Barriers to circular economy adoption and concomitant implementation strategies in building construction and demolition waste management: A PRISMA and Interpretive structural modeling approach

Abstract

Waste generated by building construction and demolition (BCD) activities contributes to the major proportion of urban solid waste. A large amount of the waste is still sent to the landfill or downcycled globally. The adoption of circular economy (CE) in the building construction industry (BCI) could leverage significant gain in managing the waste from BCD activities. While studies have been conducted on CE in the BCI, a comprehensive review of the barriers to CE adoption in building construction and demolition waste (BCDW) management is thus far limited. Hence, to bridge this research gap and provide an improved understanding, the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guideline was adopted to systematically explore related literature towards the development of a web of barriers, integrated framework, and implementation strategies for CE adoption in BCDW management. The barriers to CE adoption in BCDW management were gleaned from 23-countries and consolidated as institutional and regulatory barriers, technological and information barriers, and organizational barriers, among others. A blended conceptual framework indicating the causality and interrelationship among the groups of barriers was determined using the interpretive structural modeling (ISM) approach. Ultimately, an integrated basket of recommended implementation strategies were put forward to combat the identified barriers. Theoretically, this study has created a distinct character of the barriers to and strategies for the comprehensive promotion, implementation, and diffusion of CE in BCDW management. It has made a useful contribution to the existing literature through the mapping of a comprehensive co-existence and relationship among the barriers. This study has triggered a variety of empirically-based research studies on the barriers, drivers, and success factors to promote CE in BCDW from a developed and developing economies perspective in the future.

Keywords: Barriers; Building construction and demolition waste, Circular economy; Strategies

1. Introduction

The upsurge in urbanization of cities has engendered a series of environmental concerns, such as depleting natural resources, surged carbon emission, increased materials consumption, and overwhelming urban solid waste occupying the limited landfill spaces. This situation is more prominent in the BCI (the most resources intensive sector globally). Due to the improper management of the BCI resources vast BCDW is generated annually. Thus, the BCI has been characterized as the highest waste generator globally. For instance, the BCDW contributes to about 40% and 30% of the total solid waste generated in the United States and Europe respectively (Rios et al., 2021). By 2025, 2.2billions tonnes of BCDW would be generated globally (Schandl & Miatto, 2018). This confirms the entrenchment of the linear economy of *take, use, and dispose* in the BCI.

The linear economy is a system deficiency in sustainable resources management. In BCI, the linear economy is defective in sustainability attainment and cleaner production of resources (Akanbi et al., 2020). The increased pressure on finite resources has made natural resources conservation and sustainability a critical issue in the urban sector (Benachio et al., 2020; Jæger et al., 2021). In recent times, the BCI and other sectors globally were 10% circular in 2019 and 2020 on average (Ayçin & Kayapinar Kaya, 2021). Therefore, CE as a concept for promoting sustainable production and consumption of resources in the cities is being advocated for in the research and practice.

Circular economy has materialized as an economic system to curb the challenges of the linear economy and to promote *"waste to wealth"*. The term *"waste-to-wealth"* refers to the process of transferring the waste from a depleted utility level to a more desired one (Lacy & Rutqvist, 2016). Hence, transforming waste into a usable product via CE is considered a means of generating wealth. CE is aimed at elongating the useful life of resources while protecting resource value and eliminating waste (Bilal et al., 2020; Upadhyay et al., 2021c). The advantage of CE is enormous. Its relevance has been acknowledged in the coffee, mining, textile, and food sectors as a sustainable way of resource management (Hartley et al., 2022; van Keulen & Kirchherr, 2021). The cumulative benefits of CE in other sectors have made its adoption more imperative in the BCI.

Notwithstanding the strength of CE, its adoption is still in its infancy in BCDW management (Oluleye et al., 2022). This is evident in the monumental circularity gap in BCI. Thus, CE adoption cannot be in absence of barriers (Al Hosni et al., 2020). The transition towards a CE in the management of BCDW is militated by myriads of barriers (Mahpour, 2018). These barriers must be figured out to have a smooth circularity. Many countries are still struggling with the implementation of CE due to inadequate information on the barriers and the driving strategies for a successful circularity (Kirchherr et al., 2018). CE practices are not ubiquitous in the BCI. Hence, some strategies could enable its wide adoption under certain circumstances only if the barriers are understood from a global perspective.

CE research is thriving. Studies have been conducted on barriers to CE in the built environment. Many of these studies are contextual and none considered the uniqueness of waste in the BCI. Due to the fragmented nature of the BCI and the peculiarity of waste generated at end of life

(EoL), it is necessary to understand the barriers to CE adoption in BCDW. However, there exists a dearth of research on the review of the barriers to CE adoption in BCDW management at EoL and how they could be connected to the implementation strategies and stakeholders. The interrelationship among the group of barriers to CE in BCDW management is still underrepresented in literature. The progress of CE is ascertained based on the level of implementation and success attained, and there could be a reward of $4.5% to the economy if measures are taken on how waste could be transformed into wealth at a global level (de Jesus & Mendonça, 2018; Guerra et al., 2021).

Therefore, this study systematically explores related literature towards the development of a web of barriers, integrated framework, and implementation strategies for CE adoption. This study is one of the very first efforts to link the barriers to CE adoption in BCDW management with the appropriate implementation strategies and the concerned stakeholders: To achieve this aim, these research questions were conceived: (i) What are the barriers to CE adoption in BCDW management relayed in previous research studies? (ii) How do the CE barriers interconnect with one another? (iii) What are the potential implementation strategies and the appropriate stakeholders for overcoming these CE barriers? To achieve the research questions the paper poses some objectives viz: (i) Firstly, the preferred reporting items for systematic reviews and meta-analysis (PRISMA) approach was used to identify and summarise the barriers (ii) Secondly, the ISM and system thinking approaches were used to conceptualize the interrelationship among the group of barriers. (iii) and finally, the consolidated barriers informed the development of the implementation strategies. Thus, since this research is exploratory in nature, SLR, system thinking, and interview are considered necessary as a solution method over the questionnaire approach.

The developed framework and the implementation strategies can provide new lens that enables decision-makers to understand how the barriers are interconnected with the CE system and where change strategies should be implemented to enable CE development. Theoretically, the findings will contribute to CE literature by shifting attention from the overall BCI to the BCDW management which is a particular issue in the urban sector. The rest of this paper is structured as follows. Section 2 provides the theoretical background for this study. Section 3 describes the research procedures. Section 4 presents the results of the review, while Section 5 explains the barriers and implementation strategies. Section 6 presents the conclusion, implications of the study, and future research directions.

2. Theoretical background

2.1 CE development in the building construction industry (BCI)

CE is a regenerative and restorative industrial system. CE in construction is an all-encompassing umbrella concept that is deeply entrenched around waste management, resources management, and seeking to prolong resource life. More broadly, CE expresses the proclivity to extend the productive life of resources to produce value and mitigate value degradation (Upadhyay et al., 2019). CE is an alternative approach to linear economy; it is focused on changing the usual tendency of "take, make, dispose of" and extending the life of building resources by treating waste as useable materials (Jraisat et al., 2021). It is aimed at elongating the life span of products and resources and eliminating waste through efficient design and use of resources (Upadhyay et al., 2022). This concept has been demonstrated in empirical studies to be a pathway to cleaner production and construction resource conservation.

CE puts into consideration the following key features: increased remanufacture and repair of products, prolonged recycling of materials, more thriving long-lived materials through configuration and design, increased productivity of materials, enhanced asset utilization, and refashioned consumer behavior (Akinade et al., 2020; Kirchherr et al., 2017). The expected effect of these attributes includes a reduction in demand for virgin materials, secondary raw materials substitution in production, secondary sector expansion, and products becoming more durable and repairable (Agrawal et al., 2022; Kumar et al., 2019). CE operates at three levels viz: (i) micro-level (products, companies, and consumers), (ii) macro levels (city, region, countries, and more), and (iii) meso level (eco-industrial parks). The fundamental goal of CE in BCI is to break the link between economic growth and environmental deterioration, as well as resource consumption, using a contemporary manufacturing system (Upadhyay et al., 2021b; Upadhyay et al., 2021a). It is prompted by several schools of thinking, including cradle-to-cradle design, natural capitalism, blue economy, and performance economy. In waste minimization the 3R principles (recycling, reuse, and recovery) are the foundation of CE. The shift towards CE in BCDW management needs the implementation of various frameworks. The inherent significance of CE in the BCI is vast but its achievement is not free from barriers. Understanding these would be very useful in designing enablers and strategies for swift circularity in BCI.

2.2 Theoretical framework

CE adoption in BCI is a socio-technical issue. This implies that CE adoption requires an understanding of its social and technological dimensions. However, the socio-technical paradigm of CE is directly related to three principal theories viz: (i) Paradox theory (ii) Technology acceptance model (TAM), and (iii) Theory of planned behavior (TPB)

Paradoxes theory entails contradictory although interrelated phenomena that exist concurrently and persist over time in CE transition. The theory of paradox had gained some application in CE and circular business model literature. Moreover, TAM theory is centered around attitude, and intent which eventually affect the behavior of technological adoption. However, since this study is based on the social aspect of CE, thus, this research relies on the TPB as a veritable theoretical lens for CE adoption. Studies on the TPB model across sustainability disciplines are augmenting. Hence, this makes it more relevant in this study. The TPB developed by Ajzen (1991) forms the foundation for the barriers and drivers established in this study. The TPB posits that undertaking a CE behavior could be captured by three fundamental constructs: (i) personal attitude (*What are the implementation strategies or enablers for CE adoption*); (ii) subjective norms (*what are the social pressure to perform or not to perform a CE behavior*?); and (iii) perceived behavioral control (*What are the barriers to CE adoption*?). Thus, the theory in this study is built on the personal *attitude and perceived behavioral control*.

