INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

IJIE

Vol. 17 No. 7 (2025) 144-154
https://publisher.uthm.edu.my/ojs/index.php/ijie

Contractors' Perception in Integrating Circular Economy in Industrialised Building System (IBS)

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DOI: https://doi.org/10.30880/ijie.2025.17.07.015

Article Info

Received: 15 Mac 2025
Accepted: 3 November 2025
Available online: 31 December 2025

Keywords

Sustainability, waste management, STEEP matrix, offsite construction, construction & demolition (C&D) waste

Abstract

Industrialised Building System (IBS) is well-recognised in improving sustainable deliverables for construction projects. However, the lack of integration of a circular economy (CE) in IBS construction hinders the continual use of resources and limiting waste elimination. This study investigated the IBS contractors' perceptions of integrating CE in managing construction and demolition (C&D) waste. The STEEP (Social, Technological, Economic, Environmental and Political) matrix adopted in this study determined the drivers, enablers, challenges, and barriers to integrating CE into the IBS application. Twenty respondents from IBS construction companies participated in semi-structured interviews to provide insights into integrating CE in C&D waste management. The results highlighted that IBS contractors in Malaysia strongly associated CE with waste separation activities, reduction of waste generation, recycling and re-use materials of building components to extend its value. Although CE harbours greater potential in terms of the level of circularity (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, re-purpose, recycle and recover), the limited knowledge of CE among IBS contractors has hindered the optimisation of IBS from contributing to sustainability. Building on the STEEP matrix, the outcomes of the study initiate further study to determine strategies to improve efficient integration of CE in managing C&D waste for IBS projects.

1. Introduction

Malaysia is a developing country experiencing rapid development, which leads to the massive generation of construction and demolition (C&D) waste annually. C&D waste is defined as any solid waste produced from construction or demolition activities, including progress work, preparation, restoration or renovation works [1]. Managing a high volume of waste requires an effective approach and commitment from all stakeholders. This is to ensure that the C&D waste does not damage the environment and, at the same time, enables stakeholders to gain economic benefits from the construction activities. The current approach to managing C&D waste could be more efficient and requires a revolution to support sustainable development. The depletion of resources demands that the construction stakeholders provide alternatives rather than depending on raw materials. Globally, previous reports have shown that the construction industry is responsible for sending approximately 23% to 44% of waste to landfills [2], [3]. Based on the nature of the C&D waste, more than half of the waste that is sent to the landfill can be recycled [4]. Umar et al. [5] stated that the rate of recycling C&D waste in Malaysia is low due to a lack of data and practices, as contractors prefer to use new materials over recycled ones. Additionally, the study reveals that Malaysia lacks an institutional mechanism that clearly outlines the obligations of stakeholders. Furthermore, promotion in terms of waste minimisation from the viewpoint of waste separation and less waste production is also limited. However, the Malaysian government is encouraging stakeholders to adopt new and advanced technologies to improve the delivery of construction projects.

The Industrialised Building System (IBS) or prefabricated building is well-recognised for its ability to reduce construction cost and time, as well as minimise construction waste. With its potential as a sustainable solution, integrating CE into IBS can further improve sustainable deliverables [6]. Previous studies have demonstrated that CE can enhance economic productivity and social benefits by improving the effectiveness of resource management in IBS applications [6], [7]. However, studies focusing on integrating the circular economy (CE) into IBS are limited [6]. In the design stage, consultants have focused more on reducing construction time, neglecting the issue of generating construction waste [8]. The lack of integration of the circular economy in IBS construction hinders the continual use of resources and limits waste elimination. One of the recurrent problems during project construction is the lack of capacity amongst stakeholders to evaluate the amount of waste generated [9], especially from IBS construction. This leads to conflicts, losses, and poor performance in the IBS construction work. As a result, the landfill will still be filled with construction waste, leading to environmental issues. This has led stakeholders to hold negative perceptions of IBS and to be unable to fully realise its potential [10]. A transformation is highly required to manage C&D waste in Malaysia, thereby improving sustainability in the construction industry.

A linear economy is a conventional approach that relies on the notion of “take, make, and dispose” [11]. The linear economy in the construction industry relies on the extraction of raw materials from natural resources, which involves a significant amount of embodied and operational energy. These materials will be fabricated to suit the product's purpose. Then, the product will be installed in a building or infrastructure and later will most likely be discarded into a landfill or incinerated after the end of the structure’s lifetime. On the other hand, a circular economy is an alternative approach to keep resources in use for as long as possible. This approach maximises the value of resources while they are in use and then recovers and reuses products and materials [12]. According to Ellen MacArthur Foundation [13], there are three core principles that underpin a circular economy, namely (i)design waste and pollution, (ii)keep products and materials in use, and (iii) regenerate natural systems. This study will explore all three principles to identify the drivers, challenges, enablers, and barriers to formulating strategies that improve the performance of the IBS application and enhance its sustainability.

