etc. These measures are mainly focused on the economic aspect. Hence, the metrics are identified as total expenditure, cost per unit, cost-to-income ratio, and cost savings. Furthermore, Núñez-Cacho et al. (2018b) explain that design for deconstruction, waste collected for reuse and waste collected for recycling etc are some CE measures to assess the CE. As the metrics of the identified measures, the authors have

defined percentages as suitable metrics. Considering the definitions above and examples, it explains that measures and metrics have different definitions that cannot be used to refer to the same aspect. Hence, CE measures are identified as "*specific actions implemented to assess, monitor, and promote the transition towards a CE at a more focused and granular level*". These measures are more focused on achieving respective CE indicators. The metrics are "*units that are used to measure the CE measures*". For instance, under the waste CE indicator, waste collected for recycling is identified as the relevant measure. The percentage of collected waste to the total waste is identified as the suitable metric for the identified measure. Crucially, measures can be quantitative and qualitative, and respectively their metrics can vary.

According to the Oxford Dictionary, an index refers to "a number giving a measurement of something compared with a particular standard", while indices refer to the plural form of the term index. González et al. (2021) developed the material circularity index, energy circularity index, water circularity index, and social circularity index for construction projects. For instance, the energy circularity index is an equation, which explains the renewable energy coming from on-site generation or nearby sources and energy saving from active or passive energy-saving mechanisms to the total thermal energy and electricity consumption. Further, the water circularity index refers to the cycled water coming from different water re-utilisation or wastewater sources; water comes from the own building or upstream to the total water utilisation of the construction project. Besides, Smith and Thomas (2021) developed the index for construction materials using the multi-criteria decision-making method by considering the multiple attributes that define the circularity of the material by a number. However, these two studies have not compared with any standard, when developing the index. Considering these points, the CE index can be defined as "*a quantitative measure that typically incorporates a range of indicators or measures to assess CE performance and progress, facilitating comparisons over time and across different entities*". There are several other related terminologies such as meter, scale, parameters, and assessment frameworks occasionally used along with CE indicators, which are not discussed here.

4. CIRCULAR ECONOMY TAXONOMY

The term 'Taxonomy' is derived from the Greek words 'taxis', meaning 'arrangement or division', and nomos, meaning 'law' (Enghoff, 2009). Moreover, Enghoff (2009) stated that taxonomies are compiled with taxonomic units known as 'taxa', frequently arranged in a hierarchical structure. Thus, simply a taxonomy is a methodology that involves systematically classifying elements in a defined hierarchical form. According to Xueqing Liu et al. (2012), taxonomies are crucial for systematically organising knowledge within a specific domain, enabling users to easily access and analyse relevant information. As explained in Section 1, there is an ongoing issue with misusing CE-related terminologies in the literature, which creates confusion among researchers and industry practitioners, when studying and implementing the CE concept. To answer this issue, this study developed a taxonomy of CE terminologies, which is shown in Figure 2.

