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Potential of BREEAM-C to support building circularity assessment: Insights from case study and expert interview

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ABSTRACT

Lack of knowledge and tools hampers circular transition in the construction industry. This study analyzes the potential of a framework of circular indicators put forward by the Building Research Establishment Environmental Assessment Method (BREEAM-C) as an answer to the prevailing need of a metric for building circularity assessment to promote circular construction. A qualitative analysis approach is adopted, involving literature review, comparative case study and semi-structured interviews conducted for collecting expert opinions. An in-depth scrutiny of the BREEAM-C indicators revealed that they are rooted in circular principles, cover building circularity realizable through circular strategies, and have given due consideration to circularity in different impact areas, structural layers and life-cycle stages of buildings. Moreover, BREEAM-C indicators not only show capacity in identifying CE-related practices implemented, but also serve as benchmarks testifying that CE principles/strategies are incorporated in the design, construction, operation and management of the buildings. Despite having room for expansion, BREEAM-C has proven to be applicable and practical with potential for use in Taiwan as confirmed by expert opinions. Nevertheless, adaptation/localization is required to cater for different concerns with respect to climate and safety as well as local context and legislations.

1. Introduction

Buildings are responsible for 50% of global material use, consuming 42.4 billion tons of material annually, and account for approximately 40% of energy-related global carbon emissions with around 25% of all building emissions related to material production and construction (Green Building Council Australia GBCA, 2021). The construction industry as a major consumer of the world's precious but limited resources and a significant contributor to global greenhouse gas emissions and wastes is urgently in need of an alternative to the prevailing take-make-waste mentality (Benachio et al., 2020). Circular economy (CE), restorative and regenerative by design and aims (Ellen MacArthur Foundation (EMF), 2013), promises a way to decouple economic growth from resource consumption (Ellen MacArthur Foundation & McKinsey Center for Business and Environment, 2015). Hence, circular transition in the construction industry is seen as the key to achieving a 'resource-efficient' and 'resource-sufficient' society. However, application of CE in the construction industry is still largely confined to construction waste minimization and recycling (Adams et al., 2017). A more comprehensive circular transformation of the sector is hindered due to the lack of assessment tools and guidance for CE implementation. In particular, there is a lack of consensus on what aspects of circularity are to be measured and how (Haas et al., 2015), and what circular buildings are. The plethora of definitions and interpretations on CE (Kirchherr et al., 2023), circular building and building circularity (Zhai, 2020) makes it difficult to determine the focus or delimit the aspects/items to be assessed.

In 2018, BREEAM, which stands for Building Research Establishment Environmental Assessment Method, expanded their original version for green building assessment (BREEAM-G) into a framework for circular buildings with suggested indicators catered for assessing building circularity (BREEAM-C) (Kubbinga et al., 2018). To the knowledge of the authors, the proposed BREEAM-C indicators have not been validated or applied. This study aims to assess (1) whether the proposed indicators

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do cover CE strategies or five R-imperatives (namely Rethink, Reduce, Reuse, Repair, and Recycle) to achieve building circularity, and (2) whether BREEAM-C answers the need for a tool to gauge CE application in the construction industry with potential to support circular construction. A qualitative analysis approach is adopted, involving match check via literature review, comparative case study and semi-structured interviews conducted for collecting expert opinions. This research is the first analysis of the proposed indicators, which would contribute knowledge to the current literature on the development of circularity assessment metrics and guides for application of CE to construction.

The rest of this article is organized as follows. Section 2 contains the literature review on challenges in building circularity assessment, the lack and the need for a valid and practicable assessment tool. Section 3 presents the methods used for the in-depth scrutiny of BREEAM-C on its validity and practicality as a framework for circularity assessment and its potential for application to support circular construction. Analysis results are presented in Section 4, followed by discussion on the key findings in Section 5. The conclusion along with study limitations and points for future research are detailed in Section 6.

2. Literature review

2.1. Challenges of circular transition for built environment

Though aware of the necessity and the benefits to shift toward more life-cycle thinking for the built environment and having great potential for CE implementation (Brambilla et al., 2019), the construction industry has been slow in embracing CE concepts and related strategies. Hart et al. (2019) identified seven sectoral challenges (see Appendix Table A1) of circular transition in the construction industry that arise from a defining feature of the built environment; that is, complexity of buildings. Indeed, each building is a unique entity comprising layers and layers of materials and components in multitude, featuring different characteristics, serving different functions and having different lifespans (Eberhardt et al., 2019). Brand's 'shearing layer' concept (see Appendix Figure A1) illustrates the six structural layers of a building and their potential service life with each layer concerning multiple stakeholders (Brand, 1994). Moreover, buildings tend to have long life cycles having various actors with different incentives and priorities. Diverse stakeholders and actors involved as well as long lead times would render continuity of control and ownership hardly possible (Zimmann et al., 2016).

Another obstacle to CE transition in the construction industry are deficient knowledge and lack of tools (Foster, 2020). These tools include design tools and guides covering design for CE, disassembly, and adaptability, a range of collaboration tools, building and material information tools and circularity metrics (Hart et al., 2019). As the well-known saying "what gets measured gets done" (Nuñez-Cacho et al., 2018), the circularity breakthrough of the construction industry demands to make circularity measurable and quantifiable, taking into consideration the complexity of buildings. However, the recent review of Bilal et al. (2020) on the present state and barriers to CE in the construction industry highlights scarcity of research with specific focus on the assessment of CE implementation for the construction industry, especially in developing countries. In Munaro et al. (2020), 39% of research works they analyzed are on the theme of recycled/reusable materials while only 17% cover the topic on tools and assessment to support circular construction. Furthermore, circularity metrics of the construction industry developed so far are more on assessment of materials and manufactured components at the micro-level (Elia et al., 2017) but not buildings at the meso-level (Pomponi and Moncaster, 2017; Kristensen and Mosgaard, 2020). Compared with manufactured components that entail less complicated production processes and are of a shorter life span, buildings are far more complex structures made up of and from a wide range of materials and products that will last different lifespans, involves multiple stakeholders, massive investments, capital risks and long lead times. Hence, evaluating building materials and manufactured products only is insufficient for assessing how circular a building is.

2.2. Obstacles for building circularity assessment

Like the sectoral challenges encountered by the construction industry, obstacles for building circularity assessment abound, which account for the lack of or the existence of few assessment tools/models. The first obstacle is not knowing what aspects of circularity are to be measured and how (Haas et al., 2015). The second hurdle arises again from the inherent complex nature of the building (Rahla et al., 2019). The average life cycle of modern buildings ranges from 65 to 70 years while that of most other manufactured products does not exceed a decade. Thirdly, buildings contain many different products. Some account for considerable proportions of the total masses/volumes, and others could be of special relevance to environmental or health impacts. Each product has its own life span and has to be replaced during the building's lifetime. Fourthly, the building itself might undergo major changes, like refurbishment, additional constructions/extensions, and other occupants with different resource consumption patterns. Finally, buildings usually have a unique design and that may complicate the development of a standardized tool.