The circular economy, or CE, is a sustainable approach that provides solutions for climate change, biodiversity loss, pollution, and, most importantly, construction and demolition waste. It is an approach that aims to keep materials in a closed loop. The material should be reused, recycled, or remanufactured at its highest value without being sent to the landfill after meeting its end-of-life requirements [14]. In the context of IBS, the CE approach encompasses the project delivery life cycle, including design and building operation, which minimises waste and emissions and maximises the use of renewable and recyclable materials. The characteristics of IBS enable the use of modular coordination, allowing for easy disassembly and reuse of building components. Designing modular buildings for disassembly and reuse can decrease waste production and material depletion [15]. Zairul [6] highlighted that IBS is an ideal solution for waste reduction and lean supply chain management in the construction industry. However, despite global recognition of the potential of the CE approach for sustainability, limited studies have been conducted to investigate the challenges, barriers, drivers, and enablers in employing this concept in the IBS application in Malaysia.

Transforming from a linear economy to a circular economy requires commitment and cooperation from stakeholders at all levels, including micro, meso and macro. Esa et al. [16] stated that the three levels are also known as the “three-circles” or “three-layers” approaches. At the micro level, the focus is on the manufacturing process, which encourages the adoption of cleaner production processes and eco-friendlier designs. The meso level focuses on an eco-friendly design that requires the application of a waste trading system. The macro level is demanding a broader collaborative network and cooperation among industries, which encourages the elements of reuse, reduction, and recycling. By understanding the significance of each level, relevant stakeholders could collaborate in identifying the action plans to prevent waste from being sent to landfills. The commitments of all stakeholders, including the government, local authorities, businesses, communities, and individuals, are crucial to ensuring the success of this approach.

This study investigated contractors' perceptions of integrating CE in managing C&D waste. The drivers, enablers, challenges, and barriers in integrating CE with the IBS application were identified and analysed.

2. Methodology

Semi-structured interviews were adopted to gain insights into the IBS contractors' perceptions of employing CE in managing C&D waste. This method provided researchers with opportunities to interact constantly with the respondents and posed additional follow-up questions to meet the research objectives [17]. A similar approach was adopted by Ratnasabapathy et al. [18] to investigate respondents' opinions on the barriers to implementing waste trading practices in the Australian construction industry. The IBS contractors for this study were identified from the directory published by CIDB Malaysia, which includes a list of registered IBS suppliers, IBS contractors, IBS consultants, and IBS statistics. The respondents were contacted by email and invited to participate in the semi-structured interviews. The objectives and methodology of the study were explained to the respondents before they signed the consent form. In total, 20 respondents agreed to participate in the interview. The respondents included top-level managers and technical experts involved in the IBS projects. The respondents were from various organisations or held different responsibilities for the IBS projects. They have worked in the industry for at least 10 years, with more than 5 years of experience in IBS construction. Table 1 shows the information of the respondents in the study.

Table 1 *Information about the respondents*

No.	Code	Position	Contractors' Grade	Highest Level of Education	Location
1.	C01	Managing Director	G7	Bachelor's degree	Putrajaya
2.	C02	Project Manager	G7	Diploma	Putrajaya
3.	C03	Site Engineer	G7	Bachelor's degree	Putrajaya
4.	C04	Quantity Surveyor	G7	Bachelor's degree	Putrajaya
5.	C05	Managing Director	G6	Bachelor's degree	Selangor
6.	C06	Project Engineer	G6	Bachelor's degree	Selangor
7.	C07	Engineer	G7	Bachelor's degree	Selangor
8.	C08	Inspector of Works (IoW)	G7	Diploma	Selangor
9.	C09	Project Manager	G6	Bachelor's degree	Putrajaya
10.	C10	Managing Director	G6	Diploma	Johor
11.	C11	Managing Director	G6	Bachelor's degree	Johor
12.	C12	Site Engineer	G6	Bachelor's degree	Johor
13.	C13	Inspector of Works (IoW)	G6	Diploma	Johor
14.	C14	Project Manager	G6	Bachelor's degree	Johor
15.	C15	Quantity Surveyor	G7	Bachelor's degree	Kuala Lumpur
16.	C16	Project Manager	G7	Bachelor's degree	Kuala Lumpur
17.	C17	Managing Director	G7	Advanced Diploma	Melaka
18.	C18	Site Engineer	G7	Bachelor's degree	Melaka
19.	C19	Quantity Surveyor	G7	Bachelor's degree	Melaka
20.	C20	Inspector of Works (IoW)	G7	Diploma	Melaka

Table 2 *Semi-structured interview questions*

No.	Questions
1.	Based on your understanding, what does a circular economy in managing C&D waste mean?
2.	What are the main challenges in employing CE to manage C&D waste?
3.	How can the circular economy be employed in managing C&D waste?
4.	What are the enablers for integrating CE in managing C&D waste?
5.	Could you state the drivers for employing the circular economy in managing C&D waste in Malaysia?
6.	Could you please summarise the main barriers that affect the effectiveness of C&D waste management in Malaysia?
7.	Could you please explain how we can address the barriers that you have mentioned?

