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A CONCEPTUAL FRAMEWORK TO MANAGE CIRCULAR ECONOMY KNOWLEDGE IN CONSTRUCTION PROJECTS

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ABSTRACT

Circular Economy (CE) implementation in the construction industry has gained wider attention worldwide due to its ability to minimise the negative impacts of construction industry practices. However, gaps in CE knowledge have hindered CE implementation in the construction industry. Although the necessity of Knowledge Management (KM) for CE transition has been raised in numerous studies, existing literature has a dearth of CE KM studies, which is further limited in the construction context. Thus, this research aims to develop a conceptual framework to manage CE knowledge in construction projects by investigating required CE knowledge for construction professionals. A comprehensive literature review was undertaken to achieve this aim by analysing the literature using manual content analysis. The findings of this research highlight the overlaying impact of knowledge and KM on financial, market, technology, policy, and culture-related enablers and barriers of CE implementation in the construction industry. Furthermore, the potential of knowledge on addressing context and concept-related barriers to implementing CE was discussed, and a bespoke KM cycle with seven steps has been established, highlighting the importance of the KM cycle for CE KM rather than using the KM process. Finally, a conceptual framework for CE KM of the construction industry has been developed, revealing a shell view of these concepts. These findings will be beneficial for construction practitioners to i). understand areas of knowledge to be improved, and ii). identify KM actions to initiate improvements to ensure the implementation of CE principles.

Keywords: *Circular Economy; Construction Industry; Knowledge Enablers and Barriers; Knowledge Management.*

1. INTRODUCTION

The construction industry is considered one of the highest resource-consuming industries in the world, with substantial emissions and waste generation (Ababio & Lu, 2023; Adams et al., 2017; Munaro & Tavares, 2023). Accordingly, various attempts exist to mitigate the problems of overconsumption of resources, waste generation and harmful

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emissions of construction practices. CE is one of the promising concepts for the construction industry, which offers new opportunities and perspectives to reduce the overconsumption of resources and waste generation by feeding back products to the supply chain and thereby contributing to a reduction in harmful emissions (Bilal et al., 2020). Furthermore, the application of CE in the construction industry contributes to reducing ecological footprint, waste, and resource depletion (Wuni, 2022). CE in the construction context refers to an economic system that helps to create slow, narrow, and close loops of production and consumption of resources (Oluleye et al., 2022), contrary to the traditional “end of life” mindset (Shooshtarian & Maqsood, 2023). It comprises different R principles. These principles have evolved, leading to twelve potential R principles to be adopted in the present context: refuse, rethink, redesign, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, and regenerate (Collins et al., 2023).

However, despite the diverse approaches to Circular Economy (CE) in the construction industry, such as waste, energy, water, materials, emissions, and general practices (Bilal et al., 2020); the industry remains in the early stages of CE adoption. This situation underscores the need for further action to facilitate the transition to CE within the construction sector (Ababio & Lu, 2023). This transition required a broader diffusion of CE into construction materials, products, processes, philosophies, stakeholders, and organisations in the industry (Wuni, 2022). Being a dynamic, complex, labour-intensive, and changing industry (Charef et al., 2021; Hart et al., 2019) with long-term project-based interactions in supply chains (Senaratne et al., 2021), the construction industry faces the challenge of CE transition (Adams et al., 2017; Munaro & Tavares, 2023; Charef et al., 2021). Numerous barriers impede CE transition in the construction industry, including financial, regulatory, knowledge, organisational, cultural, technology and stakeholders (Ababio & Lu, 2023; Bilal et al., 2020). Similarly, lack of experienced, skilled workers and insufficient knowledge have been portrayed as two of the top five barriers to CE transition in the construction industry, and KM has been proposed as a viable solution to address this barrier (Charef et al., 2021). Furthermore, researchers have highlighted that lack of CE knowledge, the complexity of the CE concept, inadequate skills and awareness of stakeholders, and the complexity of the industry as more specific and significant causes for the lack of CE implementation in the construction industry (Hart et al., 2019; Osei-Tutu et al., 2023; Charef et al., 2021; Wuni, 2022). Accordingly, the absence of CE knowledge and the CE KM system have hindered CE implementation in the construction industry. Henceforth, it is necessary to apply CE KM methodologies in the construction industry (Charef et al., 2021).