While Nuñez-Cacho et al. (2018) have pointed out that a specific scale of measurement for the construction industry to guarantee its future sustainability is missing, building circularity assessment metrics/indicators do exist albeit few and under development, not to mention they are ambiguous and inconsistent (Zhang et al., 2021). Table 1 summarizes the special features and focuses of the existing building circularity indicators and indices (Cottafava and Ritzen, 2021).

Of note is that although MCI, the two BCIs and BCIX are all developed in the Netherlands, none of these assessment metrics has been recognized as a certification or labeling methodology for Dutch constructions (Zhai, 2020).

2.3. BREEAM-C – from green to circular

BREEAM-C stands out from among the existing metrics in that it is the only one expanded from a green rating scheme (BREEAM-G). Contrary to the under-developed or yet-to-be-applied circularity assessment metrics, different schemes and certifications for evaluating and verifying green buildings are available worldwide and have all been in use since the 1990s. Their focus is on assessing the impact of building on society and environment with the goal to reduce carbon dioxide emissions during the use of the buildings and their construction processes. Hence, their direct application to circularity assessment would not suffice to serve the purpose of waste minimization through enhancing circularity or resource efficiency. The focus of BREEAM-C is to embed circularity in a green economy context. While designing out waste and salvaging residual value are chief concerns of achieving CE, environmental impact should not be left unattended when aiming for waste elimination and value retention. Moreover, the wide application and popularity of BREEAM-G may help promote the acceptance and adoption of BREEAM-C.

Until the time this research was carried out, building circularity assessment has been relatively underexplored (Zhang et al., 2021), and the proposed BREEAM-C indicators have neither been validated nor applied. Hence, to fill the knowledge gap, this study conducted an in-depth analysis on the validity of BREEAM-C as a circularity assessment tool, its practicability to gauge CE application in the construction industry, and its potential to support circular construction.

3. Methodology

Fig. 1 shows the research flowchart that summarizes the methods used in the present analysis on the validity, applicability and potential of

Table 1
Existing circularity assessment metrics/indicators.

Circularity Assessment Metrics/Indicators	Year	Developed/ Proposed by	Characteristics	Focus
Material Circularity Indicator (MCI)	2015	EMF and Granta Design (Ellen MacArthur Foundation, & Granta Design, 2015)	Measures how restorative the material flows are at product level	End-of-life circularity
Building Circularity Indicator (BCI)	2016	Verberne (Verberne, 2016)	Determines circularity at building level using indicators for Materials (MCI), Products (PCI), Systems (SCI) and Building (BCI)	Input, functionality and output performance of building
Building Circularity Indicator (BCI)	2018	van Vilet from Verbene's BCI	Determines circularity at building level	Disassembly potential
Building Circularity Index (BCIX)	2018	Alba Concepts (Alba Concepts, 2018)	Determines circularity at building level	Technical cycle and disassembly potential
Madaster Circularity Indicator (CI)	2018	Madaster Foundation (Bronsvoort and van Oppen, 2018)	Has its basis on MCI developed by EMF Improved & adapted for circularity at building level BUT did not take into account circularity of different building layers.	Circularity scored according to circular properties of Materials & Products used during the Construction, In-use and End-of-life phases
Framework of Circularity Indicators (BREEAM – C)	2018	Building Research Establishment Environmental Assessment Method (BREEAM)	Expanded from BREEAM's green building certification scheme (BREEAM-G) Rooted in Metabolic's 7 CE pillars and Circle Economy's 8 key CE elements (See Appendix Table A2)	7 desired impact areas with 47 proposed indicators mainly under Material, Energy and Water Cycles (See Appendix Table A3)
Platform CB'23 Guide for Measuring Circularity in the Construction Sector	2020	Ministry of Infrastructure and Water Management, the Netherlands	Measurement goals: material preservation, environmental protection and value retention Quantitative indicators for objects/sub-objects Qualitative indicators listing adaptive properties for each building layer	Adaptive capacity of the building BUT lacks an overall BCI.

BREEAM-C. Given the absence of quantitative data on the application of BREEAM-C, a qualitative approach is adopted for analyzing this proposed framework. The various analysis items are attended with mixed methods including match check via literature review, comparative case study and semi-structured interviews to solicit expert opinions.

3.1. Validity analysis – Match check via literature review

First, to be qualified as circularity indicators, they must have roots in CE principles. In this study, BREEAM-C indicators are matched against eight CE key elements, namely (1) Prioritize regenerative resources, (2) Stretch the lifetime, (3) Use waste as a resource, (4) Design for the future, (5) Rethink the business model, (6) Incorporate digital technology, (7) Team up to create joint value, and (8) Strengthen and advance knowledge to determine their CE roots. These eight elements are put forward by Circle Economy, an advocate of transition toward CE for global sustainability, offering advice and providing strategies and tools for a smooth transition.

Second, BREEAM-C indicators are matched against five R-imperatives (5Rs), namely (1) Rethink, (2) Reduce, (3) Reuse, (4) Repair, and (5) Recycle. Condensed from the full list of Lombard Odier (2020), these five R-imperatives are the most utilized in CE-related literature (Reike et al., 2018). This match-check serves to validate whether the proposed circularity indicators cover circular strategies applicable to constructions for enhancing high material efficiency in circular construction.

Third, as mentioned above, buildings are complex, comprising various structural layers and tend to have long life cycles (Zimmann et al., 2016). Hence, BREEAM-C indicators are matched against the six building layers delineated by Brand (1995) (Figure A1), namely (1) Stuff, (2) Space plan, (3) Services, (4) Skin, (5) Structure, and (6) Site, as well as the five life-cycle stages across the holistic construction supply chain, namely (1) Design, (2) Manufacture & Supply, (3) Construction, (4) In use & Refurbishment, and (5) End of Life.

3.2. Applicability analysis – Match check & comparative case study

The applicability of BREEAM-C to building circularity assessment is examined using a two-pronged approach that involves match check and comparative case study.

3.2.1. Match check

First, BREEAM-C indicators are matched against 30 circular practices identified from five CE-focused pilot building projects (hereinafter CE-30) (Table 7 of Tserng et al., 2021). In contrast to those theoretically characterized from literature review (Table 4, Benachio et al., 2020), CE-30 have been practically applied to actual building projects designed and implemented with CE as the guiding principle. It can be said that they are of greater relevance to achieving CE in the built environment; their applicability has been demonstrated, and they can be adopted/adapted by other CE-focused construction projects. In view of these, CE-30 makes a good starting point for matching against the BREEAM-C indicators.