The semi-structured interviews were conducted either face-to-face or online using appropriate platforms such as Google Meet, Zoom or Webex. A set of semi-structured interview questions was provided to explore the respondents' perceptions of integrating CE to manage C&D waste for IBS projects. The main questions are provided in Table 2. The interview sessions lasted 50-75 minutes each to complete. The respondents were given the opportunity to ask questions related to the topic and were provided with clarification for any issues or questions raised.

For the analysis, the researchers first read through the transcripts from the interview sessions. The data was transferred to NVivo 10 software to assist with the analysis. Thematic analysis was performed on the data. The data was coded, and themes were generated.

3. Findings

The analysis reveals that contractors' understanding of employing CE in managing C&D waste for IBS projects remains low. Several challenges and barriers have been identified in this study. The respondents have also identified drivers and enablers to support the integration of CE in the IBS application. The next section provides a discussion of the results and findings from the semi-structured interviews.

3.1 Knowledge in Circular Economy for Industrialised Building Systems

The respondents' understanding of CE in managing C&D waste was investigated. Several respondents noted that a lack of awareness and misconceptions about CE were initial challenges to transitioning away from the conventional linear economy approach. The lack of knowledge about CE principles and their benefits was the primary reason why most top management in IBS applications hesitated to shift from the linear economy to CE. Respondent C01 highlighted that improving awareness of CE could increase an organisation's capability to shift from a linear economy to CE and create a conducive environment.

> "It's really about educating the whole project team, including the top and executive level, on the importance of transforming the linear economy to CE. Every stakeholder should be aware of the negative impacts of the linear economy and support the transition to CE" – C01.

The lack of awareness of the CE concept was identified as a contributing factor that limited the scope of CE policies and strategies developed and introduced by government agencies and local authorities in Malaysia. As most respondents were more familiar with the 3Rs (Reduce, Reuse, and Recycle), the holistic concept of CE in managing C&D waste was not fully utilised in the IBS application.

> "I don't really understand how I could contribute or participate in the CE, but I am a bit sure that our organisation is encouraging the implementation of 3Rs (Reduce, Reuse and Recycle) for a few types of material that we have on construction, such as metal, concrete and aggregates" – C12.

The benefits of CE should be promoted so that industry players are aware of its importance and how it can benefit the construction sector in terms of economy, environment, and society. The advantages of CE in supporting sustainable development need to be highlighted through a clear definition and understanding of CE. Training and workshops on CE in the IBS application should be provided to stakeholders, including the management and people involved at the project level. Certification programmes can increase the quality of workers at the project level and support the implementation of CE. The availability of reports, articles in journals or newspapers and official statements on social media related to CE in the IBS application will provide guidelines for construction players to refer to in their efforts to implement CE in their construction activities.

> "If there are easy and simple guidelines or accessible information on CE in the IBS application, it will help me to be more involved and contribute more to CE for the construction industry. Specific workshops or training on the CE for IBS application will be helpful" - C08.

The majority of the respondents agreed that they had a limited understanding of the CE in managing C&D waste, especially in the IBS application. They agreed that CE has the potential to improve sustainable development in the construction industry. In managing construction waste, most practices the 3Rs, whereby they provide separation bins to separate construction waste that can be reused or recycled. The CE approach should be adopted holistically, from design to demolition. A clear understanding of CE can help construction players apply CE in an effective and systematic manner.

3.2 STEEP Matrix

The STEEP factor analysis is a technique to categorise the drivers, challenges, enablers, and barriers identified in the interview session. The analysis was adopted from Iyer-Raniga et al. [19] to identify drivers, challenges, enablers, and barriers in mapping the Circular Economy Ecosystem for the State of Victoria in Australia. The five key areas in the STEEP Matrix are social, technology, economic, environment and political. The matrix helps researchers identify external factors that influence CE by understanding stakeholders' perceptions, which in turn affect their decision-making in managing C&D waste.

The matrix in Table 3 illustrates that the major influential factors of CE are not only economic aspects but also significant in other key areas, including environmental, social, and political aspects. The importance of technology was also highlighted by the respondents in the interview.

