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SYNERGY BETWEEN BLOCKCHAIN AND CIRCULAR ECONOMY IN IMPROVING CONSTRUCTION WASTE MANAGEMENT: A LITERATURE REVIEW

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ABSTRACT

The inverse relationship between the development of the construction sector and the preservation of the ecosphere is highly manifested by the excessive waste products resulting from the construction processes that are irrepressible by the existing waste management practices. Research has been conducted on utilising smart technologies such as blockchain technology and modern concepts such as the circular economy (CE) in enlightening waste management practices. Yet, the applicability of intervening the synergy of the two concepts of "blockchain-circular economy" is not adequately addressed in the existing literature from the perspective of effective construction waste management. Therefore, this study aimed at identifying the applicability of blockchain technology and circular economy in enhancing the effectiveness of construction waste management. Accordingly, a comprehensive literature review was conducted on the existing research on the enablers, barriers and strategies for the integration of the blockchain-circular economy, blockchain-waste management, and circular economy-waste management. The collected data were analysed using content analysis. The findings suggested that enablers such as supportive legislations and sustainability increments, barriers such as risks and lack of knowledge, and strategies such as introducing regulatory standards and adaption to technologies are common for the integration of the concepts. Accordingly, this study reveals the potential of assessing the practicability of integrating blockchain, circular economy and waste management in a common platform to establish resource optimisation in the construction sector.

Keywords: *Blockchain; Circular Economy; Construction Industry; Waste Management.*

1. INTRODUCTION

For decades, the construction sector was considered as the mirror image of a nation's technological advancement as it reflects the prosperity and industrial development of a country (Sepasgozar et al., 2018). Explicitly, the construction industry is the major

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contributor to global revenue growth and it sustains a contribution of 6% of the global GDP (El-Sayegh et al., 2020). Aleksanin (2019) affirms that the construction industry is dynamically progressing and simultaneously Crawford et al. (2017) stressed about the corresponding progression in construction waste. Construction waste can be identified as the unwanted products and resources that are generated during the construction processes (Fikri et al., 2020) and the global construction waste generation is approximately 10 billion tons per annum (Ahmed & Zhang, 2021). Furthermore, Osmani and Villoria-Sáez (2019) stated that the ratio between construction waste and inputs is higher than 0.5 which manifests that more than half of the construction resources are sent to landfills. Moreover, the excessive generation of waste is a key reason for the cost overruns of construction projects, that emphasise the apparent need for proper waste management systems in the construction sector (Udawatta et al., 2015).

The necessity of proper waste management (WM) systems is explicit with the growing complexity of WM in the world (López et al., 2020; Malinauskaite et al., 2017). Specifically, many applications are used to reduce the generation of construction waste and among these applications, the waste hierarchy principle and zero waste principle are considered important (Umar et al., 2017). Further, the use of closed-loop models is considered a highly effective way for WM since these circular models optimise the use of resources by effectively circulating the value of the materials while integrating with waste cycles (Malinauskaite et al., 2017). In this sense, circular economy models which is a multi-WM model are relished by the industries for their peculiarity of circulating the material streams while being environmentally sustainable and economically permissible (Hidalgo et al., 2019).

The circular economy (CE) is defined as a regenerative system where materials and energy loops are decelerated, narrowed, and closed intending to reduce waste generation and energy emissions (Geissdoerfer et al., 2017). Benachio et al. (2020) affirm that traditional economies are revolved around linear economy models where the resources are streamed in a linear process, i.e., take, make, use, dispose and Jones and Comfort (2018) argue that the circular process of the CE, i.e., take, make, use, reuse is the best solution for the excessive waste generation in linear models. Besides, the increasing scarcity of natural resources and supply deficiencies emphasise the apparent need for an immediate transition to a CE (Bianchini et al., 2019). However, Guerra and Leite (2021) highlight that several challenges hinder the transition to a CE, yet Romero-Hernández and Romero (2018) emphasise that a CE is essential to overcome the existing WM issue. Hence, Rada et al. (2018) stress the need for assessing the link between WM and CE in manifesting the productivity of this integration. Moreover, Islam et al. (2020) emphasised that intervention between different concepts can be easily managed with the capabilities of new technologies such as blockchain.