This match check serves the following purposes. First, it validates the applicability of BREEAM-C indicators in terms of their capacity in recognizing known/implemented circular practices. Second, it reveals what known circular practices are left out, implying whether there is room for further expansion in BREEAM-C so that circular practices can be acknowledged, contributing to the recognition/certification of the building/project as circular. Third, relevant to achieving CE in the built environment, what other circular practices in addition to CE-30 the indicators are looking for.

Of the five CE-focused pilot building projects, three are from the Netherlands and two from Taiwan. Located respectively in Europe and Asia, the two localities chosen reflect different concerns in construction. The three Dutch pilot projects are Park 20 | 20 (Zwart, 2018, 2019), Venlo City Hall (VCH) (C2C Expo Lab, 2014; Eurbanlab, 2015), ABN

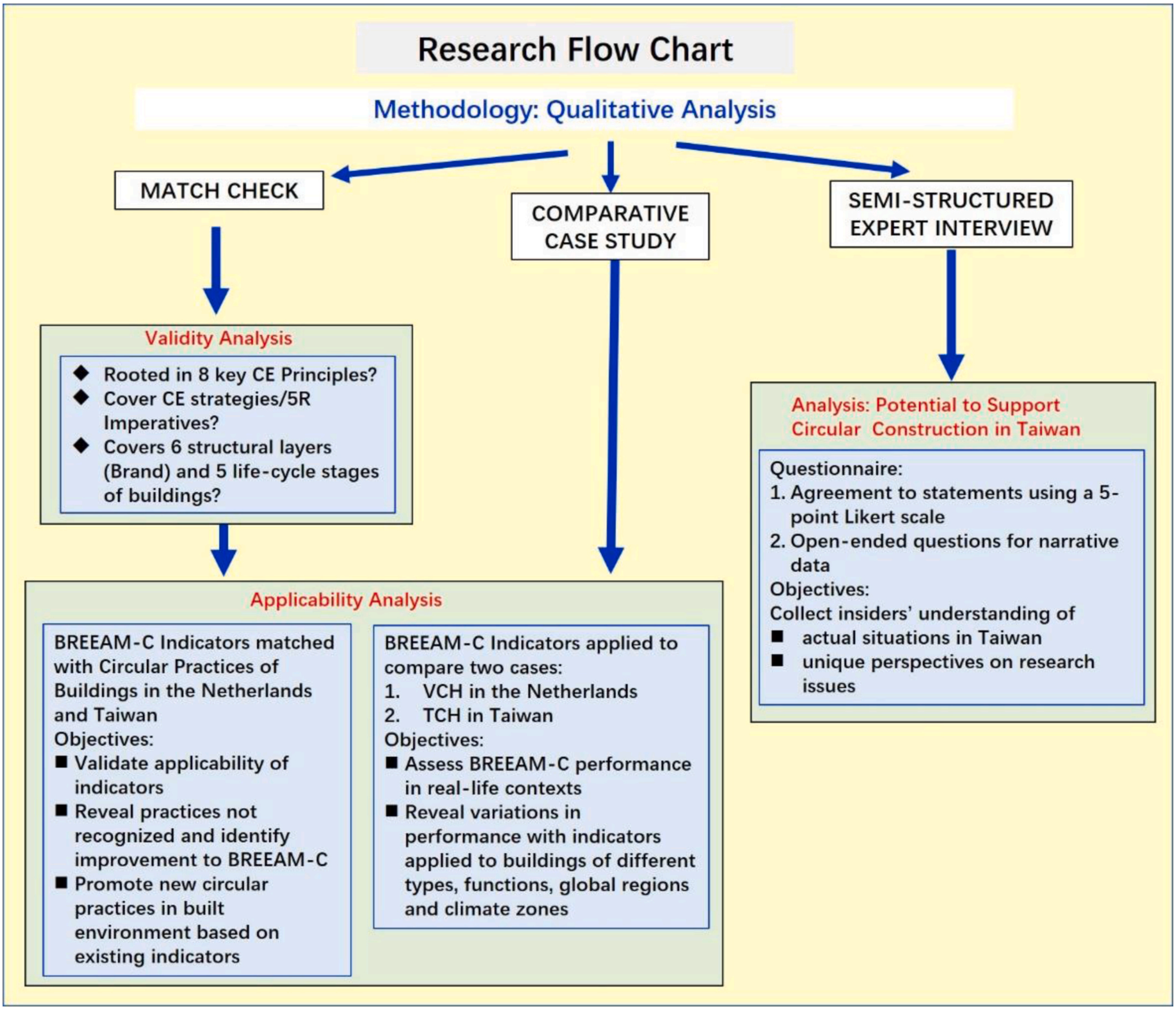

Fig. 1. Research flow chart showing the analysis items and the methodology of this work.

AMRO CIRCL (Circle Economy & ABN AMRO, 2017); and the two Taiwanese pilot projects are TaiSugar's Circular Village (TCV, also known as Shalun Circular Housing) and Nangang Public Housing.

3.2.2. Comparative case study

Second, comparative case study is performed using BREEAM-C indicators to assess two of the above CE-focused building projects, namely VCH of the Netherlands and TCV of Taiwan. On one hand, the analysis is a 'mock' validation of BREEAM-C in terms of its capacity for building circularity assessment in real-life contexts; and on the other hand, it is a 'maiden' assessment of VCH and TCV in terms of their circularity performance, testifying whether they really live up to its name as circular constructions. Moreover, analyzing the similarities and differences between cases would reveal whether there are variations in performance when BREEAM-C indicators are applied to constructions of different types, for different functions, in different global regions and climate zones. The comparative case study is conducted using document analysis with diverse data of the respective cases collected from project documentation, publications and official websites.

3.3. Analysis on potential for application in Taiwan - semi-structured interviews

This assessment on BREEAM-C's potential is a context check on its possible application in Taiwan to facilitate CE transition in the construction sector. Taiwan is a new player in the field of circular construction; hence, related literature is scarce and data for quantitative analysis are few. Instead, semi-structured interviews were conducted, which would have more potential in acquiring in-depth information and evidence (Ruslin et al., 2022).

The questionnaire used in the interview comprises statements, including "BREEAM-C can be applied to circular building assessment in Taiwan", to which the interviewees were asked to indicate their agreement using a five-point Likert scale, and open-ended questions for collecting their narrative data. (The translated English version of the original Chinese questionnaire can be seen in Appendix A). Prior to the interview, general background information of BREEAM-C and the questionnaire were sent to the respondents. A face-to-face meeting in person or over the Internet then followed with all exchanges audio-recorded and then transcribed for interpretative analysis.

4. Results

4.1. Validity – Match check

Table 2 matches BREEAM-C indicators against key CE principles and strategies as well as building layers and life-cycle stages. As can be seen, each of the BREEAM-C indicators has its basis in CE principles, with the majority of indicators rooted in the "Use waste as a resource" principle, justifying that these indicators are valid criteria for circularity assessment. Moreover, the indicators cover at least one and often several R-imperatives for achieving circularity. Similarly, the indicators cover more than one and often all six building layers, i.e., the entire building; and can thus be considered comprehensive. In the same way, the indicators cover at least one and sometimes all the life-cycle stages, implying due consideration given to the long life span of buildings.