Due to its ancient origins, KM comprises well-established principles, practices, tools, and strategies. Furthermore, it has been applied in a wide range of research domains. However, the systematic, continuous, multi-dimensional and complex nature of CE emerges the necessity of organising pertinent information, analysing, applying, and evaluating them properly, defining accurate sources and holistic ideas of workable concepts (Formisano et al., 2021). Further, despite the availability of KM practices, CE KM requires the circulation of knowledge and know-how in the process of CE transition, which requires unique insights into “what knowledge”, “which individuals/groups”, "what methods", and “communication channels” (Chembessi, 2023).

Despite the importance of KM in processing, storing, visualising, and sharing CE data and information regarding products, processes, and stakeholders, CE KM can be considered an under-examined area in current academic literature (Klapalová, 2019). Acerbi et al. (2020) discussed the connection of CE with KM in a lean context and revealed that CE KM is an essential area for waste management and sustainable manufacturing. Nonetheless, the prospective role of KM methods and tools incorporating CE in this context is rarely investigated. Accordingly, Chembessi (2023) has suggested three directions to initiate research in this under-examined area as investigating; i). KM processes for CE, ii). KM methods for CE, and iii). micro-level application of CE KM to ensure a macro-level transition to CE. Additionally, Formisano et al. (2021) highlighted that while a correlation between KM and CE exists, with KM serving as a key pillar in CE implementation, most developed countries have yet to take substantial initiatives to effectively manage knowledge within the context of CE. Similarly, concentrated and specific models, frameworks, methods, tools, and evaluation indicators are urgently needed to assist the transition to CE (Peralta et al., 2020).

Even though many studies have emphasised the importance of CE KM in the construction industry, CE KM studies are further limited in the construction context. Shooshtarian and Maqsood (2023) emphasised the importance of KM through collaborations and partnerships to facilitate the implementation of CE in the Australian construction industry. Moreover, the findings of Senaratne et al. (2021) regarding the trends of KM research in the construction industry have revealed the gaps in CE KM research and identified the importance of developing a generic KM model focusing on connecting stakeholders covering all stages of a construction project to ensure CE using social, economic, and environmental pillars of sustainability. Overall, the findings mentioned above revealed the limited attention on CE KM in academia, which is further limited in the construction context, irrespective of the need for a tailored CE KM model for the construction industry. Thus, the methods of integrating elements of CE and elements of KM in the construction context to ensure CE transition are limited in the literature. Henceforth, this research aims to develop a conceptual framework that can be used to utilise KM for CE transition in the construction industry.

2. RESEARCH METHOD

This study is developed based on a comprehensive literature review in CE, KM, and the construction industry by exploring theories, concepts, and patterns to develop a conceptual framework to manage CE knowledge in construction projects. The studies of Chembessi (2023) and Peralta et al. (2020) have used a similar method of literature review to investigate the role of KM in CE transition. Accordingly, keywords for literature retrieval were established as “circular*”, AND “knowledge*”, AND (“enabler*” OR “benefit*” OR “advantage*” OR “barrier*”, OR “limitation*” OR “disadvantage*”) AND (“construction*” OR “built* environment*” OR “building* industry*”). These keywords were pursued in the "Web of Science", "Scopus", and “Engineering Village” databases, as well as the “Google Scholar” search engine, to identify appropriate results. Consequent to the dearth of studies collectively contributing to these three fields of studies, both distinct and combined search terms were used to identify results. After thoroughly reviewing the search outcomes' titles, abstracts, and keywords, this sample of papers was purposively selected to cover a more comprehensive range of articles on CE enablers and barriers, seminal studies in KM, and current contributions in CE KM.