Ajzen (1991) explains the attitude as the degree to which one has a favorable or unfavorable evaluation of the behaviors in question. A positive or negative behavior respectively could strengthen or weakens CE adoption. In this study, attitude is considered as "the degree to which BCDW circularity is valued by decision-makers". Khan et al (2020) explain that decision-makers are often willing to promote environmental sustainability and implement CE. Therefore, it is assumed that decision-makers have a positive attitude towards CE adoption in BCDW management. Thus, decision-makers are expected to put some strategies in place to guide CE adoption such as CE polices development, secondary market promotion, and awareness creation on CE. These attributes could be ascribed as the enablers or drivers for promoting the attitude of people towards CE.

Ajzen (1991) described perceived behavior as the ease or difficulty of executing a certain behavior, often showing experience together with impediments and barriers. In CE adoption, perceived behavior could be affected by certain variables such as barriers or risk which may hamper or retard the probability of CE adoption. Thus, in this study, we consider the perceived intention behavior as "the barriers to CE adoption in BCDW management". Therefore, the two constructs (*attitude towards behavior, and perceived behavioral control*) often influence the willingness and intention of stakeholders and decision-makers towards CE adoption in BCDW management. In this study, and regarding TPB constructs explored in extant studies, the adoption of CE in BCDW management is usually determined by CE strategies/drivers/enablers and CE barriers. This is described as 'perceived behavioral control', and 'attitude towards behavior' (Fig. 1).

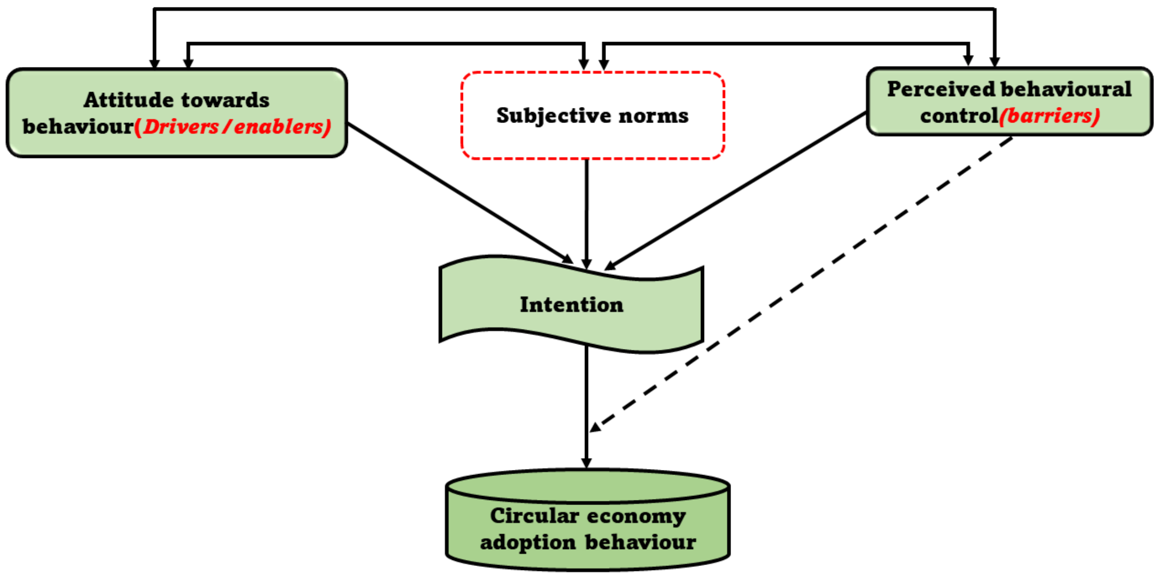

Figure 1: Theoretical framework for CE adoption based on TPB (Modified from Ajzen (1991))

3. Research methodology

This study was carried out by applying the interpretive philosophical approach using published articles as the elements of analysis. This approach ensures researchers' close interaction with the articles to understand concepts, and ideas and delineate new knowledge. This procedure has been used in sustainability literature in areas like CE in BCDW management, artificial intelligence in facility and construction management, and digital procurement. The operational application of this philosophy in this research was attained through a systematic review using the PRISMA approach in Fig. 2.

This review followed an evidence-based PRISMA approach to identify and summarize the barriers to CE adoption in BCDW. The approach contains two aspects (i) the systematic literature review (SLR), and (ii) the meta-synthesis. SLR is an important technique for determining the progress and state of art of research in a domain (Wuni & Shen, 2019). However, meta-synthesis is an approach that combines all the data obtained from the systematic review. Meta-synthesis is stronger than a single study analysis because of the increased number of articles analyzed (Leary & Walker, 2018).

Meta-synthesis adopts a qualitative research design through the integration of numerous interrelated studies (Finfgeld-Connett, 2018). It helps to advance phenomena and association with recent theoretical development by integrating interrelated qualitative studies. Meta-synthesis gives a methodical framework that enables researchers to recognize certain research questions (Paterson, 2011). This is accompanied by search, selection, evaluation, and integration of both qualitative and quantitative evidence as a solution to the identified question. Several notable reviews have adopted meta-synthesis in the construction domain. For example, Wuni and Shen (2020) adopted a meta-synthesis in a review of the barriers to modular integrated construction. Also, Saka and Chan (2019) adopted the same approach to review the development of BIM in Africa. Based on the meta-synthesis strength, it was adopted for collation and integration of the extracted CE barriers. Barriers with close meaning were consolidated and recast. In case of discrepancies, it was resolved by discussing them with the research team for better and more coherent naming. The framework of the research methodology is presented in Fig. 2.

3.1 Search strategies and snowballing sampling method

In collating the relevant articles, a comprehensive search was carried out in the Scopus database. The choice of Scopus rests rest on the fact that it has vast coverage, accurate, easy to retrieve articles from it relative to Web of Science and other databases The specific theme-based keywords used for the search include: ‘circular economy’, ‘circularity’, ‘circular business’, ‘barrier*’, ‘critical barrier*’, ‘challenge*’, ‘problem*’, ‘factor*’, ‘constraint*’, ‘waste management’, ‘construction waste’. A wild card (*) was attached to certain words to include their plural form during the search. Sequel to the result generated from the first-round search, a combination of *forward* and *backward snowballing* approaches was conducted to evade the omission of relevant articles.

3.2 Inclusion and exclusion criteria

The criteria for inclusion and exclusion were used for benchmarking literature selection. In this study, the inclusion yardstick encompasses the following major points: (i) studies have a strong connection with CE in BCI (ii) studies considered the barriers to CE in waste management (iv) studies considered the barriers to CE at building end of life. Because of the embryonic stage of CE in the built environment, this inclusion criterion was developed to construct the barriers to CE from a large body of research. The exclusion criteria also entail some major factors viz: (i) the study language was not English (ii) the full text of the articles is not available. To ensure relevant studies were not left out, there was no special restriction in selecting literature based on types of articles, publication years, and countries.

3.3 Articles content review

Based on the initial screening conducted, 490 articles were noted to be relevant to this study. The content of the 490 articles was reviewed and those whose abstracts focused on CE were retained, and this resulted in 145 articles. Further screening was done by downloading the articles to read the full text and at this stage articles without full text were excluded. After reading the full text, only 32 articles sailed through and were adopted for the review as they have the requirements for their inclusion. Due to the small number of articles, 6 more articles were identified via backward and forward snowballing. This makes the total number of articles adopted to be 38 (that is, 32 from Scopus and 6 from snowballing).

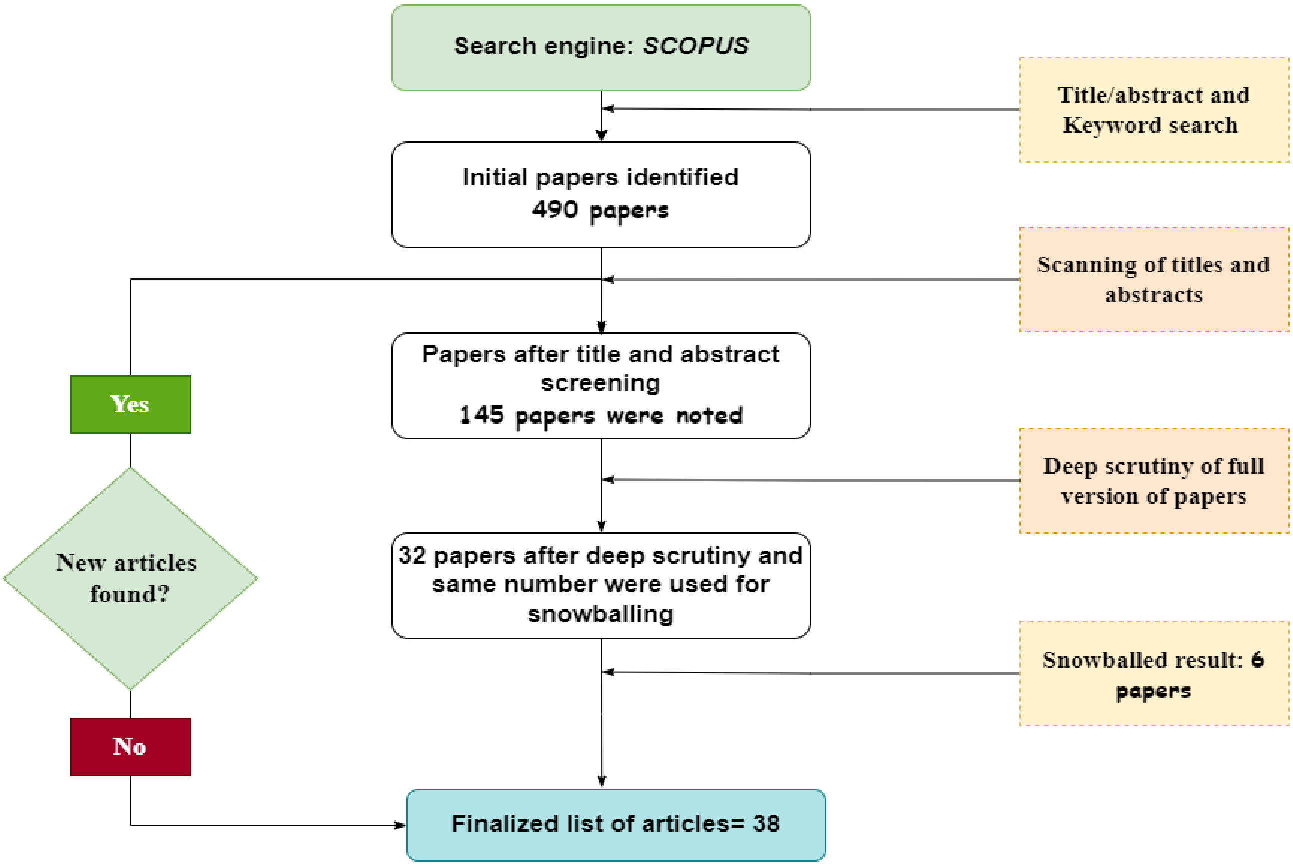

Figure 2: Flow diagram of literature selection for review

4. Results and discussion

4.1 Attributes of the retrieved papers

At the time this study was undertaken, it was revealed that at least 38 studies on the barriers to CE in BCDW management had been published. This number made it clear that great importance has been attached to the barriers over times-this is because of the yearnings of the

4.2 Yearly distribution of the retrieved articles

This research covers the period from 2015-to 2021 (Fig. 3). There was a steady rise as seen in Figure 3 in the number of articles published from 2015-to 2019 with a total number of 17 articles. However, 2021 recorded a major landmark with 19 articles. This significant rise implies that there has been a credible researcher's commitment to having a clearer picture and understanding of the barriers to CE in BCDW management. Finally, it should be noted that this research was conducted in late 2021, therefore the data collected for 2022 is not captured.