Table 3 *STEEP matrix of drivers, challenges, enablers and barriers of CE*

STEEP Matrix	Drivers	Challenges	Enablers	Barriers
Social	Local talent & workers employability	Lack of understanding of CE	Recognition as a CE or sustainability expert and leader Community empowerment Increase awareness Collaboration and cooperation between stakeholders	Lack of demand from industries/clients Limited coordination across the supply chain
Technology	Government investments for kicking off new & advanced technology in the advancement of recycling or CE infrastructures	Shortage of advanced technologies Linear supply chains and infrastructure	Supply chain innovations Circular design techniques	Lack of collaboration between manufacturers and recyclers. Limited infrastructure & IT facilities
Economic	Entrepreneurial / business opportunities Increase in Gross Domestic Product (GDP) due to CE Cost/benefits analysis for circular business model	Lack of financial viability Conventional organisational structures	Demand from the market for recycled or reusable products Financial support and initiatives for SMEs.	Uncertainties and viability of the circular business model
Environment	Limited landfill area for C&D waste High cost in managing C&D waste, including transportation and tipping fees Commitment to SDG	No standardization	Reduction of GHG emissions by applying CE	Lack of commitment and cooperation in preserving the environment Focus on profit-oriented.
Political	Government priority as shown in government policies	Most policies only focus on 3R (Reduce, Reuse & Recycle), and higher-order CE principles are not fully covered in policy targets	Appropriate and accepted industry standards and guidelines	No consistency in metric/indicator to measure CE at the project level

3.3 Drivers

Table 3 shows that there are nine drivers for contractors to employ the circular economy in managing C&D waste for IBS application. The drivers are categorised into social, technology, economic, environment and political dimensions. For the social dimension, the drivers identified from the interview sessions are local talent and workers' employability. Dependency on unskilled foreign workers in the construction industry can be eliminated by improving working conditions, such as shifting to automation and adopting IBS in the construction industry [20]. Employment opportunities can be created by offering local institutions or polytechnic graduates the opportunity to operate and manage construction activities, including waste management for IBS applications. The elimination of 3D (dirty, dangerous and difficult) images for the construction industry will improve local talents' interest in participating in the construction sector.

The support from the Malaysian government in encouraging investments to kick-start new technologies in advancing recycling and circular economy infrastructure is the driver identified in the technology dimension. Commitment and cooperation from the government are vital to ensure the successful implementation of the CE concept in managing C&D waste. There are three drivers that have been identified in the economic dimension, namely, (i) entrepreneurial/business opportunities, (ii) an increase in GDP due to circular activities, and (iii) cost/benefits analysis for circular business models. By understanding the CE concept, more business opportunities can be created while also preserving natural resources.

The three drivers from the environmental dimension that have been identified are (i) limited landfill allocated for C&D waste, (ii) high cost in managing C&D waste, including transportation and tipping fees, and (iii) commitment to the Sustainable Development Goals (SDG). The only driver for the political dimension highlighted by the respondents is the "government priority". This can be articulated in the government policies by highlighting the importance of CE. Respondent C05, C10 and C11 admitted that the commitment shown by the government should encourage other stakeholders, such as the contractors, consultants and users, to employ CE in managing their C&D waste.

3.4 Challenges

As illustrated in Fig. 1, the key challenges to employing circular economy in managing C&D waste are (i) lack of understanding of CE, (ii) shortage of local talents and skills in operating new and advanced technologies, (iii) linear supply chains and infrastructure, (iv) lack of financial viability, (v) conventional organisation structures, (vi) no standardization, and (vii) higher order of CE principles are not fully covered in policy targets.