This study critically reviews: (i) connection of CE and the construction industry, revealing CE principles, practices, benefits, and strategies applicable to the construction industry; (ii) Impact of knowledge as an enabler and a barrier for CE implementation, (iii) the necessity of KM to CE implementation in the construction context, and (iv) KM steps to develop a conceptual framework for CE KM for the construction industry to contribute to CE transition. Manual content analysis was conducted to review and analyse the selected articles, following the author's opportunity to review them extensively.

3. LITERATURE FINDINGS

3.1 CIRCULAR ECONOMY PRINCIPLES, PRACTICES, STRATEGIES AND BENEFITS FOR THE CONSTRUCTION INDUSTRY

The CE principles, practices, and strategies are closely related terms, while principles refer to the fundamental guidelines and concepts that describe procedures for transitioning from a traditional take-make-dispose approach to a circular approach (Adams et al., 2017). The practices or strategies refer to actions taken to reduce waste generation from natural resources and energy consumption and lead to ensure sustainable and cleaner production (Oluleye et al., 2022). Accordingly, CE strategies have been drawn based on CE principles, and many authors have used these two terms collectively to describe the actions for CE transition in the construction industry.

The CE principles keep evolving in the academic literature, and authors have provided different arguments about them. According to the Ellen MacArthur Foundation (2016), which is considered a pioneer organisation researching CE: (i) design out waste and pollution (slow), (ii) keep products and materials in use (narrow), and (iii) regenerating natural systems (close) has been identified as the overview of the fundamental principles for the circularity movement. A recent study by Collins et al. (2023) has identified twelve CE principles as reuse, repair, redesign, remanufacture, refurbishment, recycle, replace, recover, repurpose, rethink, reduce and regeneration. This classification of CE is a substantial guideline of principles for CE implementation, directed to achieve the focus of CE, closing and narrowing the resource loop. A variety of CE strategies have been identified for the construction industry. For instance, Charef et al. (2021) have identified five leading strategies for CE implementation in the construction industry: implementing CE design, developing CE competencies, ensuring the CE value chain, managing CE practices, and tracking CE development. Furthermore, Wuni (2022) identified a set of strategies targeting different clusters of CE barriers, including common strategies of increasing government interference, improving material quality, expanding evidence-based knowledge, professional training, and improving design strategies.

Izquierdo et al. (2024) have mentioned twelve practices for CE implementation in the built environment: (i) material and product selection, (ii) design for modularity, (iii) design for adaptability and flexibility, (iv) design for standardisation, (v) design for disassembly, (vi) design for prefabrication, (vii) built out of waste, (viii) building in layers, (ix) selective demolition, (x) disassembly, (xi) upcycling, and (xii) downcycling. A similar view has been disclosed by Wuni (2022). The author has mentioned that design for waste elimination and value recovery operations are CE practices applicable to the construction industry. Accordingly, it is evident that these practices coincide with CE strategies proposed by Charef et al. (2021), such as implementing CE design, developing CE competencies, ensuring the CE value chain, and managing CE practices. Henceforth, these principles and strategies are developed to ensure attaining R principles and use concurrently in the academic literature. For example, design for adaptability and flexibility contributes to ensuring "reuse", and the build-out of waste ensures "reduce."

There are a variety of benefits to implementing CE principles, practices, and strategies for the construction industry, which primarily contribute to sustainable development. CE contributes to minimising energy use, waste generation, and greenhouse gas emissions, ensuring optimal resource usage and, therefore, portraying a prominent step towards sustainability (Illankoon & Vithanage, 2023). Furthermore, as emphasised by Oluleye et al. (2022) and Shooshtarian and Maqsood (2023), the implementation of CE strategies helps innovation and collaboration regarding technologies and best practices, contributing to sustainability in the construction industry and provides prolific ways for implementation of construction activities. In addition, implementing CE practices adds value to construction organisations and makes them reputed for initiating actions, embracing this novel concept. Moreover, though the implementation of CE practices is costly by the construction industry (Charef et al., 2021), it has the potential to save lifecycle costs of construction projects as it reduces transportation costs (Oluleye et al., 2022), increase the durability of products (Collins et al., 2023), promote reusing of components and design for modularity (Izquierdo et al., 2024). Overall, it is evident that CE implementation provides substantial benefits to the construction industry.