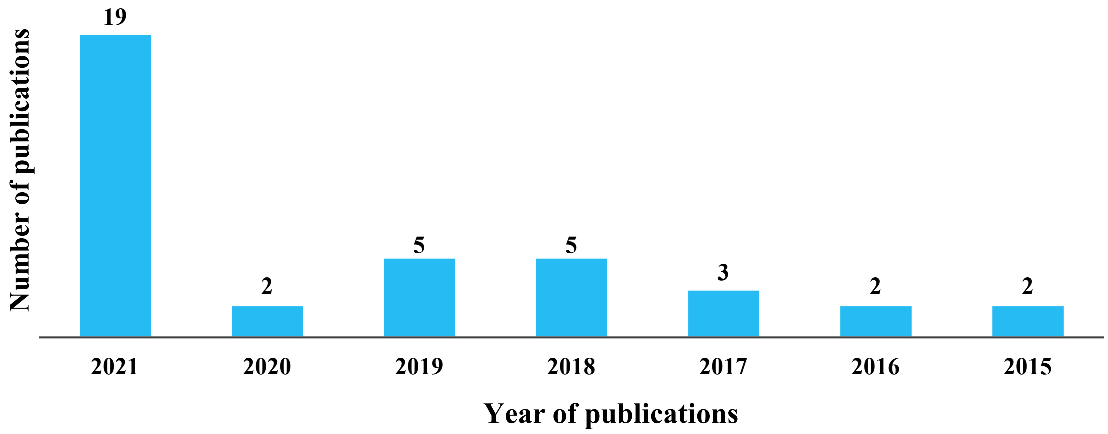

Figure 3: Annual distribution of selected articles over a period of 2015-2021

4.3 Analysis of barriers to circular economy in BCDW management based on articles from 23 countries

Cirular economy is now widely regarded as a stepping stone toward the management of BCDW and the consumption system. (Osobajo et al., 2020). The shift towards CE in BCDW management has a crucial economic and environmental effect on all economies (Superti et al., 2021). Furthermore, knowing the extent to which it happens, and the barriers associated with it may have a bigger impact on environmental management and policy across many economies. The diffusion of CE as an innovative and regenerative economy is evaluated based on the expected satisfaction and inherent benefits attached to it (Hossain et al., 2020). The comprehensive acceptance of CE in the BCI requires an overall transformation of the production and consumption system of the industry. BCI is sluggish in changing its system of production and consumption, it, therefore, means that proper widespread and implementation of CE in all economies are bedeviled by myriads of complicated issues.

Since the barriers to the implementation of CE in BCDW management differ across nations of the world due to the uniqueness of each country and level of development, and also country-specific research on barriers cannot be used to draw conclusions for the globe although it could be referred to as motivating the need to integrate all the barriers from various economies to have a better, concise and useful information on barriers to CE adoption in managing BCDW. Having done a rigorous search of barriers, 33 barriers were extracted from the extant literature. They were later grouped to have a better understanding and later consolidated into a sole-concise framework. The clustering of these barriers was done with attention to the lesson learned from the previous grouping in the extant literature. This was carried out in order to eliminate researchers' prejudice and subjectivity. The grouping of these barriers becomes necessary because it provides a better way of examining the barriers without complications. The categories of the barriers are presented in Fig. 4 and 5

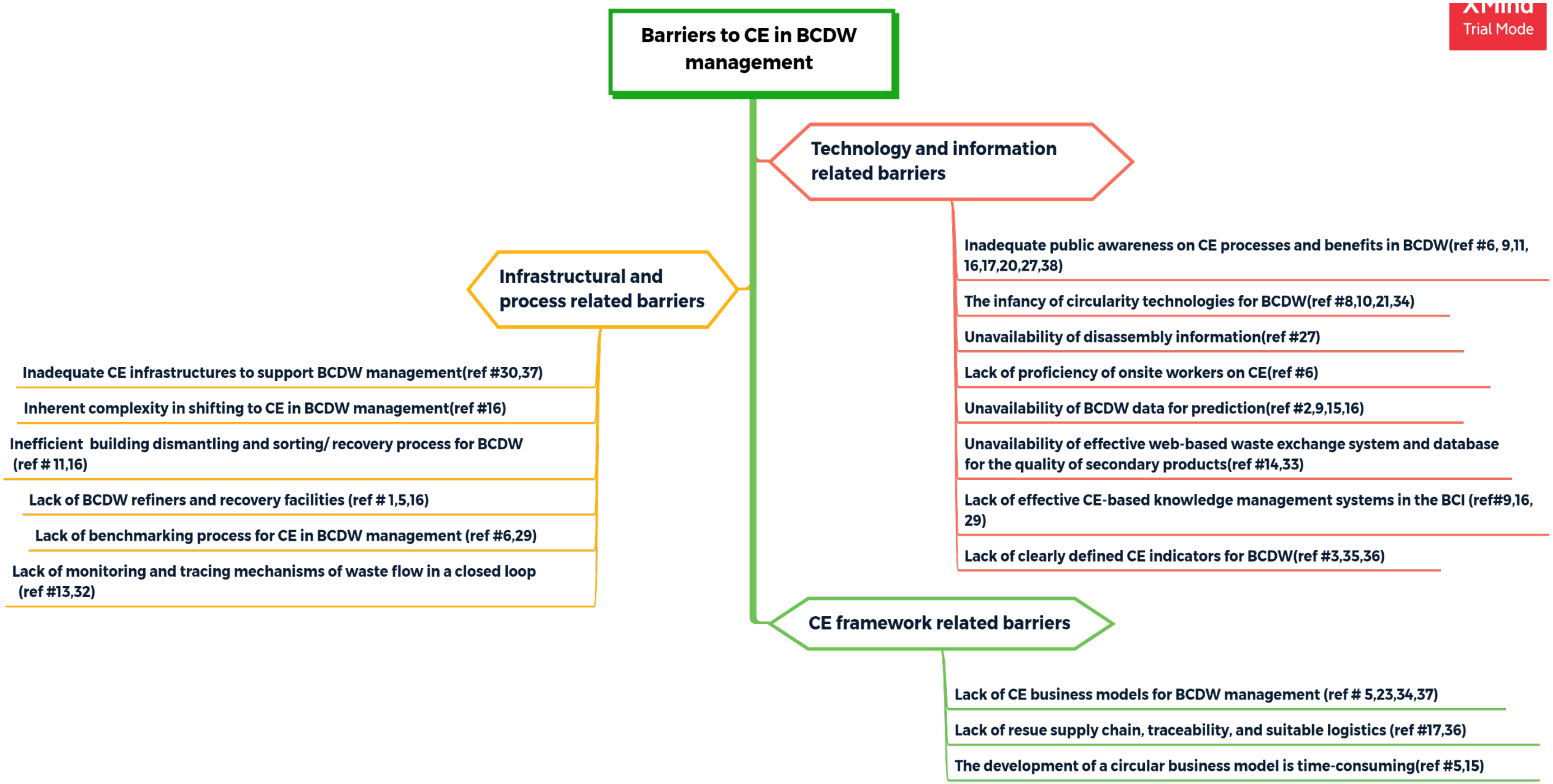

Figure 4: Web of barriers to CE adoption in BCDW management (*technology and information, infrastructural and process, and CE framework barriers*)
Note: ref= references; (#): refers to Appendix (A) for the references