4.2. Applicability – Match check

Table 3 categorizes CE-30 in terms of their status of development and extent of implementation and whether they are covered by BREEAM-C indicators or not; while Table 4 lists the CE-30 covered by BREEAM-C indicators according to the respective impact areas and those not covered by BREEAM-C.

As seen in Tables 3 and 4, BREEAM-C indicators cover more than half of the 30 identified circular practices, the majority of which are well-developed and widely implemented, especially those related to the Energy and Water cycles, Biodiversity and Ecology, Health & Well-being. It can be said that these practices are both green and circular, such as water recycling, solar energy and natural lighting. The same is true for practices involving material reuse/recycle and waste minimization. Nevertheless, there are several innovative material-related approaches eagerly put to practice by the construction industry for achieving circularity, including use of lightweight structure, lifespan extension, and resource circular flow. Pioneering practices acknowledged by BREEAM-C indicators but with room for further development are product as service/material ownership by supplier, modular construction and flexible unit, and material passport. The benefits of these practices are yet to be validated and advocated to different stakeholders of the building. The fact that these practices are recognized and given due credits by BREEAM assessment would promote their adoption and implementation.

On the other hand, a closer look at the 13 practices without corresponding BREEAM-C indicators reveals that they are not totally neglected or left out. Among the six practices under Material Cycle, 'Construction waste recycling system' has already been included in BREEAM-G under WST 1 'Waste management on the construction site'. Under M2 'Reutilization of materials, components and elements', the reuse of construction waste should have been included though not specifically mentioned. Three other practices, 'Modular unit' (e.g., modular partition/exterior), 'Prefabrication system' and '3D printing' share the advantages of enabling or facilitating reuse/repair of materials and minimizing material use/waste, which contribute to prolong the lifespan of building materials. It is thus suggested that under M1.2 'Design for flexibility' or M1.4 'Design for reassembly', a 'Design for Manufacture and Assembly' sub-strategy should be added to recognize modularity practice as well as prefabricated or 3D-printed materials in construction.

Taking buildings as 'Material Banks' forms the backbone of circular transitions, with buildings seen as repositories or stockpiles of valuable, high-quality materials. Hence, practices such as 'Material Passport' documenting the inventory and flow of materials used, M1.2 Design for flexibility with the objective of enabling materials to be easily taken apart, recovered and reused as well as M2.4 Future use are all related to this. Thus, it can be said that the concept of 'Material bank' has been embedded in several circular practices. As for the last practice of 'Quantifying residual value of materials', understanding the total use cost of a whole building life-cycle can provide a better economic estimation for building materials to be reused. Hence, this should be specified as a required information item in the Material Passport.

Finally, of the six circular practices not classified under any of the impact areas, 'Leftover recycle system' refers mainly to organic leftovers is related to WST 5 'Compost' in BREEAM-G. Practices including 'Sharing space' in residences and workplaces, 'Sharing ownership' of vehicles and appliances, and 'Exchange platform' of used goods and agricultural products, all aim for maximum resource efficiency and waste reduction are certainly CE-related especially during the in-use/operation phase but do not fall under any of the impact areas of BREEAM-C. Similarly, other CE-related certifications such as C2C for product circularity and BS8001 for organization circularity, though not currently included in BREEAM-C should be given due credits for their contribution to the overall circularity of the building.

4.3. Applicability – comparative case study

Table 5 compares circular features of VCH and TCV under Material, Energy and Water Cycles against BREEAM-C indicators. As can be seen, over 90% of the indicators have matching circular practices implemented in the two building projects. Alternatively, characteristic features deemed compliant with CE principles by both VCH and TCV are also recognized as such according to the BREEAM-C indicators. Hence, it can be said that BREEAM's proposed framework does fulfill its purpose of gauging implemented circular features and pointing out potential ones for consideration by the construction industry in future planning to meet such criteria. In addition, when assessed by BREEAM-C indicators, VCH and TCV indeed have good circularity performance and uphold CE principles in their construction. True to VCH's initial goal and TCV's name, both building projects can be deemed circular constructions designed and built in accordance with CE principles.

4.4. Analysis on potential for application in Taiwan – context check

The experts interviewed have been involved in CE-focused building projects, serving to represent actual practitioners and stakeholders in the related field. The four respondents included (1) the project manager (PM), responsible for managing the construction of the social housing complex in Taipei City, comprising a total of 1500 units in 2 buildings each with 23 floors, which would serve as the flagship project demonstrating what circular buildings are and how they are constructed according to CE concepts; (2) the director (Dir) of the construction company responsible for building TCV; (3) the principal architect (PA) of the architecture firm responsible for designing TCV; and (4) a PhD candidate (PhDc) involved in research and promoting application of CE to construction.

All respondents shared positive appraisal of BREEAM-C, deeming it feasible and valid for circular building assessment and apt for use in Taiwan. With CE designated by the Taiwan government as one of the transformational strategies in national development, the current condition in Taiwan can be said to be favorable for promoting circular construction. However, without a building circularity assessment/accreditation system, practitioners involved in building projects do not know the standards required to meet or the criteria for gauging performance. More importantly, these standards/criteria can guide and facilitate turning CE concepts into defined action plans or circular practices for implementation. To fill the missing gap, Taiwan has to either adopt an existing building circularity assessment metrics or develop one on its own like its green building certification scheme, the EEWH – Ecology, Energy saving, Waste reduction and Health, which has been in use since September 1999.

Most of the respondents are not familiar with the existing circularity assessment systems. The one most heard of and sometimes adopted is the MCI. The PM also commented on Madaster, deeming it unsuitable for Taiwan. "A good certification system needs to be open and credible.

Table 2
BREEAM-C indicators of Material, Energy and Water Cycles in relation to CE principles that can be realized through applying R-imperatives to specific layers and life-cycle stages of buildings
Life-cycle stages are **D**esign, **M**anufacture **&** **S**upply, **C**onstruction, **I**n use **&** **R**efurbishment and **E**nd **o**f **L**ife.