3.2 IMPACT OF KNOWLEDGE ON ENABLERS AND BARRIERS TO IMPLEMENT CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY

Considering CE as a promising solution to ensure sustainability in the construction industry, various enablers and barriers to CE implementation can be identified from the literature. Hart et al. (2019) noted that enablers and barriers to implementing CE in the construction industry are two sides of the same coin, as they often relate to the same financial, cultural, political, and sectoral categories. A similar view is presented by Munaro and Tavares (2023), who categorised enablers and barriers into altered economic, technological, organisational, political, and informational classifications. In addition, Charef et al. (2021), Osei-Tutu et al. (2023), and Wuni (2022) revealed categorisations for barriers of CE, which include categories of economic, technical, technological, cultural, organisational, political, market, knowledge, supply chain, management, stakeholders, social, and environmental.

A significant aspect revealed in these studies is the necessity and relationship of knowledge with all the categorised barriers being one of the overlaying forces to enable CE (Adams et al., 2017; Illankoon & Vithanage, 2023; Oluleye et al., 2022). Thus, many studies have identified CE knowledge as an enabler and barrier (Bilal et al., 2020b; Shooshtarian & Maqsood, 2023). According to Izquierdo et al. (2024), most of the identified enablers and barriers of CE are significant in the linear economy context, and the difference is customising them to ensure the goals of CE. Accordingly, the authors reveal and argue the importance of special accreditation on CE knowledge and KM to reinforce enablers and mitigate barriers to CE implementation in the construction industry (Izquierdo et al., 2024). Furthermore, according to Wuni (2022), knowledge, awareness and skills are directly related to ensuring CE transition in the construction industry. This knowledge requirement can be identified from different viewpoints, as shown in Figure 1.