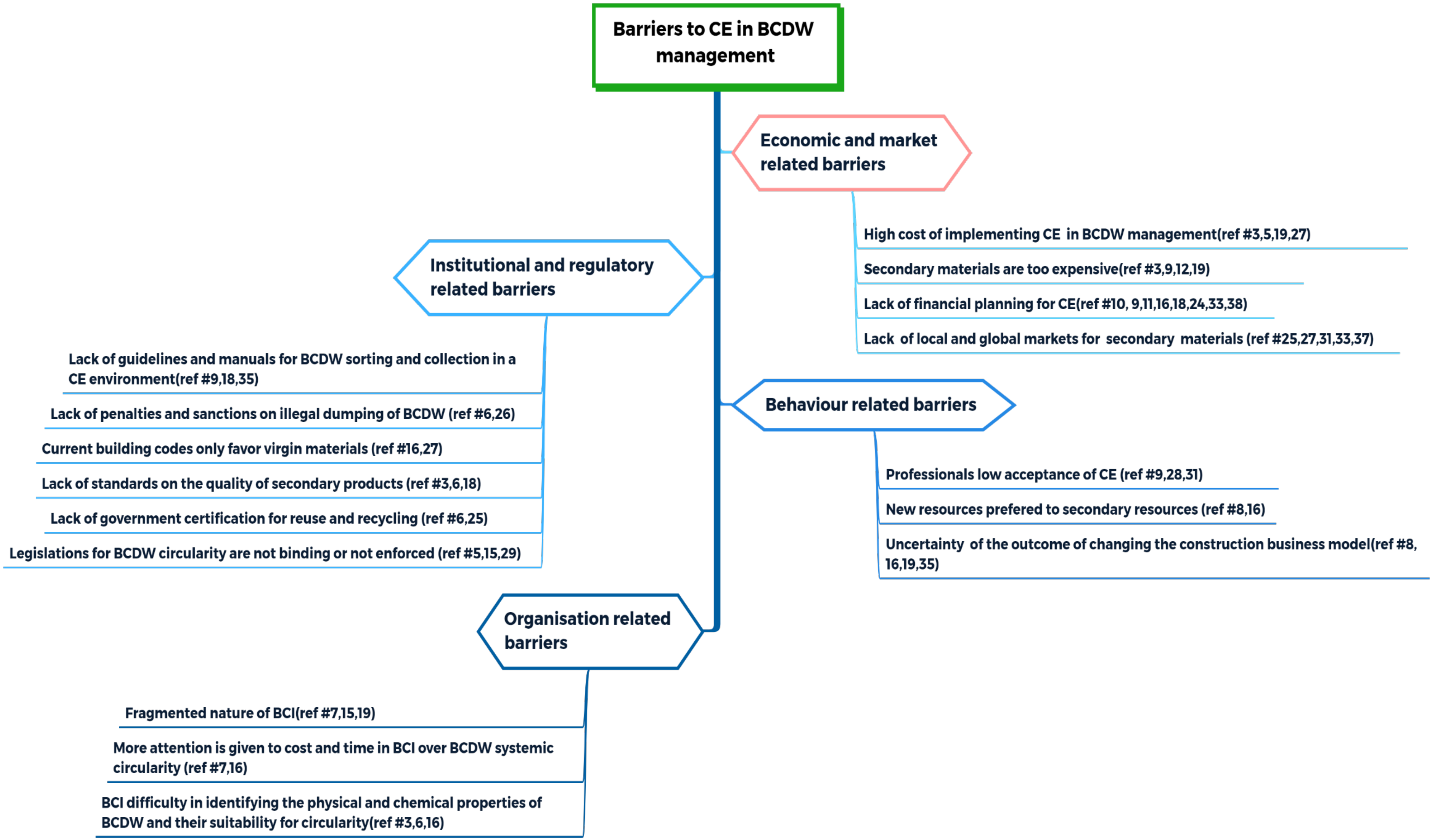

Figure 5: Web of barriers to CE adoption in BCDW management (*economic and market, institutional and regulatory, and organization related barriers)*

Note: ref= references; (#): refers to Appendix (A) for the references

5. Discussion of review findings

5.1 Clusters of barriers to CE adoption in BCDW management

5.1.1 Institutional and regulatory related barriers

Appropriate institutional and regulatory parameters are needed for the smooth transition to CE. These are machinery required to promote the adoption and implementation of CE initiatives (Liu et al., 2021). The regulatory parameters entail legal mechanisms and agglomerations of formal structures that prevail in any economy both developed and developing (Mahpour, 2018). These could be coercive (laws, regulations, rules, and norms) or mandatory (codes of conduct, and integrity pacts). However, the institutional and regulatory barriers to CE in BCDW identified in this study are related to rules, standards, and guidelines with six sub-barriers (Fig.5). The most critical based on citations in the literature include lack of guidelines and manuals for collection and sorting of BCDW and lack of standards on the quality of secondary materials.

The importance of guidelines and manuals for BCDW management has been greatly acknowledged by previous research. The present guidelines are not comprehensive enough to ensure the wider diffusion of CE in BCI in all economies (Bilal et al., 2020; Mahpour, 2018). Also, there is a great prodigious lacuna between the expected achievement by the constitution of regulations and what could be achieved by the regulations implemented. Moreover, some of the clauses in regulations in developed and developing economies are still very general and it becomes very difficult to abide by the clauses in execution (Liu et al., 2021). For example, in China, where BCDW transport and disposal measures were implemented, the regulations seem very deficient as it focuses more on the charging of BCDW disposed at landfill (Liu et al., 2017). The lack of standards on the quality of secondary materials is another factor making the adoption slow and stunted. As a result of these cumulative regulatory and institutional barriers, countermeasures still become necessary to avert the loopholes in BCDW regulation in a CE.

5.1.2 Technological and information related barriers

The adoption of a new paradigm in any organization would be possible and faster if information and relevant technology are available to push it forward. Although the concept of CE is dated back to 1970, the mystery attached to the regenerative economy has not been well understood by many industrial practitioners and stakeholders. Knowledge of CE especially in BCDW management could be acquired through information gotten from seminars, training, research, and formal education (Ormazabal et al., 2018). Previous studies are still limited on the technologies necessary to enable CE adoption (Quiñones et al., 2021). The available studies are too generic as technologies in BCI could not be applicable in other sectors due to the distinct nature of the industry. In this study, eight barriers identified from the literature were classified under this category (Fig. 4). Out of these, the most referenced are the infancy of circularity technologies for BCDW management, inadequate public awareness of the process and benefits of circularity in BCDW, unavailability of BCDW data for prediction, and lack of effective knowledge management on CE and lack of clearly defined CE indicators (Huang et al., 2018).

Modern technologies such as artificial intelligence, and blockchain are viable for implementing a systemic shift to a CE in BCI. But this is still limited, which has affected automated circularity. Also, inadequate awareness and lack of proper knowledge management on CE in BCDW have been entrenched in the BCI (Huang et al., 2018). This often influences the diffusion of appropriate knowledge on CE among experts. For example, the previous generation of construction graduates was not opportune to gather formal knowledge on CE (Liu et al., 2021; Mahpour, 2018). As a result of this, there exist limited experienced onsite experts in CE in the BCI. Thus, the role of information in promoting CE is now very germane. Accordingly, the public, construction professionals, and other practitioners' current experience levels cannot promote the diffusion of CE in BCDW management. This limited knowledge has metamorphosed into poor experience levels among practitioners and stakeholders in the BCI (Bilal et al., 2020).

Systemic circularity decision in the BCI is guided by data on materials and waste. Yuan (2017) asserted that statistical information and data on BCDW are key to understanding how urgent it is to minimize BCDW. The BCDW data gives reliable information which is useful for planning and coming up with BCDW management strategies and predictions in a CE (Akanbi et al., 2020). Although, the Environmental Protection Agency (EPA) in different economies is saddled with the responsibility for the well-organized statistics and release of solid waste and (BCDW inclusive) projection data, especially in the USA, Australia, and Hong Kong (Zhang et al., 2019). Despite this, there still exists a dearth of statistical work focusing on the collection of basic data on BCDW.

5.1.3 Organization related barriers

The performance of any sector is a function of the management system and innovative strategy put in place within the organization. The BCI is sluggish in adopting a regenerative business model due to its fragmented nature (Mahpour, 2018; Ratnasabapathy et al., 2021). These fragmented attributes of the BCI have affected the adoption and diffusion of CE in the management of BCDW in BCI. Although BCI has a greater potential to adopt CE, the industry is always slow to innovative strategies. This is far-fetched from the fact that BCI requires a drastic change in structure and business operation for waste management in a CE (Liu et al., 2021). In this study, three organization-related barriers were identified to militate the transition to CE in BCDW management (see Fig. 5). Among these, the fragmented nature of BCI and difficulty in identifying the properties of BCDW and their suitability for circularity in the BCI are the most spelled-out barriers in the literature (Ormazabal et al., 2018).

The fragmented attribute of the BCI at both management and project implementation level is challenging as it affects the move towards comprehensive CE in the BCI (Kanters, 2020). At the management level, there exist so many fragments that often times are not well connected (Mahpour, 2018). Also, the nature of CE requires integration of the overall business process in an organization as an entity. But in the BCI, the situation is different due to inadequate integration of processes. In all, it will be challenging to promote the regenerative CE for managing BCDW if the BCI remains fragmented. According to Yuan (2017), difficulty in identifying the properties of BCDW and their suitability for circularity in the BCI. Therefore, the way forward is to proffer promotion strategies that would help in mitigating these rooted challenges.

5.1.4 Behavior related barriers

Individual attitudes and values towards a new system are very important for a successful implementation. Three behavior-related barriers to CE adoption in BCDW management were identified in this study (Fig. 5). The most cited among these barriers in literature are the uncertainty of the outcome of changing the construction business model, and the professional low acceptance of CE (Shahbazi et al., 2016). Doubt in the mind of stakeholders and practitioners on CE remains a major setback to its adoption (Jaeger & Upadhyay, 2020). The fact that BCI is conservative makes changes very difficult as new business model adoption is crippled with uncertainty on results and effectiveness based on the perception of the professionals. In developing economies, for example, the uncertainty of the aftermath of shifting towards CE is one of the major barriers plaguing the adoption of CE in their construction industry (Mahpour, 2018).

5.1.5 Infrastructural and process-related barriers

The infrastructure and effective process for effective waste management in a CE is major problems in many economies (Grafström & Aasma, 2021). The adoption of CE in BCDW requires numerous infrastructures (Salmenperä et al., 2021). Due to the complexity of BCI, the process requires proper planning, coordination, and management. Therefore, successful CE adoption requires adequate integration of various processes without overlooking the needed infrastructural requirements. Fig. 4 revealed 6-related barriers to CE adoption in BCDW under this heading.

Inadequate infrastructure to support BCDW management and the unavailability of construction waste refiners and recovery facilities are significant intertwined barriers. These barriers have affected the estimation and sorting of BCDW generated in the BCI. In the same way, the high cost of these infrastructures has resulted in the inability of many economies to acquire them in managing BCDW (Salmenperä et al., 2021). Similarly, the onerous process of shifting a CE is another major barrier affecting the adoption. This has led to the difficulty in monitoring and tracing waste flow in the BCI.