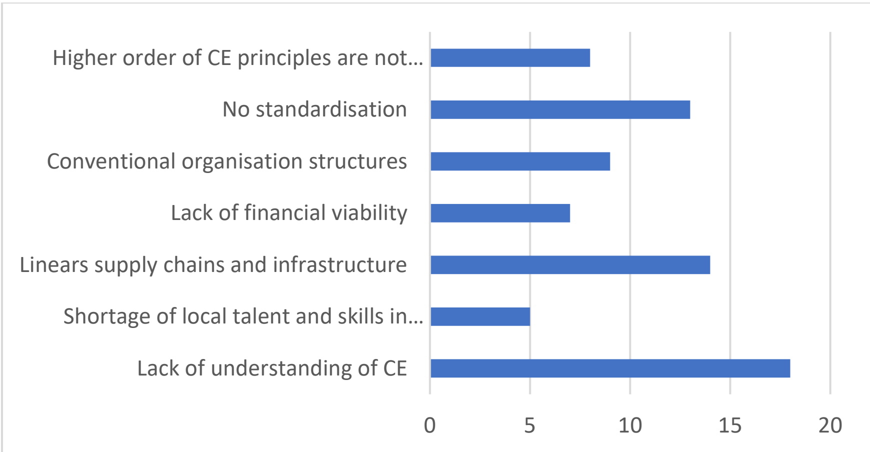

Fig. 1 *Challenges in employing CE in IBS application*

Most respondents highlighted that misunderstanding the Circular Economy concept was a primary challenge to shifting from the linear economy to CE. They viewed CE as a new concept with additional procedures and work that came at an extra cost. The long-term benefits of CE are unclear to many construction players. Respondent C17 stated, "We don't really understand the necessity to change how we do construction activities. We are unsure of the benefits of CE. However, I am sure that we need to provide more money to buy or rent separation bins and employ additional labourers to manage and organise different waste materials".

The second challenge in managing C&D waste for IBS applications is the shortage of local talent and skills in operating new and advanced technologies to manage C&D waste efficiently. The finding aligns with the results presented by Ratnasabapathy et al. [18], who reported the lack of application of smart technologies to improve waste data collection and inadequate experience, skills, and training in waste handling methods among on-site workers in Australia. Training and knowledge on operating advanced technologies for managing C&D waste should be provided to workers at the project level. Two respondents (C17 and C18) indicated that more technologies should be ready to operate new and advanced technologies in managing C&D waste. With Industry Revolution 4.0 (IR 4.0), technologies for managing C&D waste will become increasingly complex, and engineers should be IT literate to operate and maintain these technologies. Respondents C and D confessed that the limited availability of local innovation and technology in managing C&D waste for IBS also hindered the use of automation and advanced technology in this sector.

The linear supply chains and infrastructure are the third challenge to employing CE in IBS. This conventional approach converts natural resources into finished products according to customer demand, with manufacturers playing a limited role and having limited visibility and control over environmental protection [21]. The existing infrastructure needs to be extended as a complex adaptive system. This system evolves together with a broader contextual environment. Each process and activity needs to be evaluated to optimise the potential of contributing to a circular economy in the IBS application. Advanced technology, such as artificial intelligence, building information systems and the Internet of Things (IoT), should be integrated into the system to maximise the building components or material values.

From the economic dimension, the challenges highlighted by the respondents are limited financial viability and conventional organisational structures. At the project level, the practitioners focus more on profit maximisation rather than considering waste as a variable in the cost equation [3]. Similarly, clients still perceive that profit maximisation is more important than converting waste materials or components into valuable products. Top-down organisational structures hinder collaboration between project parties, preventing them from contributing to enhancing sustainability and adopting the circular economy. According to Yousaf et al. [22], organisational innovativeness is essential for expanding diverse relations among key stakeholders, including suppliers, partners, and competitors, which facilitates quick market entry. The adoption of new strategies to meet the updated technologies will assist in the development of new products and boost organisational innovativeness.

For the environmental dimension, respondents highlighted that the absence of standard regulations posed a challenge for them in implementing CE. As a developing country, the Malaysian government is collaborating with authorities and industry players to regulate waste management in the construction sector. However, the standard is insufficient because there is no regulatory framework to monitor efforts made by an organisation in managing C&D waste and a lack of a well-developed market for waste recycling [3]. Short-term and direct economic benefits drive the voluntary involvement of contractors in waste management. The government and industry players should adopt a holistic approach to developing practical and standardised regulations tailored to the local context, thereby promoting sustainability.

For the political dimension, the policies are identified as a challenge. Most policies focus on the 3R principle (Reduce, Reuse & Recycle), while higher-order CE principles are not fully covered in policy targets. This finding aligns with the results of a study conducted by Reike et al. [23]. Their study proposed the term “resource value retention options (ROs)” and translated the most common perspectives found on these options across different academic disciplines into a 10R typology, along with visualisations. The retention of resource value refers to the preservation of the material in its original properties. For the finished goods, retaining their state or reusing them with minimal entropy will extend their functional period. The government, authorities, and business organisations should have a consensus on value retention by applying a broader and more systematic approach to creating clarity in their policies and guidelines for implementing activities in the construction sector.