In this context, the technology of blockchain (BC) can be identified as a method of sharing data in a verifiable, transparent, and secure manner, and can be effectively adapted for urban WM since it develops a uniform and combined platform (Ahmad et al., 2021). Within a short period, people identified the advantages of this technology with its capacity to act as a decentralised environmental network and be used as the basis of modern concepts such as cryptocurrencies (Wang et al., 2018). Lamichhane et al. (2019) identified the key features of BC technology as anonymity, auditability, and persistence and Zheng et al. (2017) mentioned that BC technology can maximise the cost-effectiveness and efficiency of the systems without third-party involvement. In the construction industry, BC technology is mainly used to mitigate issues in design drawings and Building Information Modelling (BIM) (Li et al., 2019b). It is because BC allows identifying how and where the discrepancy occurred since each step of the BC is stored in a block while linking to the final system (Perera et al., 2020). Accordingly, Wu et al. (2018) identify BC technology as a drive to modern economic patterns.

Gopalakrishnan and Ramaguru (2019) mentioned that the applications of BC such as Plastic Bank, Recercum and Swachhcoin are being employed for productive WM in the world. At the same time, BC is used for the collaboration of the CE concept by coordinating among the specific databases which are accessible to all the relevant stakeholders in the process (Upadhyay et al., 2021). Accordingly, BC technology allows effective implementation of CE practices (Kouhizadeh et al., 2020) and many studies have been directed at the synergy of CE and BC (Akinade & Oyedele, 2019; Institute of Electrical and Electronics Engineers [IEEE], 2018; Nandi et al., 2021; Yildizbasi, 2021). However, there is a noticeable gap in the existing research on the invention of the synergy of BC and CE to increase the effectiveness and the efficiency of WM even if there are studies conducted separately on the integration of BC and WM (Akram et al., 2021; Bamakan et al., 2022; Chaudhary et al., 2021; Ongena et al., 2018; Scott et al., 2022) and the integration of CE and WM (Sharma et al., 2021; Luttenberger, 2020; Priyadarshini & Abhilash, 2020; Salmenperä et al., 2021). Therefore, to fill the above-identified gap, the study is aimed at synthesising the synergy of BC and CE concepts in improving construction WM based on the existing literature.

2. RESEARCH METHOD

Conducting a literature review can be identified as a methodical approach aimed at identifying and synthesising the existing body of knowledge regarding a specific area (Booth, et al., 2021). In addition, Hart (2018) identified that literature reviews lay the foundation of research, irrespective of the field of study and literature reviews direct the researchers to further studies on empirical grounds. Hence, the quality and reliability of the identified literature need to be at a high level, and journal articles, books and conference proceedings with well-cited references are considered high-quality sources (Xiao & Watson, 2019). Accordingly, this study was conducted by reviewing the existing literature focusing on the integration of the concepts of BC, CE and WM. Figure 1 presents the process adopted in conducting the literature review.