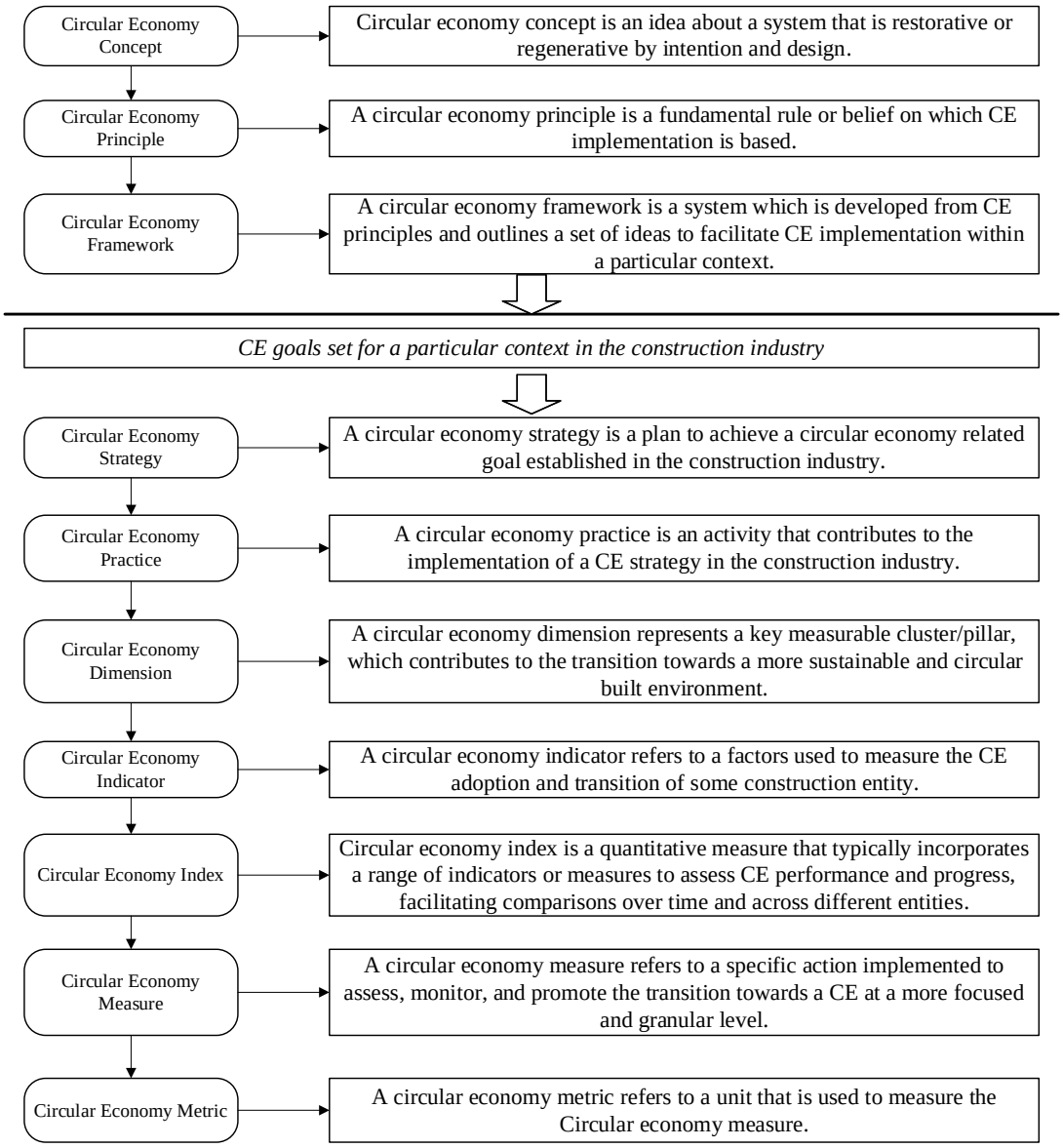

Figure 2: Proposed taxonomy of circular economy terminologies

The proposed taxonomy includes ten frequently used terminologies in implementing and assessing CE within the construction industry and follows a hierarchical arrangement. It starts with the broader concept of 'CE' and then delves into fundamental terms such as CE principles and CE frameworks. Thereafter, the taxonomy is diverted towards CE implementation within a particular context in the construction industry and followed up by the assessment of CE implementation. In addition to the hierarchical arrangement, the definitions for each term, which were derived from the above discussions are provided. An example scenario is elaborated below considering the hierarchy of the CE taxonomy.

Assume that a construction organisation has developed CE-related long-term and short-term goals considering the available CE principles and CE frameworks, which may align with their overall strategic planning process. If the construction organisation set a CE related goal to ‘reduce demolition waste at the end-of-life stage of their projects’, a strategy to achieve this goal would be ‘efficiently managing demolished material.’ A practice to realise this strategy could be ‘identifying and recycling possible demolished

materials.' Moving into the assessment of the CE practice, the 'environmental' dimension could be identified as more appropriate for the scenario, since the plan is to reduce the demolition waste. Accordingly, the CE indicator can be 'waste', the CE measure can be 'the recyclability of the demolished material' and the metric can be 'the percentage.' According to the proposed taxonomy, the CE index of the given scenario can be identified as 'the recyclability value (%) of the material', which could be obtained from the ratio between total mass and the recyclable mass of the material expressed as a fraction of 100. Similarly, the taxonomy can be applied in different contexts and for different examples.