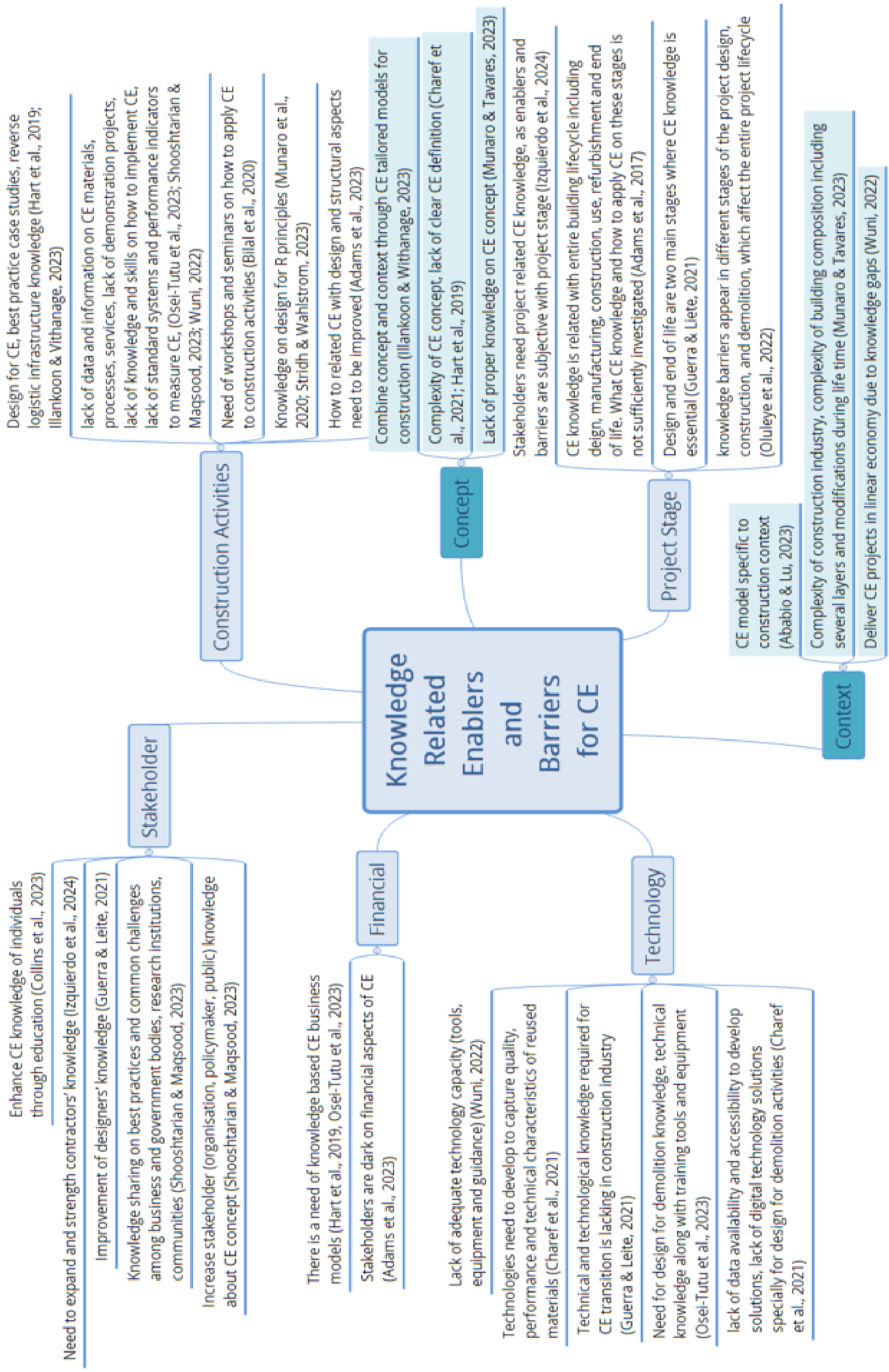

Figure 1: Circular economy knowledge enablers and barriers in the construction industry

According to Figure 1, CE knowledge is required for the construction industry from the viewpoints of stakeholders, project stage, construction activity, technology, financial, concept and context, being an enabler and a barrier for CE implementation. For instance, Izquierdo et al. (2024) emphasised that improving stakeholders' knowledge ensures the quality of CE implementation, being an enabler. Furthermore, Charef et al. (2021) conveyed that a lack of information on the quality, performance and technical characteristics of the reused materials is a barrier that hinders CE implementation. After an extensive review of existing literature, this study identified two less revealed, significant areas of knowledge barriers i.e., (i) concept, and (ii) context barriers. Even though they have been less revealed as categories of enablers or barriers, related aspects to these two factors have been highlighted in existing studies, as mentioned in Figure 1. Overall, knowledge can be argued as an overlaying force for enablers, and barriers revealed in existing studies, including finance (business models), materials, products, and processes (construction activity and technology), supply chain (project stage and stakeholders), and delivering CE in the linear economy (concept and context).

3.3 KNOWLEDGE MANAGEMENT FOR CIRCULAR ECONOMY IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY

Despite the dearth of comprehensive, systematic KM strategies, the need for KM has been revealed in existing studies, which align with the steps of the KM cycle. As per the enablers and barriers of CE, the absence of adequate knowledge and KM methods have been associated with the frequently emerged barriers to CE implementation in the construction industry (Oluleye et al., 2022; Shooshtarian et al., 2023; Charef et al., 2021, 2023; Wuni, 2022). Similarly, Charef et al. (2021) have identified KM as a suitable approach to addressing CE implementation issues of the construction companies as the construction industry requires changing working methods, training, skills building and access to additional data to enable CE. This need is because of the nature of the construction industry being conservative, uncollaborative and adversarial (Hart et al., 2019), providing complex building compositions, including several layers and modifications during the lifespan (Illankoon & Vithanage, 2023; Munaro & Tavares, 2023).