5.1.6 Economic and market barriers

The transition towards CE in the management of BCDW involves a larger capital outlay and a thriving market for secondary construction products (Bilal et al., 2020; Yadav et al., 2020). As a result, this study grouped barriers related to CE market condition, economic climate, cost, and finance under the economic and market-related barriers with 4-sub barriers

Most of these barriers in Fig. 5 are linked to cost and market issues. At a basic level, CE initiatives in the BCI require consideration of the financial commitment in the form of cost and the availability of the market for the secondary product (Shooshtarian et al., 2021). One crucial economic and market-related barrier is the lack of financial and systemic planning for CE. This study confirmed that a significant financial capital outlay is required to develop CE-based industries, produce durable materials, hire skilled manpower and purchase necessary equipment and technology. The high capital and finance for CE development have a way of leading to a high cost of secondary materials which is another significant barrier (Antwi-Afari et al., 2021). In most cases, the high cost often leads to an increase in the price of secondary materials in the market thus reducing demand for the secondary product, which is another major problem. The fact that virgin materials are often cheaper than circular materials is another significant barrier creating a lack of demand in the market. Another significant barrier is lack of market for CE materials (Akinade et al., 2020). In most economies, the market mechanisms for product recovery are absent which is very much evident in the recycled product market (Mahpour, 2018). The view on quality and uncertainties of supply is one of the major problems surrounding the underdevelopment of the market (Hossain et al., 2020).

5.1.7 Circular economy framework related barriers

Framework and models are effective roadmaps that organizations could mimic in implementing changes. In a CE, the imperativeness of the framework is crucial since all the strategies of CE are conceptualized in an interrelated framework (Norouzi et al., 2021). The transition to CE would be slow without a credible business model and framework (Salmenperä et al., 2021). However, in this study, three barriers were classified under these headings as seen in Fig. 4. They include a lack of a holistic CE business model for BCDW, a lack of reuse supply chain, and traceability, and the development of a circular business model (CBM) for BCDW is time-consuming (Salmenperä et al., 2021). The CBM is often designed to reconfigure the use of construction material resources to promote waste reduction and environmental improvement (Guerra, 2021).

There is a dearth of a complete CBM in BCDW management, which encompasses a circular supply model, a resource recovery model, product-life extension, a sharing model, and a product-service system. (Benachio et al., 2020). This has however created a big challenge on the pathway to effective BCDW management in a CE. Another critical barrier is the inappropriate supply chain in a CE framework or model, this has created a delay on the road to circularity in BCDW management. In transitioning to CE in BCI, framework implementation should be based on closing the loops, slowing the loops, and narrowing the loops.

5.2 CE Barriers in BCDW management in comparison with other sectors

Certain barriers to CE adoption in BCDW management are often peculiar to the core practice and structure of BCI. Hence, they are distinct and unique relative to other sectors. However, some barriers still cut across other sectors like coffee and textile. Therefore, it is necessary to provide some comparison of how the barriers to CE in BCDW differ from or are similar to that of other sectors. For example, the fragmented nature of BCI, lack of demolition record and data, inadequate demolition auditing, and lack of disassembly information are barriers that are quite special to CE adoption in BCDW management. Despite the imperativeness and the uniqueness of barriers to CE adoption in BCDW management, there still exist some barriers that cut across other sectors. Barriers under the umbrella of policy, information, awareness, and technology in BCI also applies to coffee, textile, and mining sectors (Kirchherr et al., 2018; van Keulen & Kirchherr, 2021). Lack of guidelines and policies and lack of government support for CE are found not only in the BCI but also in the mining, food, plastic, and textile sectors (Hartley et al., 2022). Moreover, it is generally acknowledged that in managing waste in a CE in any sector (coffee, textile, mining, food, plastic, and leather), lack of CE model, fear of the outcome of shifting to a CE, lack of market for secondary products, lack of appropriate

CE technology, lack of CE standards and lack of consensus on the CE indicators are common barriers.

5.2 Interpretive structural modeling results on barriers to CE adoption in BCDW management

To develop a comprehensive conceptual model of the relationship between the groups of barriers, experts' interviews and a system thinking approach were adopted. This was done to rationalize the argument for the developed framework. The authors utilized this approach to establish the interrelationships of the barriers. (*i* and *j*) by adopting the symbols (V, A, X, O). This was used to develop the interpretive structural model (ISM) matrix in Table 1. The ISM matrix was later turned into a reachability matrix by substituting 1 and 0 for the symbols V, A, X, and O according to the principles outlined below:

(1) V: Barrier *i* influences *j* and *j* does not influence *i*.

(2) A: Barrier *j* influences *i* and *i* does not influence *j*.

(3) X: Barrier *i* influences *j* and *j* also influences *i*.

(4) O: Barrier *i* and *j* have no links

Rules for converting to reachability matrix:

If the cell (*i, j*) is V, then cell (*i, j*) entry is 1 and cell (*j, i*) entry is 0.

If the cell (*i, j*) is A, then cell (*i, j*) entry is 0 and cell (*j, i*) entry is 1.

If the cell (*i, j*) is X, then cell (*i, j*) entry is 1 and cell (*j, i*) entry is 1.

If the cell (*i, j*) is O, then cell (*i, j*) entry is 0 and cell (*j, i*) entry is 0.

Table 1: ISM matrix of barriers to CE adoption in BCDW management

ID	Barriers to CE adoption in BCDW management	β_7	β_6	β_5	β_4	β_3	β_2	β_1
β_1	Institutional and regulatory related barriers	V	V	V	V	V	X	
β_2	Technological and information related barriers	V	V	V	V	V		
β_3	Organization related barriers	A	X	X	X			
β_4	Behavior related barriers	O	X	X				
β_5	Infrastructural and process-related barriers	A	A					
β_6	Economic and market-related barriers	A						
β_7	Circular economy framework related barriers							

Table 2: Initial Reachability Matrix of barriers to CE adoption in BCDW management

	β_1	β_2	β_3	β_4	β_5	β_6	β_7
β_1	1	1	1	1	1	1	1
β_2	1	1	1	1	1	1	1
β_3	0	0	1	1	1	1	0
β_4	0	0	1	1	1	1	0
β_5	0	0	1	1	1	0	0
β_6	0	0	1	1	1	1	0
β_7	0	0	1	0	1	1	1

5.2.1 Final reachability matrix

The transitivity technique was used to calculate the final reachability matrix from the original reachability matrix. It is a fundamental tenet of ISM: if barrier A is connected to barrier B, and B is connected to barrier C, then A is unquestionably tied to C. This could be achieved by examining each barrier manually via a loop statement. This manual approach could be prone to error and time-consuming. As a result, the Python function blow was adopted to examine the transitivity. This was important to enhance the accuracy as adopted by (Saka & Chan, 2020).

```
def transitiveClosure (matrix):
    result = ""
    length = len(matrix)
    for k in range(0, length):
        for row in range(0, length):
            for col in range(0, length):
                matrix[row] [col] = matrix[row][col] or (matrix[row][k]
and matrix[k][col])
        result += ("\n W" + str(k) +" is: \n" + str(matrix). replace("],"
, "] \n") + "\n")
    result += ("\n Transitive closure is \n" + str(matrix).replace("],"
, "]\n"))
    print (result)
    return result
transitive Closure (Barriers)
```

Table 3: Final reachability matrix

	β_1	β_2	β_3	β_4	β_5	β_6	β_7
β_1	1	1	1	1	1	1	1
β_2	1	1	1	1	1	1	1
β_3	0	0	1	1	1	1	0
β_4	0	0	1	1	1	1	0
β_5	0	0	1	1	1	1*	0
β_6	0	0	1	1	1	1	0
β_7	0	0	1	1*	1	1	1

Note: * Transitive values; Dpp dependence power; Drp –driving power

5.2.2 Reachability matrix partitioning into different levels

The antecedent and reachability set for the specific barrier are indicated in the final reachability matrix. The variables included in the reachability sets include the variable itself as well as the factors that allow it to be achieved. The antecedent sets entail the variable itself and those variables that assist to reach it. The variables set intersection for all variables was obtained. The barriers level with similar reachability and intersection set are portioned to a given level. Having figured out the top-level variables, they were discarded from other variables. At the level I, as presented in Table 4, are organization barriers (β_3), behavior barriers (β_4), infrastructural and process barriers (β_5), and economic and market barriers (β_6). Since these barriers are at a level I, they will come on the top in the ISM conceptual framework. The same procedure was carried out until the levels of all barriers were decided that is institutional and regulatory barriers (β_1) and technology and information barriers (β_2) occupy level II while circular economy framework barriers occupied level III. The iterations were presented in Tables 4 to 6. The levels of the barriers determined their respective positions in the conceptual framework. The levels further assisted in building the integrated framework of ISM as seen in Fig. 8.