5. CONCLUSIONS

The study aimed to propose a taxonomy of circular economy terminologies for the construction sector. To compare dictionary definitions of various CE-related terminologies and their appearance in the literature on this subject, the study used a comparative analysis methodology. Accordingly, consolidated definitions were derived for each term and the hierarchical arrangement of the terminologies was identified to develop the Circular Economy Taxonomy. The findings of the study revealed that most CE terminologies are inappropriately used in the literature with regards to their dictionary meaning and many occasions were identified with misuse of these terminologies. The developed taxonomy would directly contribute to the existing body of knowledge and answer the prevailing issue of misusing terminologies in the CE literature. In addition, the taxonomy would assist in the proper implementation of CE within the construction industry as it demarcates each step that needs to be considered during implementation and assessment. It is recommended to follow the hierarchical order given in the taxonomy to gather information and properly plan the CE implementation process within the construction industry. Further research can be carried out to validate the proposed taxonomy with empirical data collected from experts' opinions and case studies and assess its applicability to other industries.

6. REFERENCES

Ababio, B. K., & Lu, W. (2022). Barriers and enablers of circular economy in construction: a multi-system perspective towards the development of a practical framework. *Construction Management and Economics*, *41*(1), 3-21. Retrieved from https://doi.org/10.1080/01446193.2022.2135750

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: current awareness, challenges and enablers. In *Proceedings of the institution of civil engineers-waste and resource management*, (Volume 170, Issue WR1, pp. 15-24). ICE Publishing. https://doi.org/10.1680/jwarm.16.00011

Benachio, G. L. F., Freitas, M. d. C. D., & Tavares, S. F. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *260*, 121046. Retrieved from https://doi.org/10.1016/j.jclepro.2020.121046

Benyus, J. M. (1997). *Biomimicry: Innovation inspired by nature*. New York: William Morrow & Co.

Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of industrial and production engineering*, *33*(5), 308-320. Retrieved from https://www.tandfonline.com/doi/epdf/10.1080/21681015.2016.1172124?needAccess=true

Boulding, K. E. (1966). The economics of the coming spaceship earth. In H. Jarrett (Ed.), *Environmental Quality in a Growing Economy* (pp. 3-14). Johns Hopkins University Press.

British Standards Institution. (2017). *Framework for implementing the principles of the circular economy in organizations – Guide*(BS 8001:2017). BSI Standards Publication.

Buyle, M., Galle, W., Debacker, W., & Audenaert, A. (2019). Sustainability assessment of circular building alternatives: Consequential LCA and LCC for internal wall assemblies as a case study in a Belgian context. *Journal of Cleaner Production*, *218*, 141-156.

Caruso, V., Kosem, I., & Kosem, K. (2011). Online specialised dictionaries: A critical survey. In *Proceedings of eLex*, (pp. 66-75).

Cheshire, D. (2019). *Building revolutions: Applying the circular economy to the built environment* (1 ed.). RIBA Publishing.

Chizaryfard, A., Trucco, P., & Nuur, C. (2020). The transformation to a circular economy: framing an evolutionary view. *Journal of Evolutionary Economics*, *31*(2), 475-504. Retrieved from https://doi.org/10.1007/s00191-020-00709-0

Corona, B., Shen, L., Reike, D., Rosales Carreón, J., & Worrell, E. (2019). Towards sustainable development through the circular economy: A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling*, *151*. Retrieved from https://doi.org/10.1016/j.resconrec.2019.104498

de Oliveira, C. T., Dantas, T. E. T., & Soares, S. R. (2021). Nano and micro level circular economy indicators: Assisting decision-makers in circularity assessments. *Sustainable Production and Consumption*, *26*, 455-468. Retrieved from https://doi.org/10.1016/j.spc.2020.11.024

Ellen MacArthur Foundation. (2012). *Towards the circular economy - an economic and business rationale for an accelerated transition*.(Volume 1), Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an

Ellen MacArthur Foundation. (2015). *Delivering the circular economy: A toolkit for policymakers*. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/a-toolkit-for-policymakers

Enghoff, H. (2009). What is taxonomy? : An overview with myriapodological examples. *Soil Organisms*, *81*(3). 441-451.