Material Cycle

Indicator	CE Principles	R-imperatives					Building Layers						Life-cycle Stages				
		Rethink	Reduce	Reuse	Repair	Recycle	Stuff	Space Plan	Services	Skin	Structure	Site	D	M & S	C	I & R	EoL
M1.1.1	Stretch lifetime	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓				
M1.1.2	Reduce consumption	✓	✓					✓					✓				
M1.1.3		✓	✓				✓		✓				✓	✓			
M1.2.1	Design for future	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M1.3.1						✓			✓				✓			✓	
M1.3.2	Stretch lifetime				✓				✓				✓			✓	
M1.3.3					✓				✓	✓	✓		✓			✓	
M1.4.1	Design for future	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
M1.4.2		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
M1.4.3		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
M1.5.1	Reduce impact on environment	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M1.5.2		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M2.1.1	Use waste as a resource			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M2.1.2				✓			✓			✓	✓			✓	✓	✓	
M2.2.1				✓			✓		✓					✓	✓		
M2.2.2		✓					✓		✓					✓	✓		
M2.3.1				✓			✓		✓					✓	✓		
M2.3.2				✓			✓		✓					✓	✓		
M2.3.3		✓					✓		✓					✓	✓		
M2.4.1	Rethink business model	✓			✓	✓	✓	✓	✓							✓	✓
M2.4.2		✓			✓	✓	✓	✓	✓							✓	✓
M2.4.3		✓			✓	✓	✓	✓	✓							✓	✓
M2.4.4		✓			✓	✓	✓	✓	✓							✓	✓
M3.1.1	Prioritize regenerative resources			✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		
M3.1.2				✓		✓	✓							✓	✓		
M3.2.1	Reduce consumption	✓					✓	✓	✓	✓	✓	✓		✓			
M3.2.2		✓					✓	✓	✓	✓	✓	✓		✓			
M3.3.1		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M3.3.2		✓					✓	✓		✓			✓	✓	✓	✓	✓
M4.1.1	Strengthen & advance knowledge	✓					✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
M4.1.2		✓					✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
M4.1.3	Design for future	✓				✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

Energy Cycle

Indicator	CE Principles	R-imperatives					Building Layers						Life-cycle Stages				
		Rethink	Reduce	Reuse	Repair	Recycle	Stuff	Space Plan	Services	Skin	Structure	Site	D	M & S	C	I & R	EoL
E1.1.1	Reduce consumption		✓						✓							✓	
E1.1.2			✓						✓						✓	✓	
E1.1.3	Incorporate digital technology	✓	✓						✓							✓	
E1.1.4	Reduce impact on environment	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓		
E2.1.1	Incorporate digital technology	✓							✓							✓	
E3.1.1	Reduce impact on environment	✓	✓						✓							✓	
E4.1.1	Incorporate digital technology	✓							✓							✓	
E4.1.2		✓							✓							✓	
E4.2.1		✓							✓							✓	

Water Cycle

Indicator	CE Principles	R-imperatives					Building Layers						Life-cycle Stages				
		Rethink	Reduce	Reuse	Repair	Recycle	Stuff	Space Plan	Services	Skin	Structure	Site	D	M & S	C	I & R	EoL
W1.1.1	Reduce consumption		✓	✓		✓			✓							✓	
W1.1.2	Incorporate digital technology	✓							✓							✓	
W.2.1.1	Use waste as a resource			✓		✓			✓							✓	
W2.2.1				✓					✓							✓	
W2.3.1				✓		✓			✓							✓	
W3.1.1	Incorporate digital technology	✓							✓							✓	

Madaster involves complex calculations requiring relevant building data, and the Madaster Platform functions as a closed system, like a black box.". His view on a prospective circularity assessment metric for Taiwan would be to adopt/adapt a current one rather than starting from scratch to develop a new one. He acknowledged the difficulty involved and highlighted that EEWH took seven years to come into being, not to mention the funding and manpower involved.

A unique human factor worthy of consideration when choosing or developing a building circularity assessment system for Taiwan is that most practitioners in Taiwan's construction industry are familiar with indicators for green building certification. After all, they have been following and complying with those for twenty years. Faced with the new trend for going circular, building designers and construction engineers often ask if there are equivalents of such indicators or evaluation criteria that they can refer to in planning and decision-making. Hence, it is likely that different stakeholders in the construction industry may find green building-based circularity assessment metrics easier to understand, accept and adopt. Although the respondents have not reviewed

BREEAM-C in great detail, they considered BREEAM's use of their green building assessment as the basis and expanding it with circular indicators a sound and appropriate approach that would most likely succeed and be adopted for use as a circularity assessment metric in Taiwan.

5. Discussion

As defined by Saidani et al. (2019), an indicator is a "quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect changes connected to an intervention, or to help assess the performance of a development actor". Such definition reveals an essential function of indicators as a metric for measurement and evaluation, making it analogous to an assessment tool/model. On the other hand, an indicator, like a pointer, also designates aspects of significance that require attention, serves as a signpost that the actors should aspire for transition to CE; and can be used as a decision-making tool for designers.

Table 3
30 circular practices identified from selected CE-focused pilot building projects covered (✓) and not covered (**X**) by BREEAM-C indicators.

Circular Practices		BREEAM-C	
Well-developed & widely implemented Total: 11 practices ✓: 9 practices X: 2 practices	Passive (energy)/green/bio-architectural design	✓	
	Natural lighting system	✓	
	Solar energy system	✓	
	Heat recovery system	✓	
	Water recycle system	✓	
	Urban agriculture	✓	
	Zero waste/zero energy consumption	✓	
	Reusing green and healthy materials	✓	
	Using renewable or recycled materials	✓	
	Leftover recycle system		X
	Construction waste recycling system		X
Innovative & eagerly adopted Total: 8 practices ✓: 3 practices X: 5 practices	Lightweight structure	✓	
	Closed loops (e.g., on-site resource circular flows)	✓	
	Lifespan extension (smart maintenance/repair/renewal)	✓	
	People-oriented design (e.g., good indoor environment)		X
	CE-related certification (products/materials/organization)		X
	Prefabrication system		X
	Sharing space (e.g., co-working space)		X
	Exchange platform (e.g., used goods, agricultural products)		X
Pioneering with room for further development & use promotion Total: 11 practices ✓: 5 practices X: 6 practices	Innovative business model (e.g., material ownership by supplier)	✓	
	Flexible unit (e.g., design for disassembly & reassembly)	✓	
	Building materials/equipment tracking (e.g., QR code)	✓	
	Product as a service (e.g., lighting, elevator, furniture appliance)	✓	
	Material passport	✓	
	Innovative financial model (e.g., flexible taxation)		X
	Modular unit (e.g., Modular partition/exterior wall)		X
	3D printing		X
	Sharing ownership (e.g., appliance, vehicle)		X
	Quantifying residual value of materials		X
	Material bank		X
	Total number of circular practices:	17	13

Table 4
Matching between BREEAM-C indicators and circular practices.