3.5 Enablers

The most important enabler identified by the respondents is having “appropriate and accepted industry standards and guidelines”. This enabler is categorised into the political dimension. The Malaysian government has been committed to minimising C&D waste and supporting any initiatives in this direction for the past few years. This is evidently demonstrated by the enforcement of series of waste management policies and regulations such as Policy for Integrated Solid Waste Management (2001), National Strategic Plan for Solid Waste Management (2005), Master Plan on National Waste Minimization (2006), Enforcement of Solid Waste and Public Cleansing Management Act – Act 672 (2011) and National Solid Waste Management Policy (2016). The 6th objective in the National Solid Waste Policy focuses on reinforcing legislation and institutions on solid waste management which led to the development of Regulation of Solid Waste and Public Cleansing Management (Licencing – Undertaking or Provision for Collection Services for Construction Solid Waste) (2018) and Regulation of Solid Waste and Public Cleansing Management (Scheme for Construction Solid Waste) (2018)[24].

From the social dimension, the enablers identified are (i) recognition as CE or sustainability expert and leader, (ii) community empowerment, (iii) increasing awareness, and (iv) collaboration and cooperation between stakeholders. Every player in the construction industry is responsible for increasing their knowledge and understanding of the CE concept and working together as a team to ensure success in integrating CE in managing C&D waste for IBS applications. Each party’s contribution should be recognised, and incentives should be given to those who participate in CE. This is crucial for motivating more sustainable initiatives at the project level.

For the technology dimension, two enablers have been identified: supply chain innovations and circular design techniques. The integration of information technologies, such as digitisation, Building Information Modelling (BIM), Cloud Supply Chain Solutions, and the Internet of Things (IoT), will ensure that information about building components and waste materials is available for value evaluation. Additionally, circular design techniques will ensure the physical and behavioural performance of the building components can be examined throughout their life cycle. This will assist the contractor in dismantling the IBS building and minimising waste generation at the end of the building's life.

For the economic dimension, the enabler includes positive market demand and government financial. For CE to succeed, a positive market demand for recycled and reusable building components is needed. The government should also provide financial support and initiatives for Small and Medium Enterprises (SMEs). In Australia, Ratnasabapathy et al. [18] report that markets for metals, glass, and timber have already been established. This provides a platform for the materials to be recycled and reused in the construction industry. Additionally, the government can also provide rewards to promote behavioural changes towards successful adoption of CE and improve sustainable practices. Effective reward and penalty systems, in terms of monetary gains, would motivate project stakeholders to reduce waste [25].

Reduction of Greenhouse Gas (GHG) emissions is identified as the enabler for the environmental dimension. The IBS has been acknowledged as an effective strategy for reducing GHG emissions due to its controlled and efficient production processes [26]. During the interview session, three respondents highlighted that the IBS components could be reused after their end of life if the properties of the components are recorded. Additionally, non-destructive testing can be executed to determine the functionality of the IBS components. This will reduce the need to process new raw material, minimising embodied energy. The GHG emissions will be reduced when the IBS components are reused.

3.6 Barriers

The findings from the interview reveal eight primary barriers to implementing the CE concept in IBS construction. For the social dimension, two main barriers have been identified: a lack of demand from industries/clients and limited coordination across the supply chain. Ratnasabapathy et al. [18] found that an inadequate supply of materials caused discontinuity in the material supply and impeded the resource recovery. As a result, there was a lack of demand for secondary materials among market users. The respondents (C04, C07, C18, and C19) highlighted the limited coordination across the supply chain, as there was no client involvement or leadership in reducing waste. The consultants and local authorities should provide general instructions to prevent pollution and emphasise the importance of recycling waste generated by project activities. A consensus and early collaboration among all stakeholders, including manufacturers, will provide documented action plans to develop new materials or products that maintain the value of unwanted materials normally sent to landfills.

The “lack of collaboration between manufacturer and recycler” and “limited infrastructures & IT facilities” have been identified as the main barriers to the technology dimension. According to Berlin et al. [27], supply network collaboration is vital for understanding the actual activities in which actors are engaged. The respondents (C04, C06 and C19) stated that a link should be created between the manufacturer and recycler to ensure both parties understand the actual activities and material properties that need to be recycled or manufactured. An agreement or contract between both parties will sustain the collaboration in the supply chain of the circular economy. A systematic and reliable platform for communication among C&D actors should be established. This will help the actors keep track of the resources and material properties processed for the new building components. Limitations of infrastructures and IT facilities can hinder the development of marketplaces for C&D waste [28], [29]. In addition, the limited availability of the required technical specifications and guidelines can lead to uncertain quality of recycled materials and low social acceptance [18].

Uncertainties and the viability of the circular business model have been identified as the main barriers to the economic dimension. The respondents highlighted their concerns about the sustainability of their business when investing in the initial cost of machines, staff and equipment to adopt the circular business model. Nyström et al. [30] stated that companies might be willing to invest in additional upfront costs to improve their services or products. However, they always have concerns over the risk of being unable to recover these investments if premature obsolescence occurs due to future uncertainties. A comprehensive study should be conducted to evaluate the viability of the circular business model in the IBS application for generating returns on investment.