Esser, F., & Vliegenthart, R. (2017). Comparative research methods. In *The international encyclopedia of communication research methods*, (pp 1-22). John Wiley & Sons, Inc. doi:10.1002/9781118901731.iecrm0035

Frosch, R. A., & Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American*, *261*(3), 144-153.

Gamage, I., Senaratne, S., Perera, S., & Jin, X. (2024). Implementing circular economy throughout the construction project life cycle: A review on potential practices and relationships. *Buildings*, *14*(3). 653.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy : A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757-768. Retrieved from https://doi.org/10.1016/j.jclepro.2016.12.048

Ghobadi, M., & Sepasgozar, S. M. E. (2023). Circular economy strategies in modern timber construction as a potential response to climate change. *Journal of Building Engineering*,*77*, 107229. Retrieved from https://doi.org/10.1016/j.jobe.2023.107229

González, A., Sendra, C., Herena, A., Rosquillas, M., & Vaz, D. (2021). Methodology to assess the circularity in building construction and refurbishment activities. *Resources, Conservation & Recycling Advances*, *12*, 200051.

Guerra, B. C., Shahi, S., Mollaei, A., Skaf, N., Weber, O., Leite, F., & Haas, C. (2021). Circular economy applications in the construction industry: A global scan of trends and opportunities. *Journal of Cleaner Production*, *324*, 129125.

Illankoon, C., & Vithanage, S. C. (2023). Closing the loop in the construction industry: A systematic literature review on the development of circular economy [Review]. *Journal of Building Engineering*, *76*, 107362. Retrieved from https://doi.org/10.1016/j.jobe.2023.107362

Ishan, M., Gamage, I., & Lingasabesan, V. (2023). Highly effective circular economic practices for the life cycle of a construction project. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ramachandra, T. and Ranadewa, K.A.T.O. (Eds). *Proceedings of the 11th world construction symposium, Sri Lanka*, 21-22 July 2023, (pp. 532-544). Retrieved from https://doi.org/10.31705/WCS.2023.44

Iyer-Raniga, U. (2019). Using the ReSOLVE framework for circularity in the building and construction industry in emerging markets. In *IOP conference series: Earth and environmental science*, (Vol. 294, No. 1, p. 012002). IOP Publishing. doi:10.1088/1755-1315/294/1/012002

Jayakodi, S., Senaratne, S., Perera, S., & Bamdad, K. (2023). Digital technology enabled circularity in the construction industry: a bibliometric study. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ramachandra, T. and Ranadewa, K.A.T.O. (eds). *Proceedings of the 11th world construction symposium Sri Lanka*, 21-22 July 2023, (pp. 460-470). doi: 10.31705/WCS.2023.38

Khadim, N., Agliata, R., Marino, A., Thaheem, M. J., & Mollo, L. (2022). Critical review of nano and micro-level building circularity indicators and frameworks. *Journal of Cleaner Production*, *357*. 131859. Retrieved from https://doi.org/10.1016/j.jclepro.2022.131859

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221-232.

Klein, N., Ramos, T., & Deutz, P. (2020). Circular Economy Practices and Strategies in Public Sector Organizations: An Integrative Review. *Sustainability*, *12*(10), 4181. Retrieved from https://doi.org/10.3390/su12104181

Lee, P.-H., Juan, Y.-K., Han, Q., & Vries, B. D. (2023). An investigation on construction companies' attitudes towards importance and adoption of circular economy strategies. *Ain Shams Engineering Journal*, *14*,(12), 102219. Retrieved from https://doi.org/10.1016/j.asej.2023.102219

Liu, X., Song, Y., Liu, S., & Wang, H. (2012). Automatic taxonomy construction from keywords. In *Proceedings of the 18th ACM SIGKDD international conference on knowledge discovery and data mining*, New York (pp. 1433-1441). https://doi.org/10.1145/2339530.2339754

Lovins, A. B., Lovins, L. H., & Hawken, P. (1999). A road map for natural capitalism. In *Understanding business environments*, (1st ed, pp. 250-263). Routledge

Lyle, J. T. (1996). *Regenerative design for sustainable development* (1st ed.) John Wiley & Sons.

Martinho, V. J. P. D. (2021). Insights into circular economy indicators: Emphasizing dimensions of sustainability. *Environmental and Sustainability Indicators*, *10*, 100119.