	CE-30 covered by BREEAM-C indicators		CE-30 NOT covered by BREEAM-C indicators
Material Cycle	M1.1.3	Lightweight structure	Construction waste recycling system
	M1.2.1	Flexible unit	Prefabrication system
	M1.3.3		Modular unit
	M1.4.1	Lifespan extension	3D printing
	M1.4.2		Material bank
	M1.4.3		Quantifying residual value of materials
	M2.1.1	Reusing green and healthy materials	
	M2.1.1		
	M2.2.1	Using renewable or recycled materials	
	M2.3.1		
	M2.3.1		
	M2.4.1	Innovative business model Closed loop Zero waste	
	M2.4.3	Product as a service/Material ownership by supplier	
	M3.1.1	Using renewable or recycled materials	
	M3.1.2		
	M4.1.1	Material Passport	
	M4.1.2		
Energy Cycle	E.1.1.1	Passive (energy) architectural design	
	E.3.1.1	Solar energy system Heat recovery system	
Water Cycle	W1.1.1	Water recycle system	
	W1.1.2		
	W2.1.1		
	W2.2.1		
	W3.1.1		
Biodiversity & Ecology	BE2.2	Bio-architectural design Urban agriculture	
Health & Wellbeing	HW2.2	Natural lighting system	People-oriented design
			Leftover recycle system Sharing space Exchange platform Other CE-related certification Sharing ownership Innovative financial model
No. of circular practices		**17**	**13**

First, the match check revealed that BREEAM-C with circular indicators on materials and resources incorporated into a green building certification scheme is a valid framework well-grounded in CE principles and covers building circularity realizable through R-imperatives applied to different structural layers and life-cycle stages of buildings. This echoes the conclusion of Moraga et al. (2019) that no one but a set of indicators are necessary for CE assessment. Moreover, existing building circularity assessment metrics comprise mainly quantitative indicators involving calculations and few qualitative indicators. Nevertheless, not everything that can be measured is important and not everything that is important can be measured. Hence, an ideal assessment system should give due consideration to both quantitative and qualitative measurements. BREEAM-C is the only qualitative circularity assessment developed so far, its strengths and inadequacies can be useful references for other qualitative metric developers.

Second, when matched against prevalent circular practices (CE-30), BREEAM-C indicators fulfill its role as assessment criteria for identifying circular practices implemented; and when applied to assess CE-focused constructions, BREEAM-C indicators also serve as benchmarks testifying that CE principles/strategies have been put to use or incorporated. It should be pointed out that the same CE strategies in BREEAM-C

Table 5
Circular features under (a) Material Cycle, (b) Energy Cycle and (c) Water Cycle of Venlo City Hall and TaiSugar's Circular Village matched against BREEAM-C indicators.

(a) Material Cycle

Indicator	CE Principles'	Venlo City Hall	TaiSugar's Circular Village
M1.1.1	Stretch lifetime	VCH is a new development because the structural layout of the old building cannot accommodate spatial and functional transformations in line with C2C principles. Of note is that VCH catalyzes renovation of an old neighborhood factory that now offers accommodation	
M1.1.2	Reduce consumption		
M1.1.3			
M1.2.1	Design for future		Flexible floor design for housing and community center
M1.3.1	Design for future	Solar chimneys installed to capture solar heat and create thermals for air circulation. Heat exchangers and air wells installed for temperature regulation	Air-conditioning system combined with waste energy recovery
M1.3.2	Stretch lifetime		
M1.3.3			
M1.4.1	Design for future		Modular design for more efficient installment and reassembly process.
M1.4.2			
M1.4.3			Prefab process in construction
M1.5.1	Reduce impact on environment		
M1.5.2			
M2.1.1	Use waste as a resource	C2C-certified products made from reused materials are procured	
M2.1.2		Local sourcing of reusable green and healthy raw materials	Local and reusable material for the urban farming area. (steel and hardwood from old rail tracks)
M2.2.1		C2C-certified products made from reused components are procured	
M2.2.2		Local sourcing of reusable green and healthy components	Local and reusable components for the urban farming area. (steel and hardwood from old rail tracks)
M2.3.1		C2C-certified products are procured	
M2.3.2		Significant share of total material consumption attributed to numerous C2C-certified products used	
M2.3.3		Local sourcing of reusable green and healthy elements	
M2.4.1	Rethink business model	Guaranteed takeback systems to preserve residual values reutilized Material ownership by supplier/Innovative business model/Closed loop	Product as a service is implemented in lighting, furniture, appliance, bath, elevator, food waste machine.
M2.4.2		C2C-certified products are procured to enhance material reutilization/recycling	
M2.4.3		'Buy and buyback' scheme for selling recovered materials back to manufacturers for reuse Retain residual value of materials used	
M2.4.4	Prioritize regenerative resources	C2C-certified products procured to enhance product reutilization	
M3.1.1		C2C ensures perpetual flow of materials in technical cycle	
M3.1.2		C2C ensures perpetual flow of materials in biological cycle	Aquaponics and composting
M3.2.1	Reduce consumption		No critical material being used for health reasons
M3.2.2		Material passport documenting types and flows of materials used	
M3.3.1			
M3.3.2			
M4.1.1	Strengthen & advance knowledge	Material passport	Material bank, BIM-based material flow documentation
M4.1.2		Material passport	
M4.1.3	Design for future	'Green demolition' plan with guidelines on how to disassemble the building so as to create continuous material cycles and to maximize the building's potential as a material bank.	BAMB concept (BAMB, 2019)

(b) Energy Cycle

Indicator	CE Principles	Venlo City Hall	TaiSugar's Circular Village
E1.1.1	Reduce consumption	Solar chimneys installed to capture solar heat and create thermals for air circulation. Heat exchangers and air wells installed for temperature regulation	Air-conditioning system combined with waste energy recovery
E1.1.2		Open access to energy consumption information	Open access to energy consumption information
E1.1.3	Incorporate digital technology	Open access to energy consumption information	Open access to energy consumption information
E1.1.4	Reduce impact on environment		
E2.1.1	Incorporate digital technology		
E3.1.1	Reduce impact on environment	Solar energy-fueled electricity & heating system Solar panels installed on the south façade	On-site solar panels Biogas from food waste Electric cars and scooters sharing and charging
E4.1.1	Incorporate digital technology	Open access to energy consumption information	Open access to energy consumption information
E4.1.2		Open access to energy consumption information	Open access to energy consumption information
E4.2.1			

(c) Water Cycle

Indicator	CE Principles	Venlo City Hall	TaiSugar's Circular Village
W1.1.1	Reduce consumption	Open access to water consumption information	Open access to water consumption information
W1.1.2	Incorporate digital technology	Open access to water consumption information	Open access to water consumption information

(*continued on next page*)

Table 5 (*continued*)

(c) Water Cycle			
Indicator	CE Principles	Venlo City Hall	TaiSugar's Circular Village
W.2.1.1	Use waste as a resource	Grey water filtered and used for toilet flushing	Use grey water in urban farming
W2.2.1		Rain water collected from the roof to water the green wall	Use rainwater collection in urban farming
W2.3.1		Nutrients extracted from waste water	Water reused in urban farming
W3.1.1	Incorporate digital technology	Open access to water consumption information	Open access to water consumption information

sometimes have different manifestations in VCH and TCV. For example, under Material Cycle, the concern for VCH is provision of 'heating' with heat exchangers and air wells installed for temperature regulation while the focus of TCV is on enhanced efficiency of the 'air-conditioning' system through waste heat recovery. Their dissimilar emphases and approaches are attributed to their different geographical location as well as geological and climatic conditions; VCH in Europe with temperate climate while TCV in central Taiwan with tropical climate. This highlights the need for indicators to be adapted or localized due to differences in function and location, culture and climate.