For the environment dimension, two main barriers have been identified by the respondents. The barriers include a lack of commitment and cooperation in preserving the environment, as well as stakeholders being more profit-oriented. In Australia, human factors in waste management are mandatory to improve the performance of waste management practices [3]. Clients must be convinced about the benefits of waste management. Due to the short-term profit-driven nature of the construction industry, most decisions are made based on financial returns and cost savings. Stakeholders should be made aware that economic prosperity is closely linked to environmental attitudes and behaviour [31]. The organisation must recognise the benefits of waste management and focus on long-term profitability to enhance the performance of waste management practices in IBS projects.

4. Conclusions

The study examined how contractors in Malaysia perceived the relationship between the circular economy and construction activities in their IBS projects. One of the key findings generated from the interview data highlighted the significance of recycling and reuse in operationalising the circular economy in construction projects. The recycle and reuse initiatives are not new to contractors. However, the findings indicate that their understanding of the CE remains low. The ladder of circularity, consisting of refuse, reduce, redesign, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover, was presented to the respondents to increase their understanding of CE in IBS applications. However, the study showed that most respondents assumed CE involved only recycling and reuse, and they did not fully understand the entire process and levels of circularity. The contractors reported that the local authorities required them to manage the construction waste effectively. The authorities have established several regulations and guidelines to effectively manage construction and demolition (C&D) waste. In current practice, contractors provide separate bins to collect main construction waste, such as metal, paper, and wood. The recycling operators will collect the waste, which will normally provide a side income for the project. Bricks, plywood, timber and tiles are some of the construction wastes that can be reused for other projects. The materials need to be stored in a covered area to ensure the quality and value of the materials can be maintained. Additional costs for transportation and handling will be incurred to protect the materials from being damaged. The STEEP analysis identifies the enablers, challengers, drivers and barriers to employing CE in managing C&D waste for IBS application. Further study is required to develop strategies that improve efficiency in managing C&D waste and to gather perceptions from other stakeholders about the implementation of the circular economy.

Acknowledgement

This research was supported by the Ministry of Higher Education (MOHE) through the Fundamental Research Grant Scheme (FRGS/1/2021/SS02/UTHM/02/2).

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***Study conception and design:*** *Riduan Yunus, Bambang Trigunarsyah;* ***Data collection:*** *Eizzad Amirul Arash Mohd Nizam, Siti Norain Abdullah;* ***Analysis and interpretation of results:*** *Riduan Yunus, Bambang Trigunarsyah;* ***Draft manuscript preparation:*** *Riduan Yunus, Mimi Nahariah Azwani Mohamed. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Government of Malaysia (2007, August 30). Solid Waste and Public Cleansing Management Act 2007 (Act 672). Percetakan Nasional Malaysia Berhad

[2] Ajayi, S. O., & Oyedele, L. O. (2017). Policy imperatives for diverting construction waste from landfill: Experts' recommendations for UK policy expansion. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2017.01.075

[3] Udawatta, N., Zuo, J., Chiveralls, K., Yuan, H., George, Z., & Elmualim, A. (2018). Major factors impeding the implementation of waste management in Australian construction projects. Journal of Green Building. https://doi.org/10.3992/1943-4618.13.3.101

[4] Ulubeyli, S., Kazaz, A., & Arslan, V. (2017). Construction and demolition waste recycling plants revisited: Management issues. Procedia Engineering. https://doi.org/10.1016/j.proeng.2017.02.139

[5] Umar, U. A., Shafiq, N., & Ahmad, F. A. (2021). A case study on the effective implementation of the reuse and recycling of construction & demolition waste management practices in Malaysia. Ain Shams Engineering Journal. https://doi.org/10.1016/j.asej.2020.07.005

[6] Zairul, M. (2021). The recent trends on prefabricated buildings with circular economy (CE) approach. Cleaner Engineering and Technology. https://doi.org/10.1016/j.clet.2021.100239

[7] Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. Journal of Cleaner Production. https://doi.org/10.1016/ j.jclepro.2012.11.020

[8] Al-Rifai, J., & Amoudi, O. (2016). Understanding the key factors of construction waste in Jordan. Jordan Journal of Civil Engineering, 10, 244-253.