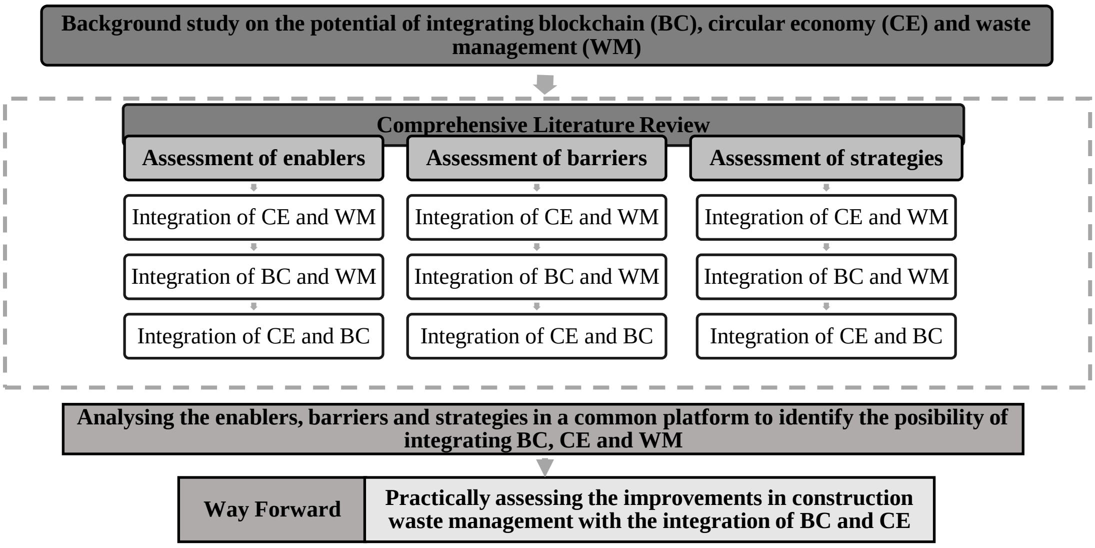

Figure 1: Research process

As Figure 1 explains, a background study was conducted, followed by a comprehensive literature survey on the enablers, barriers and strategies of the integration of CE and WM, BC and WM, and CE and BC. Subsequently, a theoretical framework was developed after analysing the enablers, barriers, and strategies in a common platform using the content analysis method since content analysis assists in deriving inferences systematically (Aggarwal & Singh, 2019). According to Osanloo and Grant (2016), the theoretical framework provides the structure for research and demonstrates the rationale of the research. This study also presents a theoretical framework for the integration of BC, CE and WM as guidance for the empirical studies on the research area.

3. FINDINGS

3.1 ENABLERS OF THE INTEGRATION OF BC AND CE FOR THE IMPROVEMENT OF THE CONSTRUCTION WM

After analysing the literature, enablers for the integration of CE and WM, BC and WM, and CE and BC were identified and common enablers of integrating the three concepts were derived. Accordingly, Table 1 provides a holistic view of the enablers of the integration of CE and WM, BC and WM, and CE and BC as per the existing literature and the highlighted enablers were identified as the common enablers for the integrations.

Table 1: Enablers for the integration of CE and WM, BC and WM, and CE and BC

CE and WM	BC and WM	CE and BC
Pre-existing policies	Guaranteeing data integrity	Offering alternative energy sources
Application of current informal circular activities	Ability to combine BC with new technologies	Development of the secondary material market
Availability of WM financing mechanisms	Way to obtain 17 Sustainable Development Goals	Reverse logistic improvement
The connection between manufacturers and traders	Creating job opportunities	Eco-industrial parks development
The ability of the government to monitor and enforce CE policies	Tracing and tracking of supply chains	Ability to monitor supply chain

CE and WM	BC and WM	CE and BC
Job opportunities	Automated and decentralised incentive system	Chance to improve company knowledge/value
Government revenue increment	Peer-to-peer transaction	Chance to improve consumer knowledge/behaviour
Revealing new revenue streams	Transparency/ disintermediation	Unchangeable databases/ immutability
Increment of new raw materials as recycled materials	Cost saving method	Way to new trading networks
Reductions in unnecessary packaging	Automated WM practices	Improving sustainability (economic, environmental, social)
Publicity for the organisation	Monitoring ability and accessibility	Trackability and traceability
Cost reduction	Immutable auditing facility	Accessibility to records
Improvements in sustainability	Efficiency	Smart contracts
Promoting new green solutions	Immutability	Decentralisation
Generation of new energy sources	Smart contracts	Disintermediation
New investors	Improved workflow	Low transaction cost
Development of enabling technologies to recover material		Incentivisation
Enhancing the value of material/product		Auditability

Sources: (Alexandris et al., 2018; Wang et al., 2020; Ezeudu et al., 2021; França et al., 2020; Guerra & Leite, 2021; Xiao et al., 2020; Hamledari & Fischer, 2021; Hamma-adama et al., 2020; Hatzivasilis et al., 2021; Kayikci et al., 2022; Kouhizadeh et al., 2020; Kumar & Chopra, 2022; Lenz & Tsangaratos, 2022; Li et al., 2019a; Paes et al., 2019; Perera et al., 2020; Rejeb, Zailani, et al., 2022; Romero-Hernández & Romero, 2018; Sahoo et al., 2021; Schneider et al., 2017; Scipioni et al., 2021; Symeonides et al., 2019; Yildizbasi, 2021)