The need for localization is echoed by the respondents. Though BREEAM-C is considered an applicable and apt building circularity assessment metric in Taiwan, its adoption should not be without adaptation or localization considering different concerns with respect to climate and safety. Moreover, a 'localized' assessment system is also more aligned with and can be more easily updated according to local legislations and regulations.

Moreover, both VCH and TCV have commendable features but the impact areas of Material, Energy and Water have no corresponding indicators. These practices are more related to ecosystems and biodiversity. For VCH, one of the design focuses is on Air Quality, aiming for enhancing the overall well-being of its users and installed at the rooftop is a greenhouse that serves as the green lung of the building. For TCV, farm plots on the rooftop aim to build a community where residents can gather and be engaged in something related to nature. The design of the circular village targets to promote a people-oriented community and the demo house is meant for promoting circular and green lifestyles. Due recognition of these people-oriented designs with positive externalities should be given. Hence, the case analyses also reveal inadequacies and room for improvement or expansion of the proposed indicators.

Possible indicators to be added include the following.

(1) Use of Natural/Sustainable and intangible Resources

Specific sub-strategies that acknowledge and encourage efficient use of 'natural/sustainable', and 'intangible' resources should be added as most of the current indicators in the Material Cycle concern 'manufactured' and 'tangible' materials. Being biodegradable at end-of-life and consuming less energy in production, timber and wooden materials are alternative circular building materials and should be encouraged and given due recognition.

(2) Circular Practices of In-Use/Operation Phase

Assessment by BREEAM is conducted at the design phase and the delivery phase. Hence, circular practices acknowledged by BREEAM concern mainly the design and construction stages. Nevertheless, CE-related concepts put into practice when the building is completed and open for use should also be aptly recognized. For example, among the CE-30 practices, 'Sharing space' in residences and workplaces, 'Sharing ownership' of vehicles and appliances in the case of TCV, and 'Exchange platform' of used goods and agricultural products are mainly implemented during the in-use/operation phase but are not accounted for in any of the impact areas of BREEAM-C. These practices target at maximizing resource efficiency and reducing waste have been left out by BREEAM-C. For them to be duly credited, impact areas should either be increased or expanded.

(3) Do More Good in addition to Do Less Harm

The current proposed BREEAM-C indicators fall mainly under Materials, Energy and Water targeting at 'zero-waste' while existing BREEAM-G indicators aim at 'zero-emission', both fulfilling the purpose of doing less harm. Indicators that would encourage doing more good such as enhancing aesthetics and biodiversity, and promoting health and well-being, should be added. For example, VCH itself from inception to completion has contributed added values in the form of benefits brought to the neighborhood/community and society. Being self-sufficient in energy, it shares its surplus with the neighboring communities. Another contribution is that it serves as a showcase for promoting C2C approach in construction (EMF, 2019) and has attracted over 25,000 visitors with a special interest in that in less than 1.5 years after its opening. Hence, CE-related efforts of designers and engineers that do good to both humans and the environment would gain rightful credits.

(4) Financial Circularity

In BREEAM-C M2.4, the future use of materials is being assessed. However, the financial benefit through achieving material circularity is not being addressed. CE-related practices are not only good for the environment and ecology but also benefit the economy. Hence, there should be indicators pertaining to monetary gain from adopting circular practices such as TCV's product as a service or innovative business model such as VCH's buy-back scheme. In the case of VCH, their investment in applying a wide variety of circular practices within a CE business model, amounting to 3.4 million Euro, has created a net saving of 16.8 million Euro over the use time of the building and a positive cash flow after the first year. Not all circular practices aiming for future material use have financial positivity, especially at the beginning, but the evaluation and quantification of residual value at end-of-life stage should be encouraged and given due credits.

(5) Flexibility and Versatility of Building Functions by Design

Buildings are designed to be used for a very long period of time. Hence, durability is often a concern to ensure usability throughout the lifespan of a building. When buildings can last longer, another feature, flexibility becomes significant. Buildings should be so constructed as to be readily adaptable to changing conditions and serving different functions as required. With flexibility built into the design for changing the functional purpose of the building, the lifespan of a building can also be extended. Working in a cycle, lifespan, durability and flexibility reinforce each other, all contributing to higher resource efficiency.

Versatile functionalities may extend to include education and promotion. Both VCH and TCV are notable examples. Visitors interested in seeing how C2C can be put to practice are attracted to see VCH, 40% of which are from overseas. Hence, in addition to being a functional municipal office building, it is a life-size showroom demonstrating C2C approaches in use, and serving as an inspiration for other organizations to apply CE principles within their own context. The demo house in TCV is also meant for educating and promoting lifestyle in compliance with CE principles.

(6) Recognition of C2C and other CE-Related Certifications

While the assessment of building circularity is still evolving, there exists some related assessment tools developed for other purposes. For example, VCH has obtained C2C certification for many of its fixtures and appliances. As construction companies and building owners would likely get such certifications, BREEAM-C can consider recognizing these as additional credits in assessment, for example, under the Multiple Value (V) impact area. In addition to C2C certification, other examples are BS 8001 (Pauliuk, 2018) and Circularity Facts Program.

For Taiwan, instead of direct application, BREEAM-C can be taken as a guide or reference to develop its own building circularity assessment metric. That is, BREEAM's attempt would be like a role model for EEWH. What the PM considered desirable and feasible is the 'transplant' of BREEAM's approach to develop a framework of circular indicators on the basis of EEWH. Currently, EEWH has evaluation manual for different types of constructions including EEWH-BC (Basic Construction), EEWH-EC (Ecological Community), EEWH-GF (Green Factory), EEWH-RS (Residential Buildings), EEWH-RN (Renovation) and EEWH-OS (Overseas Scenarios). A potential and practical development would be a new evaluation manual EEWH-CB (Circular Buildings). The PhDc shared similar thoughts and suggested incorporating circularity assessment under Waste Reduction of EEWH. That is, instead of introducing a brand new assessment metric, adding an extra type of construction or a subcategory to the widely applied EEWH would make it more acceptable. Using the EEWH as the foundation has benefits of saving the time from developing the metric from scratch and it would be more easily accepted by local practitioners given their familiarity with the existing green assessment EEWH, thus facilitating the promotion of circular construction in Taiwan.