Accordingly, Collins et al. (2023) communicate the necessity of individuals' CE knowledge for successful CE transition and convey the role of education for that. This education relates to the entire KM cycle, as education on "how to" is a crucial activity in every stage of the KM cycle. Similarly, KM actions revealed in studies of Illankoon and Vithanage (2023) and Izquierdo et al. (2024), which to provide CE guidance and to develop a CE model specific to construction could help to overcome the identified context and concept knowledge barriers, which requires efforts from entire KM cycle. Moreover, Wuni (2022) mentioned the need for “knowledge evaluation”, highlighting the need for CE-friendly technologies. Further, the lack of data availability and accessibility to develop technologies and the lack of digital technology solutions for CE, especially for “design for demolition stage activities” (Charef et al., 2021; Osei-Tutu et al., 2023) can be mitigated by enhancing "design for demolition" knowledge, and technology knowledge through evidence-based projects, which is related with “knowledge application and evaluation”.

Shooshtarian and Maqsood (2023) mention knowledge sharing on best practices as a vital step in CE implementation in the construction industry. Further, the need to promote stakeholder awareness through education, developing a CE model specific to construction, developing collaborative information-sharing tools (Ababio & Lu, 2023;

Munaro & Tavares, 2023), and conducting seminars and workshops (Bilal et al., 2020) are knowledge-sharing steps to increase knowledge regarding construction activities to foster CE transition. Moreover, Bilal et al. (2020) state that the above barriers can be addressed by educating the public on CE and conducting seminars and workshops to increase CE awareness. Thus, KM plays a vital role in the CE transition of the construction industry, which is consequent to the nature of the construction industry, which has lengthy supply chains and requires extensive stakeholder collaborations (Senaratne et al., 2021). Henceforth, the next section of this study investigates the concept of KM, identifying its steps.

3.4 KNOWLEDGE MANAGEMENT CYCLE

The KM can be considered a source of innovation and a powerful engine of production, which provides the entire basis for the proper functioning of any industry and helps to gain a competitive advantage (Nakamori, 2020). Different terminologies have been used to explain the KM process; principally, it involves the creation, organisation, distribution, and application of knowledge (Klapalová, 2019; Marinho & Couto, 2022; Nakamori, 2020). In contrast, some studies have highlighted the cyclic nature of the KM, (Fard & Selseleh, 2010; Mohapatra et al., 2016) and this cycle includes the same steps of the KM process. Accordingly, Table 1 describes the different terminologies associated with the KM process/cycle.

Table 1: Different terminologies used in literature for steps of knowledge management.

KM steps terminologies	Context	Source
Create, Capture, Refine, Store, Manage, Disseminate	General	Bose (2004)
Collection, Accumulation, Utilisation, Dissemination	General	Nakamori (2020)
Identify, Create, Store, Share, Use, Learn, Improve *	General	Evans et al. (2014)
Capturing, Coding, Publishing, Sharing, Accessing, Application *	General	Mohapatra et al. (2016)
Generation, Acquisition, Sharing, Use, Generate Value	Construction	Yepes and López (2021)
Creation, Acquisition, Sharing, Integration, Application	Construction	Yu and Yang (2018)
Acquire, Capture, Analyse, Utilise, Store, Share	CE	Klapalová (2019)
Acquire, Design, Manage, Share	CE	Chembessi (2023)
Generation, Using, Transferring, Sharing	CE	Formisano et al. (2021)

*- set of terminologies used in the KM cycle and remainders stand for the terminologies in the KM process.

By acknowledging the iterative nature of knowledge, this study considered KM as a cycle rather than a sequential process. Henceforth, Figure 2 depicts the KM model tailored for this study following the KM process of Bose (2004) and the KM cycles of Evans et al. (2014) and Mohapatra et al. (2016), considering their comprehensive explanation of KM steps.