As identified in table 1, Guerra and Leite (2021) identified that integration of CE and WM can result in cost reduction in construction projects while Sahoo et al. (2021) identified that integration of BC and WM can also result in cost savings which can be identified as a common enabler for these concepts. In addition, Rejeb, Zailani, et al (2022) identified the ability to incorporate smart contracts as an enabler for the integration of CE and BC, whereas Perera et al. (2020) identified this ability as an enabler towards the integration of BC and WM. Moreover, Schneider et al. (2017) emphasised that the integration of CE and WM can generate new energy sources which act as a major enabler while Kumar and Chopra (2022) identified the ability to offer alternative energy resources as an enabler towards the integration between CE and BC.

3.2 BARRIERS TO THE INTEGRATION OF BC AND CE FOR THE IMPROVEMENT OF THE CONSTRUCTION WM

The barriers to the integration of CE and WM, BC and WM, and CE and BC identified through the existing studies have been summarised in Table 2 and the highlighted barriers were identified as the common barriers to the integrations.

Table 2: Barriers to the integration of CE and WM, BC and WM, and CE and BC

CE and WM	BC and WM	CE and BC
Ineffective construction WM practices	Complications in fixing incorrect data	Scalability limitation
Lack of consideration for green designing	Inability to identify the ownership of the person who is responsible for waste in the chain	Specialised software development tool requirement

CE and WM	BC and WM	CE and BC
Low recyclable material usage and low willingness to use circular material	Permanent storing of personal and private data	Confusion in BC application within CE
Non-sustainable construction methods	Difficulties in selecting the correct person for incentivisation	Insufficient technological infrastructure
Lack of incentives for adaptation of CE and uncertainty of return on investment	Government rules, laws, and regulations	High development
Inadequate legal framework and policies/ supervision	Difficulties in authenticity validation without revealing private information	Low experience
Lack of responsibility in material production	Low knowledge of BC	Resistance by firms
Lack of goals to move towards CE in WM	Security risks (hacking, attacks, hijacks)	Low regulatory support and practice
Low knowledge of CE towards WM	Energy consumption	The cost of data storing, and processing is high
The high complexity of integrating CE into WM	Interoperability	Lack of performance and operational objectives
Lack of sustainable integration with WM	Resistant to change	Occurs privacy/security issues
The low number of literature	Scalability	High initial cost
Risk aversion	Risk and cost allocation	Lack of efficient communication/ collaboration
Lack of individual engagement	Data storage	Technological immaturity
Insufficient accessibility to data		Conversion to a new system
Low funding		Interoperability issues
The purpose of an organisation to save cost and time is high		Cultural differences
The low commitment of management		
Negative customer perception of used material		
Sources: (Arena et al., 2021; Ayçin & Kaya, 2021; Wang et al., 2020; Bakajic & Parvi, 2018; Dieckmann et al., 2020; Ezeudu et al., 2021; Xiao et al., 2020; Hamledari & Fischer, 2021; Hamma-adama et al., 2020; Hatzivasilis et al., 2021; Kayikci et al., 2022; Kerdlap et al., 2019; Kouhizadeh et al., 2020; Kumar & Chopra, 2022; Li et al., 2019a; M. G. Sharma & Kumar, 2020; Mahpour, 2018; Paes et al., 2019; Perera et al., 2020; Rejeb, Rejeb, et al., 2022; Rejeb, Zailani, et al., 2022; Romero-Hernández & Romero, 2018; Sahoo et al., 2021; Salmenperä et al., 2021**;** Stanislaus, 2018; Symeonides et al., 2019; Taylor et al., 2020; Yildizbasi, 2021)		