[9] Le, N. P., Nguyen, T. T. P., & Zhu, D. (2018). Understanding the stakeholders' involvement in utilizing municipal solid waste in agriculture through composting: A case study of Hanoi, Vietnam. Sustainability. https://doi.org/10.3390/su10072314

[10] Yunus, R., & Yang, J. (2012). Critical sustainability factors in industrialised building systems. Construction Innovation. https://doi.org/10.1108/14714171211272216

[11] Purchase, C. K., Al Zulayq, D. M., O'Brien, B. T., Kowalewski, M. J., Berenjian, A., Tarighaleslami, A. H., & Seifan, M. (2022). Circular economy of construction and demolition waste: A literature review on lessons, challenges, and benefits. Materials. https://doi.org/10.3390/ma15010076

[12] Shooshtarian, S., & Maqsood, T. (2022). Construction and Demolition Waste Management in Australia. Nova Science Publishers. https://doi.org/https://doi.org/10.52305/PCZT5417

[13] Ellen MacArthur Foundation (2024). The Circular Economy in Detail. Netherlands.

[14] Ellen MacArthur Foundation (2015). Towards A Circular Economy: Business Rationale for An Accelerated Transition. Netherlands.

[15] O'Grady, T. M., Minunno, R., Chong, H.-Y., & Morrison, G. M. (2021). Interconnections: An analysis of disassemblable building connection systems towards a circular economy. Buildings. https://doi.org/10.3390/buildings11110535

[16] Esa, M. R., Halog, A., & Rigamonti, L. (2017). Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. Journal of Material Cycles and Waste Management. https://doi.org/10.1007/s10163-016-0516-x

[17] Bougie, R., & Sekaran, U. (2020). Research methods for business: A skill-building approach (8th ed.). John Wiley & Sons.

[18] Ratnasabapathy, S., Alashwal, A., & Perera, S. (2021). Exploring the barriers for implementing waste trading practices in the construction industry in Australia. Built Environment Project and Asset Management. https://doi.org/10.1108/BEPAM-04-2020-0077

[19] Iyer-Raniga, U., Gajanayake, A., Ho, O., & Trewick, S. Mapping the Circular Economy Ecosystem of Victoria: Milestone report submitted to Sustainability Victoria (April 14, 2022). http://dx.doi.org/10.2139/ssrn.4478022

[20] Choon, W. F., Hashim, M. A. S., & Toudehdehghan, A. (2018). Foreign workers reduction in Malaysia Construction Industry. Inti Journal - Built Environment, 2, 1–15.

[21] Rogan, J., Fürstenberg, F., & Wieland, A. (2022). Shaping the transition from linear to circular supply chains. In Bals, L., Tate, W. L., & Ellram, L. M. (eds.), Circular Economy Supply Chains: From Chains to Systems. Emerald Publishing Limited. https://doi.org/10.1108/978-1-83982-544-620221004

[22] Yousaf, Z., Mihai, D., Tanveer, U., Brutu, M., Toma, S., & Zahid, S. M. (2022). Organizational innovativeness in the circular economy: The interplay of innovation networks, frugal innovation, and organizational readiness. Sustainability. https://doi.org/10.3390/su14116501

[23] Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or refurbished as CE 3.0? — Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resources, Conservation and Recycling. https://doi.org/10.1016/j.resconrec.2017.08.027

[24] Government of Malaysia (2016). National Solid Waste Policy. Kuala Lumpur.

[25] Chen, Z., Li, H., & Wong, C. T. C. (2002). An application of bar-code system for reducing construction wastes. Automation in Construction. https://doi.org/10.1016/S0926-5805(01)00063-2

[26] Teng, Y., Li, K., Pan, W., & Ng, T. (2018). Reducing building life cycle carbon emissions through prefabrication: Evidence from and gaps in empirical studies. Building and Environment. https://doi.org/10.1016/j.buildenv.2018.01.026

[27] Berlin, D., Feldmann, A., & Nuur, C. (2022). Supply network collaborations in a circular economy: A case study of Swedish steel recycling. Resources, Conservation and Recycling. https://doi.org/10.1016/j.resconrec.2021.106112

[28] Caldera, S., Ryley, T., & Zatyko, N. (2020). Enablers and barriers for creating a marketplace for construction and demolition waste: A systematic literature review. Sustainability. https://doi.org/10.3390/su12239931

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[29] Shooshtarian, S., Maqsood, T., Wong, P. S. P., Khalfan, M., & Yang, R. J. (2020). Market development for construction and demolition waste stream in Australia. Journal of Construction Engineering, Management and Innovation, 3, 220-231. https://doi.org/10.31462/jcemi.2020.03220231

[30] Nyström, T., Whalen, K. A., Diener, D., den Hollander, M., & Boyer, R. H. W. (2021). Managing circular business model uncertainties with future adaptive design. Sustainability. https://doi.org/10.3390/su131810361

[31] Johansson Sevä, I., & Kulin, J. (2018). A little more action, please: Increasing the understanding about citizens' lack of commitment to protecting the environment in different national contexts. International Journal of Sociology. https://doi.org/10.1080/00207659.2018.1515703