Table 4: Partition level I, II, and III

Group	Reachability Set	Antecedent Set	Intersection	Levels
Partition level I				
β_1	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	β_1, β_2	β_1, β_2	
β_2	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	β_1, β_2	β_1, β_2	
β_3	$\beta_3, \beta_4, \beta_5, \beta_6$	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	$\beta_3, \beta_4, \beta_5, \beta_6$	I
β_4	$\beta_3, \beta_4, \beta_5, \beta_6$	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	$\beta_3, \beta_4, \beta_5, \beta_6$	I
β_5	$\beta_3, \beta_4, \beta_5, \beta_6$	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	$\beta_3, \beta_4, \beta_5, \beta_6$	I
β_6	$\beta_3, \beta_4, \beta_5, \beta_6$	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	$\beta_3, \beta_4, \beta_5, \beta_6$	I
β_7	$\beta_3, \beta_4, \beta_5, \beta_6, \beta_7$	$\beta_1, \beta_2, \beta_7$	β_7	
Partition level II				
β_1		β_1, β_2	β_1, β_2	
β_2	$\beta_1, \beta_2, \beta_7$	β_1, β_2	β_1, β_2	
β_7	β_7	$\beta_1, \beta_2, \beta_7$	β_7	II
Partition level III				
β_1	β_1, β_2	β_1, β_2	β_1, β_2	III
β_2	β_1, β_2	β_1, β_2	β_1, β_2	III

Table 5: Driving power and Dependence power of Barriers to CE adoption in BCDW management

	β_1	β_2	β_3	β_4	β_5	β_6	β_7	Drp
β_1	1	1	1	1	1	1	1	**7**
β_2	1	1	1	1	1	1	1	**7**
β_3	0	0	1	1	1	1	0	**4**
β_4	0	0	1	1	1	1	0	**4**
β_5	0	0	1	1	1	1*	0	**4**
β_6	0	0	1	1	1	1	0	**4**
β_7	0	0	1	1*	1	1	1	**5**
DPP	**2**	**2**	**7**	**7**	**7**	**7**	**3**	

*Note: *Transitive values; Dpp –dependence power; Drp –driving power*

5.2.3 MICMAC analysis of barriers to CE adoption in BCDW management

MICMAC was used to group the barriers into four categories as seen in Fig 7. The four groups are autonomous, dependent, linkage, and independent. Institutional and regulatory related barriers (β_1), technological and information related barriers (β_2), and circular economy framework related barriers (β_7) are in the independent quadrant thereby implying that they have a high driving power but low dependence power. Organization related barriers (β_3), behavior-related barriers (β_4), infrastructural and process-related barriers (β_5), and economic and market-related barriers (β_6), occupies the linkage quadrant connoting that they are unstable. The barriers in this quadrant are unstable and any actions on them not only affect others but also have a spillover effect on them. No barriers exist under the autonomous (have low driving power and low dependence) and dependent quadrant (with low driving power but high dependence). Thus, all barriers under deliberation in this study are imperative and have significant consequences on the adoption of CE in BCDW management.

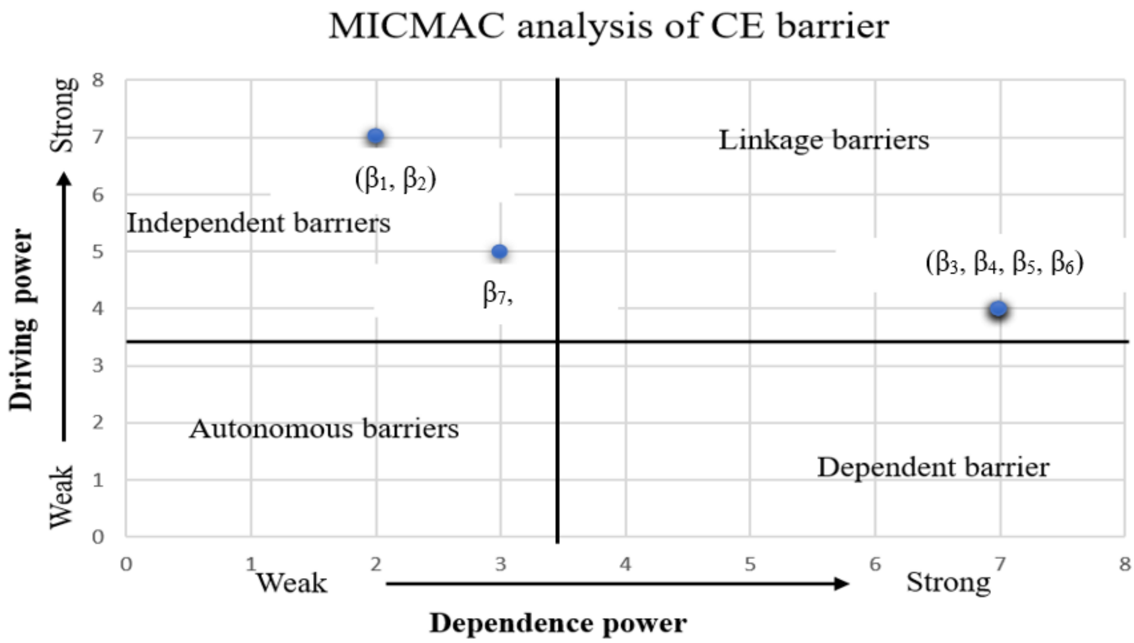

Figure 6: Cluster diagram of barriers to CE adoption in BCDW management

5.3 Blended conceptual framework of the profound barriers to CE adoption in BCDW management

In this study, a blended integrated framework was developed for barriers to CE adoption and diffusion in BCDW management. The blended framework integrated all the identified barriers to CE adoption in BCDW management. Fig 7 revealed a conceptual ISM of the barriers to CE adoption in BCDW management. The model was developed based on experts' interview and system theory (a holistic approach that considers the interrelationship among basic ingredients of a system and their pattern of relationship), the identified levels of barriers to CE, and the final reachability matrix from the ISM. This present study carries out a distinctive development of Bilal et al. (2020) where a simple ISM was developed to explore the relationship among the individual barriers to CE adoption in BCI. This present study makes a credible extension of the study through the modeling of intrinsic and extrinsic interactions among the barriers. Since many of these barriers are not sensitive to a particular geographical area, therefore, this framework is unique as it gives a holistic view of barriers from different country-context (developed and developing) which was absent in the study of Bilal et al. (2020). This is necessary to achieve generic and integrated global driving strategies to annul the barriers.

After all transitive relationships were eliminated, the framework was conceptualized. In Fig.7, several fundamental observations exist. Firstly, the consolidated barriers are on three distinct levels. Also, arrows were used to indicate the direction of the relationship between any two barriers. It is also observed that the barriers at the lower-level influence those at the upper level. From the framework in Fig. 7, economic and market-related barriers (β_6), behavior-related barriers (β_4), infrastructural and process-related barriers (β_5), and infrastructural and process-related barriers (β_6) occupied the highest level. Circular economy framework-related barriers (β_7) occupied the second level while technology and information-related barriers (β_2) and institutional and regulatory-related barriers (β_1) occupied level three.

From Fig. 7, it could be inferred that two clusters which include institutional and regulatory related barriers (β_1) and technology and information related barriers (β_2) have at least 3 interactions with other barriers. The clusters with less interaction with other clusters include organizational (β_3), behavior (β_4), infrastructural and process (β_5), economic and market (β_6), and circular economy framework (β_7) related barriers. Although they have less interaction, they are imperative in this study. Paying attention to the less interactive barriers will have a transferred effect on the more interactive barriers. Therefore, all cluster of barriers is considered imperative in this present study. Fig. 8 revealed that technology and information barriers (β_2) influence organizational (F3), behavior (β_4), infrastructural and process (β_5), and economic and market (β_6) barriers. For example, the lack of enabling technologies for CE and lack of awareness of CE has made its adoption process difficult in organizations dealing with BCDW management (Mahpour, 2018). The relationship between these barriers shows the degree to which lack of enabling technologies for CE, lack of proficiency of onsite workers on CE, and lack of awareness of CE are impeding the wider adoption of CE in BCDW management (Bilal et al., 2020). Among others clustered in Fig.7, similar interactions can also be observed.

The distinction between the technology and information related barrier (with the highest interaction) as indicated in Fig. 7 revealed that the success of CE in this dispensation must be grounded on innovative technologies and clear information on success factors, benefits, operational procedures, and innovative strategies to boost CE adoption and implementation in BCDW management(Rios et al., 2021). Institutional and regulatory-related barriers also is very prominent (based on interaction with other clusters of barriers). According to Mahpour (2018), the absence of regulations, policies, standards, and manuals supporting the need to adopt CE in the management of waste in BCI in many countries is an entrenched problem for the persistent dominance of the linear economy system. Adoption of CE could be mandated via laws and policies but also various conditions and factors must be integrated to make CE adoption possible and worthwhile (Bilal et al., 2020)

Other important interactions among the barriers are also noticed. For example, lack of proficiency of onsite workers, lack of financial planning for CE, lack of circular business model for BCDW management, and lack of manuals for CE in BCDW management is partly responsible for poor operational challenges faced in the management of BCDW (Mahpour, 2018) such as the acquisition of infrastructure and facilities for sorting. The preference for new construction resources over secondary resources and the lack of public awareness of the benefits of CE partly leads to a lack of market for secondary resources. Furthermore, the secondary and behavior-related barriers have interaction. The expensive nature of secondary materials would lead to a lack of demand which would affect the market for secondary materials. Other profound interactions within the framework in Fig.7 are clear and straightforward to comprehend.