As shown in Table 2, Ayicin and Kaya (2021) identified that one of the most common barriers towards the integration of CE and WM is the lack of knowledge regarding the adaptability between these two concepts while Sharma and Kumar (2020) identified the lack of knowledge as a major barrier in integrating BC and WM. Furthermore, Li et al. (2019a) stated that the interoperability between different concepts can be a main barrier towards integrating different concepts such as BC and WM, whereas Rejeb et al. (2022) identified that this can be a major barrier when integrating CE and BC. In addition, Dieckmann et al. (2020) stated that inadequate legal frameworks and policies can be a barrier to integrating CE and WM while Yildizbasi (2021) identified that lack of proper legal and regulatory support is a barrier to integrating CE and BC.

3.3 STRATEGIES FOR THE INTEGRATION OF BC AND CE FOR THE IMPROVEMENT OF THE CONSTRUCTION WM

To overcome certain barriers in integrating different concepts and enhance the enablers, different strategies need to be identified, which can be used to ensure smooth integration between the concepts. Accordingly, strategies for the integration of CE and WM, BC and

WM, and CE and BC were identified through a literature review and common strategies for integrating the three concepts were derived. Table 3 presents the strategies which were identified in the existing literature for the integration of CE and WM, BC and WM, and CE and BC and the highlighted strategies were identified as the common strategies for the integrations.

Table 3: Strategies for the integration of CE and WM, BC and WM, and CE and BC

CE and WM	BC and WM	CE and BC
Conducting pilot programmes	Conducting strategic analysis and development	Development of governance and legislative tools
Building collaboration with institutions (financial, WM etc.)	Obtaining regulatory support from the government	Adaptation of proper designing
Enhancing sustainability mindsets	Adapting privacy data securing methods	Using new technologies and resources
Long-term strategic planning (ERP – Enterprise Resource Planning etc.)	Using common data schema to collect and represent data	Proper organisational control and management
Enforcing policies, targets, or achievements	Entering into smart contracts	Adaptation of multi-level analysis
Using improved WM practices	Introducing tokenisation concept	Individual motivation
Adaptation of new technologies	Adapting IoT-based waste collection devices/ process	Constant monitoring
Minimising waste sources	Implementing a productive payment method	Renewable energy usage (minimise regeneration)
Conduction of awareness programmes	Securing easy accessibility to data	Utilising goods to minimise duplications (sharing economy concept)
Increasing the durability of products	Tracing and tracking of wastes	Reducing non-value-added activities (optimising)
	Reliable channelisation of waste	Adapting coopetition strategy
	Proper WM documentation	Intra-organisational collaboration
	Robot assistance	Adaptation of artificial intelligence
	Adapting proper WM practices	Using big data analytics

Sources: (Adami & Schiavon, 2021; Ahmad et al., 2021; Akram et al., 2021; Camana et al., 2021; Dao et al., 2020; Dua et al., 2020; Elia et al., 2017; Fedotkina et al., 2019; Ferronato et al., 2019; França et al., 2020; Hatzivasilis et al., 2021; Hemidat et al., 2022; Khan et al., 2022; Kouhizadeh et al., 2020; Kouhizadeh et al., 2021; Laouar et al., 2019; Luttenberger, 2020; Narayan & Tidström, 2020; Rejeb, Zailani, et al., 2022; Ribić et al., 2017; Romero-Hernández & Romero, 2018; Sahoo et al., 2021; Sen-Gupta et al., 2022; Upadhyay et al., 2021; Woodside et al., 2017; Xavier et al., 2021)

As identified in Table 3, numerous common strategies can be used to integrate different concepts and according to Fedotkina et al. (2019), the adoption of new technologies can be a proper strategy to overcome the barriers to integrating CE and WM. Similarly, Ahmad et al. (2021) identified that utilising new technologies such as IoT and Robot assistance as a strategy that can be used to successfully integrate BC and WM while Upadhyay et al. (2021) stated that new technologies can address numerous barriers to integrating CE and BC. In the same context, Hatziyasilis et al. (2021) identified that the use of big data analytics can further enhance the process of integrating CE and BC and therefore, it is evident that the use of new technologies can be a main strategy that must be considered in integrating these concepts.