Miri, S. M., & Shahrokh, Z.D (2019). *A short introduction to comparative research*. [Doctoral dissertation, Allameh Tabataba'i University], https://www.researchgate.net/publication/336278925_A_Short_Introduction_to_Comparative_Research

Munaro, M. R., Tavares, S. F., & Bragança, L. (2020). Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. *Journal of Cleaner Production*, *260*, 121134.

Nuñez-Cacho, P., Górecki, J., Molina-Moreno, V., & Corpas-Iglesias, F. (2018a). What Gets Measured, Gets Done: Development of a Circular Economy Measurement Scale for Building Industry. *Sustainability*, *10*(7). 2340.Retrieved from https://doi.org/10.3390/su10072340

Núñez-Cacho, P., Górecki, J., Molina, V., & Corpas-Iglesias, F. A. (2018b). New measures of circular economy thinking in construction companies. *Journal of EU Research in Business*, *2018*(2018), 909360

Organisation for Economic Co-operation and Development (OECD). (2014). *Education at a Glance 2014 OECD indicators*. OECD Publishing. https://www.oecd.org/education/Education-at-a-Glance-2014.pdf

Ossio, F., Salinas, C., & Hernández, H. (2023). Circular economy in the built environment: A systematic literature review and definition of the circular construction concept. *Journal of Cleaner Production*, *41*, 137738. Retrieved from https://doi.org/10.1016/j.jclepro.2023.137738

Papageorgiou, A., Henrysson, M., Nuur, C., Sinha, R., Sundberg, C., & Vanhuyse, F. (2021). Mapping and assessing indicator-based frameworks for monitoring circular economy development at the city-level. *Sustainable Cities and Society*, *75*, 103378. Retrieved from https://doi.org/10.1016/j.scs.2021.103378

Pickvance, C. G. (2001). Four varieties of comparative analysis. *Journal of Housing and the Built Environment*, *16*, 7-28.

Rodríguez, R. W., Pomponi, F., Webster, K., & D'Amico, B. (2020). The future of the circular economy and the circular economy of the future. *Built Environment Project and Asset Management*, *10*(4), 529-546. Retrieved from https://doi.org/10.1108/bepam-07-2019-0063

Senaratne, S., Kc, A., Perera, S., & Almeida, L. (2021). Promoting stakeholder collaboration in adopting circular economy principles for sustainable construction. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, K.G.A.S. (eds). *Proceedings of the 9th world construction symposium, Sri Lanka*, 9-10 July 2021,(pp. 471-482). https://doi.org/10.31705/WCS.2021.41.

Smith, J., & Thomas, A. (2021). Integrated model and index for circular economy in the built environment in the Indian context. *Construction economics and building*, *21*(3), 198-220.

Stahel, W. R. (1982). The product life factor. In S.G. Orr (Ed.), *An Inquiry into the Nature of Sustainable Societies: The Role of the Private Sector*, (1st ed., pp. 72-150) Houston Area Research Center.

Torgautov, B., Zhanabayev, A., Tleuken, A., Turkyilmaz, A., Borucki, C., & Karaca, F. (2022). Performance assessment of construction companies for the circular economy: A balanced scorecard approach. *Sustainable Production and Consumption*, *33*, 991-1004.

van Bueren, B. J. A., Leenders, M. A. A. M., & Nordling, T. E. M. (2019). Case study: Taiwan's pathway into a circular future for buildings. *IOP conference series: earth and environmental science*, (Vol. 225, No. 1, p. 012060) IOP Publishing. https://doi.org/10.1088/1755-1315/225/1/012060

Velenturf, A. P. M., & Purnell, P. (2021). Principles for a sustainable circular economy. *Sustainable Production and Consumption*, *27*, 1437-1457.Retrieved from https://doi.org/10.1016/j.spc.2021.02.018

Verberne, J. (2016). *Building circularity indicators:An approach for measuring circularity of a building* [Masters thesis, Eindhoven University of Technology]. *https://pure.tue.nl/ws/portalfiles/portal/46934924/846733-1.pdf*

Wautelet, T. (2018). *The concept of circular economy: its origins and its evolution*. https://doi.org/10.13140/RG.2.2.17021.87523