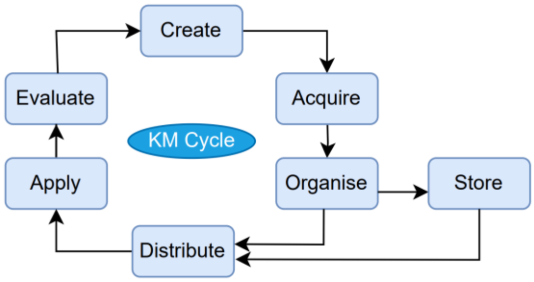

Figure 2: Knowledge management cycle

Figure 2 depicts a seven-step KM cycle covering the key actions used to manage knowledge in different contexts. Following the view of Evans et al. (2014), who have identified the possibility of having double loops in the KM cycle, a double loop has been identified for this cycle at the step of "organise". CE knowledge must be managed to ensure CE implementation in the construction industry (Charef et al., 2021; Munaro & Tavares, 2023a; Oluleye et al., 2022b) through (i) Creation of CE knowledge for the construction industry regarding the materials, processes, techniques, technologies, principles, and best practices that align with CE; (ii) Obtaining (acquiring) the created knowledge from reliable sources, (iii) Organising the knowledge to generate easily retrievable meaningful outcomes, (iv) Storing and/or distributing the organised outcomes to internal and external stakeholders of the construction industry, relevant cross-industries (e.g., manufacturing), policymakers and business innovators, (v) applying the identified CE knowledge in their contexts to enhance CE implementation, and finally, (vi) learn from applying knowledge, improve it, and feed the lessons learned from application to knowledge creation. The next section of this study reveals the conceptual framework developed for CE KM.

3.5 CONCEPTUAL FRAMEWORK

This section explains the conceptual framework developed for CE KM in the construction industry, which explains the necessity of CE transition in the construction sector, as conveyed in Figure 3.

Accordingly, two fundamental areas of CE and KM should be combined, identifying the critical areas of CE knowledge to be managed to ensure transition. Thus, the three main objectives of CE (Ellen MacArthur Foundation, 2016) and 12R CE principles (Collins et al., 2023) can be considered as the critical reinforcing knowledge to contemporise initiating solutions to current limitations of CE transition in the construction industry as discussed in Section 3.1. This information serves as inner layers of the conceptual framework, and this knowledge helps to manage enablers and barriers of CE implementation (Ababio & Lu, 2023) and formulate practices and strategies for improving CE in the construction industry. Steps of the KM cycle discussed in Section 3.3 have been integrated as the outermost layer of the conceptual framework, which is an effective procedure to synchronise information to address CE knowledge-led barriers for the construction industry and improve CE knowledge-led enablers for the construction industry as it includes all the steps of creating, acquiring, organising, storing, distributing, applying, and evaluating required knowledge for the implementation of CE practices in the construction projects and thereby transforming to a circular construction industry. This outer layer can be expanded with tailored and detailed CE KM strategies targeting different stakeholder groups, different project stages and different types of construction projects. While this framework does not replace all the existing KM studies, it will contribute to the KM domain by offering targeted and focused CE KM initiatives. Further, the outcomes of this study will assist in rendering current KM practices feasible.