6. Conclusion, limitations & future research

To conclude, while CE assessment in construction is still not yet unequivocally defined and practical approaches are especially lacking (Zhang et al., 2021), the current analysis illustrates that BREEAM-C with circular indicators on materials and resources incorporated into a green building certification scheme is a valid framework well-grounded in CE principles and covers building circularity realizable through R-imperatives applied to different structural layers and life-cycle stages of buildings. When matched against prevalent circular practices, BREEAM-C indicators fulfill its role as assessment criteria for identifying circular practices implemented; and when applied to assess CE-focused constructions, BREEAM-C indicators also serve as benchmarks testifying that CE principles/strategies have been put to use or incorporated. Through increasing the current seven impact areas and extending their coverage would enable more practices to be acknowledged. Certain indicators would have to be made more specific so as to focus on aspects worthy of due recognition. Case analysis, echoed by the experts' opinion, showed that BREEAM-C being feasible, practical and applicable can be adopted for building circularity assessment in Taiwan though not without adaptation/localization. Country-specific systems using local language and implemented with local assessors can also serve as a pragmatic marketing tool for promoting circular construction practices.

This study has several limitations. First, a potential weakness of qualitative research is subjectivity, which limit the generalizability of conclusions. However, qualitative approach using interviews with open-ended questionnaires has the flexibility for more detailed and in-depth information to be collected, which can be a strength of qualitative research (Mwita, 2022). Indeed, the perceptions and experiences of the respondents do offer insights on the research issues. A related limitation is the small sample of interviewees. Practically in square one on its path to CE transition, Taiwan has only a few CE-focused building projects, implying limited data for quantitative analysis and not many practitioners and stakeholders with sufficient experience of circular construction to share opinions and comments. While there are only four respondents, their insights do reflect those insiders' understanding of the actual situation and are hence of value to the discussion. Another drawback is that discussion on TCV remains at its circular design. Unlike VCH which has been in operation for some years, the construction of TCV has just been completed. Future research could include a comparative study of greater breadth and depth after TCV has been operated for some time and updated statistics on its in-use phase and with feedback from users available for analysis.

There is much room of research and development in formulating revisions or customizations of BREEAM's circular framework in adding new impact areas or refinements to the existing ones; in particular, on social and cultural values, human engagement, knowledge sharing, ownership and business models, local diversity in ambient conditions, ecosystem and biodiversity. In addition, research efforts devoted to refining and quantifying appropriate parameters for BREEAM circular indicators are desirable.

CRediT authorship contribution statement

Dominique Hiulong Wong: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chunbo Zhang:** Writing – review & editing, Writing – original draft, Validation, Conceptualization. **Francesco Di Maio:** Writing – review & editing, Writing – original draft, Validation, Supervision. **Mingming Hu:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendices.

Table A1
Seven sectoral challenges of circular transition in construction industry (Hart et al., 2019)

Integral	Complexity	Insufficiency
The industry itself – conservative, uncollaborative, adversarial	Long product life cycles for both buildings and materials	Lack of bandwidth compounded by absence of coherent vision for the industry
	Complexity/confused incentives	Insufficient use or development of CE-focused design and collaboration tools, information and metrics.
	Technical challenges regarding material recovery	Lacking standardization

Table A2
Metabolic's seven CE pillars and Circle Economy's eight key CE elements

Circular Economy	
Metabolic - 7 pillars	Circle Economy - 8 key elements
Materials maintained in continuous high-value cycles	Prioritize regenerative resources
Energy all based on renewable sources.	Stretch the lifetime
Water managed in a 100% circular fashion	Use waste as a resource
Biodiversity structurally supported and enhanced	Design for the future
Human society and culture preserved	Rethink the business model
Health and wellbeing of humans and other species structurally supported	Incorporate digital technology
Human activities generate value in measures beyond just financial.	Team up to create joint value
	Strengthen and advance knowledge

Table A3
Summary of number of strategies and indicators under BREEAM-C

CIRCULAR BUILDING			
Desired Impact Areas	No. of Strategies	No. of Sub-Strategies	No. of Indicators
Material Cycle	4	13	32
Energy Cycle	4	5	9
Water Cycle	3	5	6
Biodiversity & Ecology	4	5	-*
Human Culture & Society	3	3	- *
Health & Wellbeing	3	6	2
Multiple Values	2	2	–

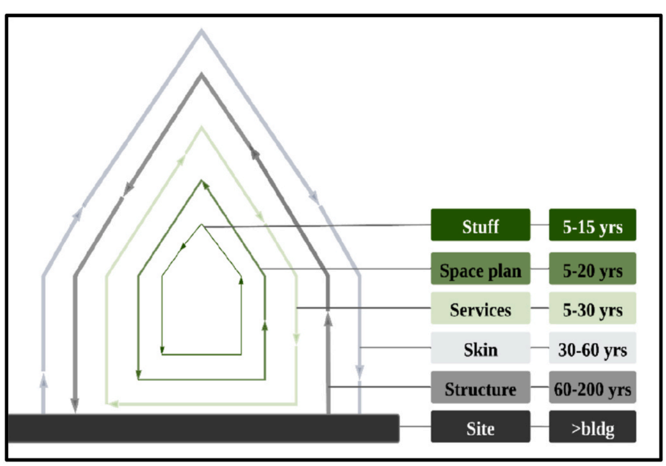

Fig. A1. Brand's building layers and their lifespans (Brand, 1994).

Questionnaire on Circular Building Assessment

Job:
Interview Questions.

1. **(Please CIRCLE)**

   How much you agree that the following are main challenges (Hart et al., 2019) for promoting circular construction in Taiwan.

   (i) Construction industry being conservative

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (ii) Building system being complex and complicated

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (iii) Long product life cycles for both buildings and materials

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (iv) Lacking technology

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (v) Lacking standardization

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (vi) Lacking coherent vision for development in circular construction

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)

   (vii) Lacking assessment metrics for circular construction certification

   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)
   (Please TELL)
   Why or why not "Lacking assessment metrics for circular construction certification" is the main challenge.
   (Please TELL)
   Do you think there are other challenges for promoting circular construction in Taiwan?
   What do you think would help promote circular construction in Taiwan?

2. **(Please TELL)**

   What are the differences between green and circular buildings? Or how are they related?

3. **(Please CIRCLE)**

   BREEAM-C (a proposed framework of circular indicators) aptly assess circular constructions.
   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)
   (Please TELL) Why?

4. **(Please CIRCLE)**

   BREEAM-C can be applied to circular building assessment in Taiwan.
   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)
   (Please TELL) Why?

5. **(Please CIRCLE)**

   A circular building assessment metric developed from EEWH (Taiwan's green building certification system) can help promote the development of circular construction in Taiwan.
   (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree)
   (Please TELL) Why?

6. **(Please TELL)**

   What does a circular building assessment metric mean to you with respect to your role in the construction industry?

7. **(Please TELL)**

What are your expectations of a circular building assessment metric?
++++++++++ End of Questionnaire ++++++++++
========== THANK YOU ==========

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