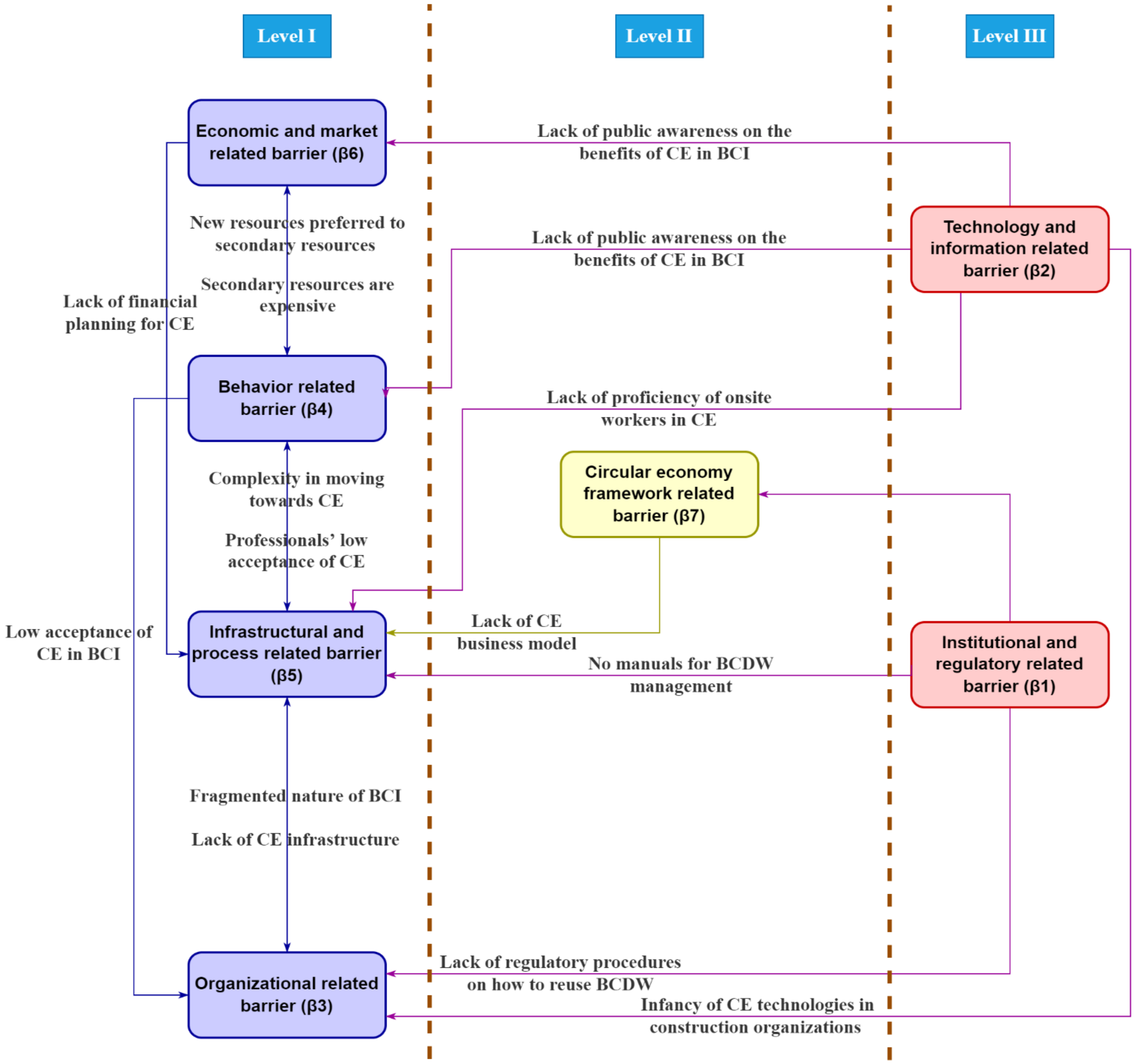

Figure 7: An integrated framework for barriers to CE adoption in BCDW management

5.4 Recommended implementation strategies and enablers to combat the barriers to the adoption of CE in BCDW management

Presently CE studies in the built environment especially in BCDW have often considered and explored the barriers, but the limited effort has been tailored to the implementation strategies that link the barriers and the actors together. Meanwhile, many other countries are plagued with the problems of integrating CE into the management of BCDW due to a lack of information on the strategies and enablers needed for the implementation and practice (Liu et al., 2021). As several strategies, enablers, and key result areas must be consolidated and integrated to achieve a successful CE in BCDW, there still exist no known studies that have conducted this holistically from a wider perspective. Accordingly, removing CE barriers could be possible by sharpening and bringing to the limelight the implementation strategies and enablers to combat them.

As a single barrier cannot affect CE, but a group of barriers, therefore, it is not rational to provide a solution to a particular barrier without considering the solution to the consolidated barriers since the barriers work together many times and they are interrelated. Also, it is not worthwhile to tackle a single barrier in isolation from other barriers. Moreover, an overall crucial message is not to see the various barriers in isolation from one another, but in terms of what Bilal et al. (2020) referred to as a web of barriers. This present study submits that a blended group of driving strategies are necessary to break the intertwined barriers to CE in BCDW management. Fig 8 revealed the barriers and the respective stakeholders who are expected in the circularity loop in promoting the strategies. Based on the above, the 38 retrieved articles form the basis for the extraction of the driving strategies and concerned stakeholders to overcome the consolidated barriers (Fig. 8). This is one of the very first efforts to link the CE barriers to the appropriate driving strategies and concerned stakeholders.

Institutional and regulatory-related barriers to the adoption of CE in BCDW can be ameliorated through the cumulative efforts of policy and decision-makers, the waste management sector, industrial practitioners, and the government (Mahpour, 2018; Salmenperä et al., 2021). Ajayi et al. (2015) averred that the stringency of policies related to BCDW management in countries with existing ones should be increased to promote CE adoption. Mahpour (2018) submitted that strict policies should be put in place to enforce and monitor BCDW management and standards for reused and recycled building components should be developed. Likewise, Bilal et al. (2020) concluded that decision-makers must be aware of the benefits of CE in BCI, and also national action plans should be put in place on the goals and vision to move towards CE in BCDW management. Meanwhile, Guerra and Leite (2021) argued that existing building codes must be reviewed to encourage the adoption of CE in BCDW management.

Technological and information-related barriers may be mitigated through the collective commitment of academic institutions, ICT organizations, construction materials experts, government, and technical institutions (Rios et al., 2021). The ICT sectors, academic institutions, and government must work together towards the development of advanced technologies for CE adoption in construction waste. Huang et al. (2018) argued that funding research for the development of innovative technologies that will promote CE in BCI is a powerful driving strategy for CE. The capacity of practitioners in the industries should be improved in CE management skills for applying the new CE technologies (Aslam et al., 2020; Udawatta et al., 2015). This could be possible through CE seminars, enlightenment, workshop, and the provision of incentives for training and acquisition of technologies for CE in BCDW(Ajayi et al., 2015). From the university level, integrating CE into university curricula could be a way to combat the information-related barriers (Mahpour, 2018).

Organizational-related barriers can be addressed by the government and industrial practitioners (Mahpour, 2018). The various organizations responsible for CE development in the BCI must work hand in hand to ensure that their organization structures agree with the CE initiatives. This could be possible by consolidating the fragmented subsections of all concerned organizations, especially the BCI. According to Ajayi et al. (2015), driving strategies for CE under the organization category include (i) BCI restructuring to support CE; (ii) integration of fragmented sections of BCI; (iii) BCI personnel commitment to BCDW reduction and management; (iv) top management support for CE development; (v) incentive CE development.

Behavior-related barriers could be annulled through the commitment of public media, industrial practitioners, and academic institutions. The BCI practitioners and stakeholders should be informed of the danger of neglecting CE in BCDW management. Also, CE seminars e.g. deconstruction training for demolition workers and workshops facilitated by academic institutions, public media, and the industrial expert should be promoted to change the negative attitude and behavior of people towards CE (Ormazabal et al., 2018). Making incentives and tax breaks available to professionals who contribute to CE could also transform the behavior of industrial practitioners to support CE (Mahpour, 2018; Ratnasabapathy et al., 2021).

Infrastructural and process-related barriers require the concerted effort of industrial practitioners, academic institutions, and the government. Six major implementation strategies were established by Bilal et al. (2020) which are (i) BCDW management should be standardized and supervised; (ii) developing infrastructures for sorting and processing of CDW; (iii) proper documentation and development of BCDW databank; (iv) use of high-quality construction materials should be encouraged; and (v) development of decision support system for CE in BCDW. In the same way, benchmarking the appropriate practice for enhancing a good operating system and management in CE will help in reducing uncertainties (Ajayi & Oyedele, 2018). The academic and research community should work with other practitioners in developing a better BCDW data bank and facilities for sorting waste in BCI.

The effort of government, financial institutions, private investors, and community groups is needed as a countermeasure to economic and market barriers (Charef & Lu, 2021; Grafström & Aasma, 2021). Stimulating the market and demand for secondary products are the driving strategies for CE in BCDW management. The achievement of this would be possible through public-private partnership in creating an enabling market and a government mandating the use of the secondary product. Also, Bilal et al. (2020) argued that the allocation of a sufficient budget to adopt and implement CE in BCDW management is a panacea for CE adoption in BCDW management. Putting these driving strategies in place would break the CE barriers to BCDW management.

Issues related to the CE framework need the attention of policymakers, industrial experts, manufacturers, and the research community (Guerra et al., 2021). To break CE framework-related barriers, it is expected that researchers with the support of the government and other industry practitioners develop a comprehensive CE framework and CE business model for enhancing the shift from a linear economy to a regenerative economy (Mahpour, 2018). This should be supported by the identification of the procedures for the adoption of the CE principles and the expected roles of the various key players in the business model. Also, there should be appropriate finance and incentive provided by the government to encourage more CE-based research and the development of a better CE model (Antwi-Afari et al., 2021).