4. THEORETICAL FRAMEWORK FOR INTEGRATION OF BC, CE, AND WM

Based on the findings of the literature review, a theoretical framework can be developed to assess the integration of the concepts of BC, CE and WM. As the literature review suggests, there are similarities in the enablers, barriers, and strategies in the existing studies on the integration of BC-WM, CE-BC and CE-WM. Accordingly, the common enablers, barriers and strategies can be analysed to understand the practicability of integrating these concepts. Eventually, it is important to develop a theoretical framework to demonstrate the significance of understanding the enablers, barriers, and strategies in a common platform to enable the successful integration of BC and CE in improving the construction WM. Ultimately, a theoretical framework is developed as per Figure 2 for the integration of the concepts.

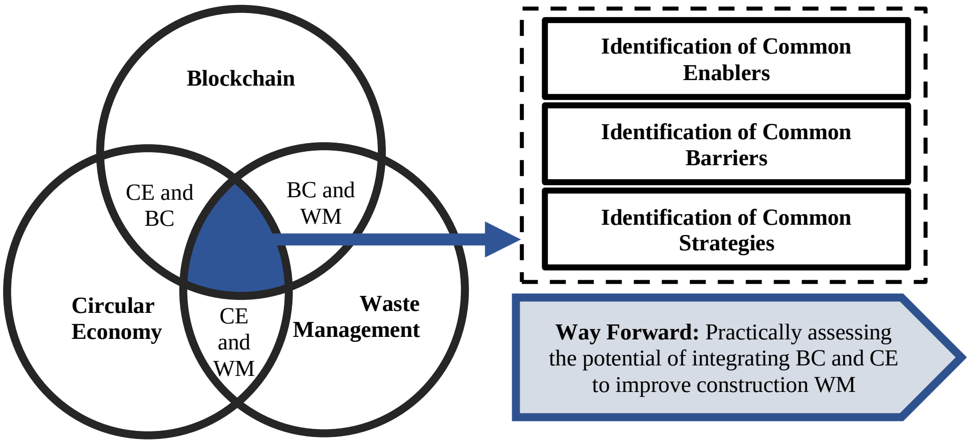

Figure 2: Theoretical framework on the integration of blockchain, circular economy and waste management

As Figure 2 explains, it is important to assess the common enablers, barriers and strategies for the integration of these concepts since it is rather productive to implement the strategic movements in a common platform. Besides, as illustrated in Figure 2, the identification of enablers, barriers and strategies particularly for the intervention of BC-WM, CE-BC and CE-WM and the identification of the similarities among these enablers, barriers and strategies paves the way to assess the potential of integrating BC and CE to enhance existing WM practices. More specifically, it will guide further studies to evaluate the practicability of the integration of BC and CE to improve construction waste management in a pragmatic approach. As identified by Mahpour (2018), integrating different concepts cannot be identified as a simpler task and therefore, how to integrate the three concepts will be the future direction of this study.

5. CONCLUSIONS AND RECOMMENDATIONS

The growing complexity of the construction processes has increased the complications in the construction WM by highlighting the need for more organised WM tools and applications. This study revealed the potential of integrating BC technology and the CE concept in enhancing the existing WM systems while limiting to the construction sector. Specifically, it was discovered that the enablers such as supportive legislations and sustainability increments, barriers such as increased risks and lack of knowledge, and strategies such as establishing regulatory standards and increasing the use of emerging technologies are common for the integration of the concepts. Accordingly, this study contributes to academia by bridging the gap between the BC, CE and WM by highlighting their enablers, barriers and strategies in a common platform. Furthermore, this study contributes to the industry by strengthening the successful intervention of the two significant concepts of BC and CE in improving construction WM.

It is important to highlight that the similarities in the enablers, barriers and strategies pave the way for the researchers to further assess the concepts of BC, CE and WM with an integrated perspective. It is further recommended that industry practitioners increase the involvement of BC and CE to enhance the existing WM techniques. Specifically, it is highly recommended to conduct further research on the practicability of integrating BC, CE and WM based on pragmatic studies.

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