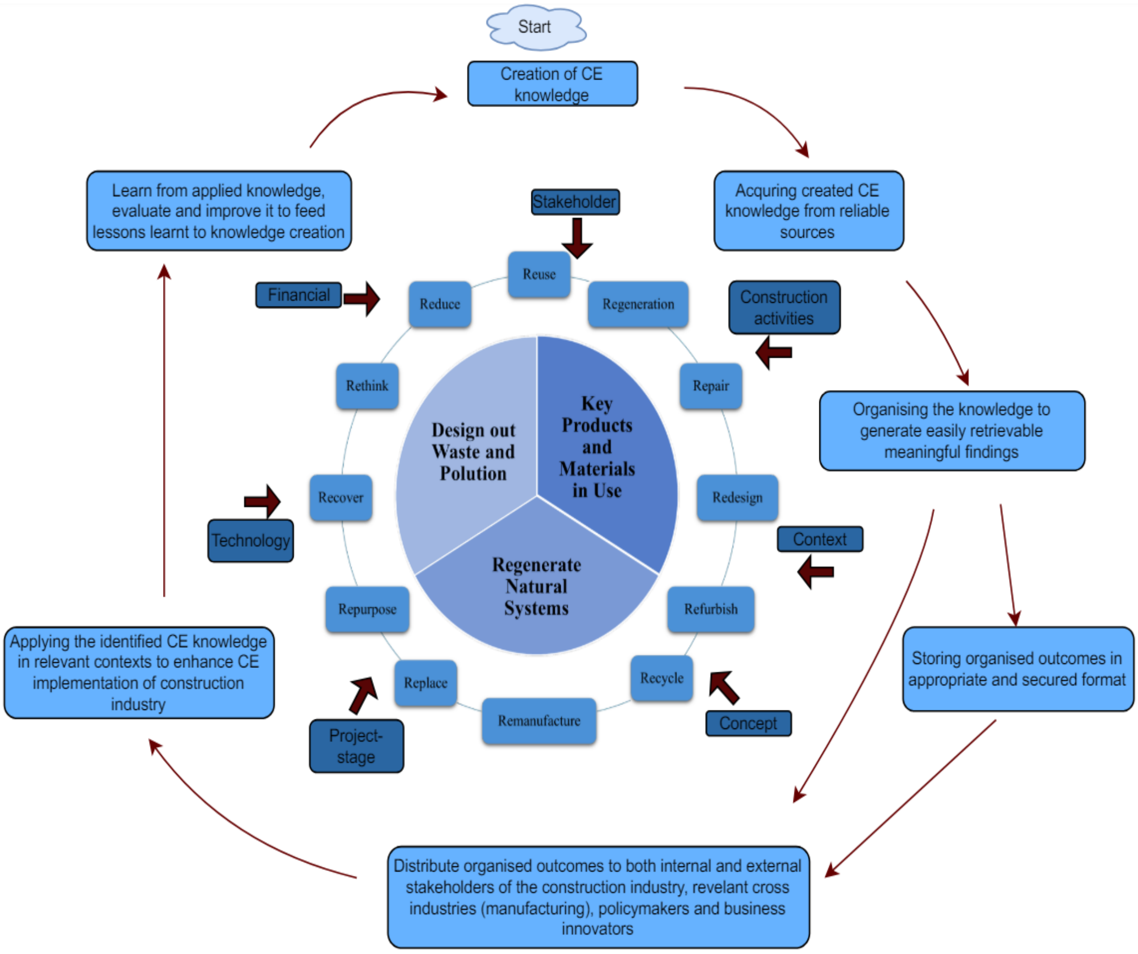

Figure 3: Circular economy knowledge management conceptual framework for the construction industry.

4. CONCLUSIONS

The construction industry, being resource-intensive, faces several challenges in the CE transition. CE knowledge has been acting as an overlaying force for these challenges, being related to different stakeholders, various stages of a project, activities of the construction process, and required technologies. Thus, a comprehensive literature review proposes a conceptual framework for CE KM by integrating CE principles, practices, and the KM cycle.

The findings highlighted that even though CE enablers and barriers have been categorised into distinct groups, knowledge serves as the primary link between them all. However, despite the extensive need highlighted in existing "CE in construction literature" to enhance CE knowledge, "how to do that" is rarely investigated. Although existing literature on CE and KM emphasises the importance of KM processes, it often lacks clarity in specifying their interconnections, thereby impeding the systematic and continuous adoption of CE. Hence, this study argues the suitability of the KM cycle over the KM process for CE transition in the construction industry.

The proposed conceptual framework insists on the shell view of CE principles, practices and KM. Accordingly, the execution of an outer shell requires inputs from the adjacent inner shell to tailor the context. This framework can be used as a basis to develop the CE KM model for the construction industry, targeting different stakeholders and various stages of the construction process. Moreover, this framework can be applied to targeting a particular category of enabler(s) or barrier(s) and/or R principle(s). This study has a few limitations. First, this literature review has not been limited to any geographical area, where some alterations may be needed to apply this framework to a particular country. Moreover, this framework needs to be validated with primary data which will be a limitation and a future research avenue.

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