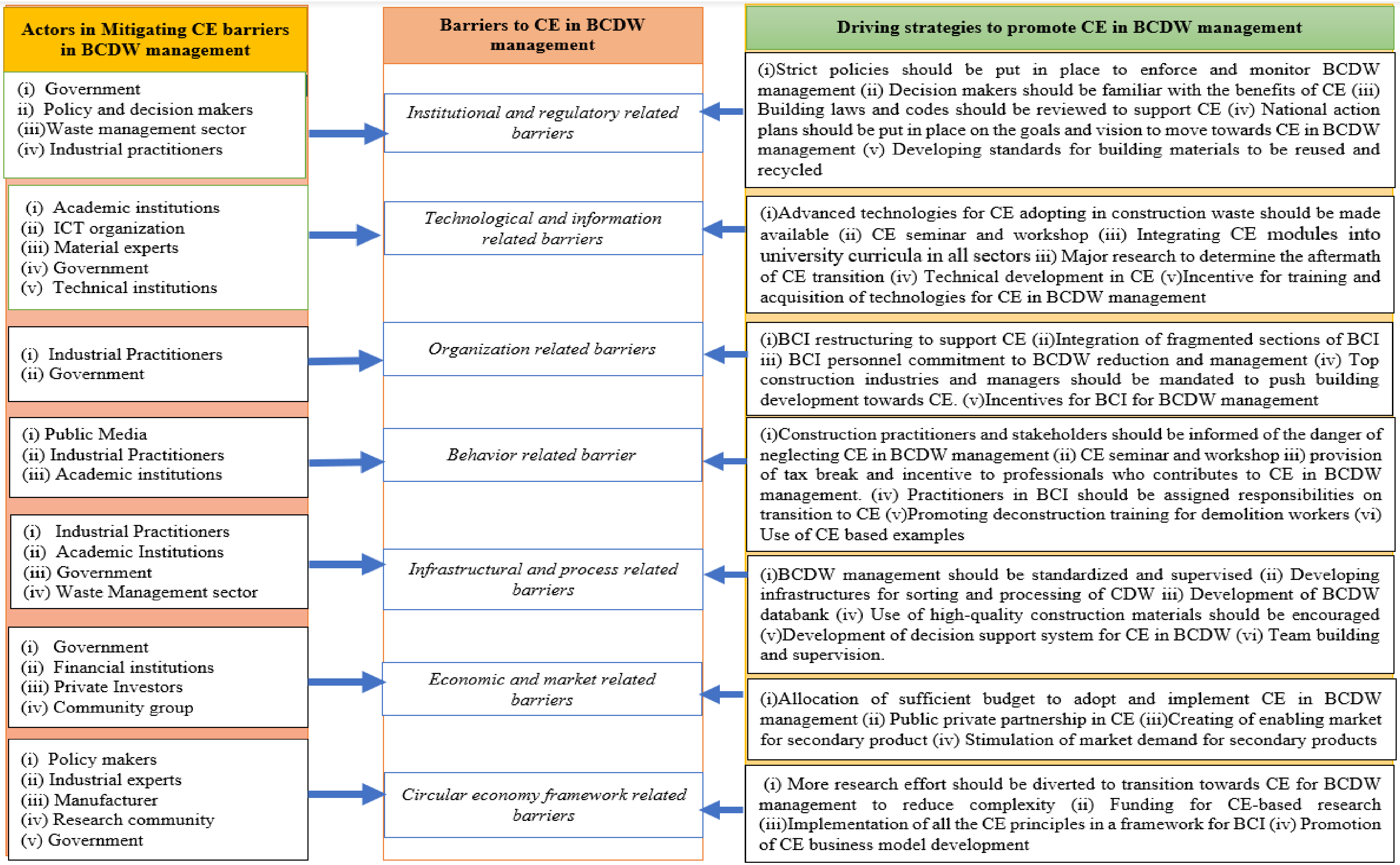

Figure 8: Implementation strategies to advance CE adoption in BCDW management

6. Conclusions, implications, and Future Research

CE in the BCI is gaining attention as a novel pathway toward resources management and sustainable development in the urban sector. Particularly, the adoption of CE in the BCI could leverage significant gain in managing the waste from BCD activities. Despite the augmenting interest, CE adoption has been limited in BCDW management in the BCI. Low adoption of CE has been frequently blamed on barriers. Thus, CE progress in BCDW management is militated by intertwined barriers and impedance and the road to CE adoption in BCDW management is not smooth. Hence, due to the fragmented nature of BCI, it is necessary to understand the barriers to CE adoption in the management of waste generated in the industry. This study conducted an international review of literature on the critical barriers to CE adoption in BCDW management. Thirty-eight articles were retrieved from Scopus search and snowballing, and carefully analyzed to give a comprehensive view of these barriers from various contexts. The 38 research articles retrieved were conducted in 23 countries and spatially distributed across 6 continents of the world.

The systematic review and analysis of the literature revealed 33 barriers to CE adoption in managing BCDW. Due to the number of these barriers and the fact that previous articles could have deployed respondents with limited experience during data collection, therefore, this study consolidated the barriers into groups via a system thinking approach. This was done to remove researchers' individual bias and prejudice. The name of each group extracted from the literature was further refined and consolidated to ensure the uniqueness of individual groups. These 33 barriers were consolidated into seven groups which are institutional and regulatory barriers technological and information barriers organization barriers, behavior- barriers, infrastructural and process barriers, economic and market barriers, and CE framework related barriers. An integrated framework for the barriers was developed based on an interview with some academic experts and a system thinking approach. This was eventually analyzed with ISM. This study reveals that there exist a plethora of barriers to the adoption of CE in BCDW management which requires urgent action to eliminate them. As a result, implementation strategies were proposed to push CE forward and overcome the profound barriers. As a result, the paper makes a credible contribution to the existing body of knowledge and scholarship on CE advancement with theoretical, and practical implications.

Theoretically, this research demonstrated the complexities of the constraints preventing CE widespread adoption in BCDW management. The research contributes to the literature by analyzing and mapping the holistic connections among the barriers. Particularly, the findings contribute to CE literature by shifting attention from the overall BCI to the BCDW management which is a particular issue in the urban sector and the natural environment. Practically, the study strengthened the need to adopt integrated strategies and enablers to mitigate the barriers and recommended some effective approaches for the various categories of barriers. The results of this study will also help practitioners and decision-makers to understand the key barriers that must be overcome to improve better CE transition. The developed integrated framework could help decision-makers understand how the barriers are interconnected with the CE system. The implementation strategy was developed to serve as a recommended guideline to help management overcome the barriers and promote the implementation in CE in BCDW management. Therefore, this study provides a comprehensive view of the barriers to CE adoption in BCDW which was lacking prior to this study. Ultimately, the outcome of this study has a significant contribution to sustainable production and consumption, waste management, and cleaner production in the BCI and urban sector generally This study also calls for stronger fostering of efforts by the public and private organisations, and the research institutions to solve the challenges of CE adoption in BCDW management through innovative research and funding.

The aim of this study was achieved, nonetheless, the study still suffers certain limitations. First, the paper emphasizes that broad generalizations of the barriers ignore their geographical sensitivity. However, it is theoretically advantageous to ignore these sensitivities and variances since they become crucial when such broad analysis is applied to a specific country as the foundation for policy suggestions. Secondly, there was no extensive study of these barriers based on questionnaire data. As a result, the current study has sparked empirically-based research on the driving strategies and success factors for promoting CE adoption in BCDW from the perspectives of developed and developing nations. Future studies would also evaluate the barriers through an international survey of CE experts.

Appendix A. List of papers included for the systematic analysis

#	Journals/Authors	Highlights
Journal of Cleaner Production		
1	Ajayi and Oyedele (2017)	Policy imperatives for BCDW diversion from landfills based on focus group discussion with UK experts.
2	Yuan (2017)	Barriers to and countermeasures for waste management in China in a CE using interview and focused group discussion with stakeholders.
3	Antwi-Afari et al. (2021)	The circularity gap in the BCI was explored scientometrically.
4	Zhang et al. (2019)	Barriers to the systemic circularity of waste in China using DEMATEL approach.
5	Salmenperä et al. (2021)	Factors faced by experts in CE transition in waste management using interview approach.
6	Liu et al. (2021)	Social Network analysis of barriers to CE application in BCDW in China.
7	Ghisellini et al. (2018)	Critical review of the application of key principles of CE in BCI
8	Shahbazi et al. (2016)	Empirical analysis of Barriers and drivers to the efficiency of materials in Sweden industries.
9	Kirchherr et al.(2018)	CE impediments in the European Union using expert interview
10	Ormazabal et al. (2018)	CE challenges and opportunities in Spain industries using factor analysis approach.
11	Bilal et al. (2020)	Barriers to and mitigating framework for CE in BCI
Resources, Conservation and Recycling		
12	Udawatta et al. (2015)	Enhancing waste minimization in Australian construction project using interview and questionnaire survey.
13	Ranta et al. (2018)	Multiple case studies on drivers and barriers to CE implementation in the US, China, and Europe.
14	Ajayi et al. (2015)	Challenges to and enablers for waste recycling in BCI were explored via phenomenological approach.
15	Kanters	Circular building development challenges and enablers
16	Mahpour (2018)	Barriers to CE adoption in demolition sector using fuzzy TOPSIS approach.
17	Hartwell et al. (2021)	Real-world challenges of circularity of facades using a mixed-method approach for data collection.
18	Huang et al. (2018)	BCDW analysis using 3R principles and interview approach for data collection.
19	Dunant et al. (2017)	Barriers to reuse of steel using a novel ranking approach in UK BCI.
Waste Management and Research		
20	Hentges et al. (2021)	CE development in Brazil BCI using exploratory approach.
21	Ayçin and Kayapinar Kaya (2021)	Barriers to CE in waste management in Turkey using Fuzzy DEMATEL approach.
Sustainability (MDPI)		
22	Ratner et al. (2021a)	Empirical Comparison of barriers and drivers to CE in Russia
Science of the Total Environment		
23	Bao and Lu (2020)	Efficient CE system for BCI in China using interview to collect data
Minerals		

24	Taha et al. (2021)	Zero waste management in a CE in Morocco using empirical approach.
#	**Journals/Authors**	**Highlights**
Recycling		
25	Cramer (2018)	Exploration of the approach for implementing high-grade recycling in Netherland BCI.
Energies (MDPI)		
26	Smol et al. (2021)	Guidelines for CE development in Poland based on reports and documents
Production Planning and Control		
27	Akinade et al. (2020)	Current practice for design for disassembly for attaining systemic circularity via interview and focus group discussion.
Journal of Materials Cycle and Waste Management		
28	Gunarathne et al. (2019)	Challenges of recycling waste generated in Sri Lanka using interview data and document analysis.
Journal of Construction Engineering and Management		
29	Rios et al. (2021)	Barriers to circular building development in US using interview approach.
Applied Sciences (MDPI)		
30	Ratner et al. (2021b)	Empirical survey on barriers to CE development in Russia using a questionnaire.
Engineering, Construction and Architectural Management		
31	Shooshtarian et al. (2021a)	Empirical evaluation of challenges to CE adoption in BCI and policy development.
Journal of Building Engineering		
32	Rakhshan et al. (2021)	Predicting the circularity of building structures in United Kingdom using a probabilistic approach.
Built Environment Project and Asset Management		
33	Ratnasabapathy et al. (2021)	Barriers to waste trading implementation in construction industry using mixed approach.
Habitat International		
34	Ilić and Nikolić (2016)	Driving factors for and bottleneck CE development for waste management in Serbia using interview approach.
Renewable and Sustainable Energy Reviews		
35	Hossain et al. (2020)	A framework development and challenges for CE adoption in the BCI
Waste Management		
36	Ramos and Martinho (2021)	Determining factors for BCDW in Portugal using questionnaire survey for data collection
International Journal of Production Economics		
37	Wang et al. (2021)	Barriers to designing circular product in New-Zealand using thematic analysis and interview.

Smart and Sustainable Built Environment		
38	Yadav et al. (2021)	A fuzzy DEMATAL approach for barriers to waste management in India.

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