sustainability

MDPI

Article

No Stakeholder Is an Island in the Drive to This Transition: Circular Economy in the Built Environment

Michael Atafo Adabre [1,*], Albert P. C. Chan [1], Amos Darko [2], David J. Edwards [3,4], Yang Yang [1] and Sherif Issahaque [5]

[1] Building and Real Estate Department, The Hong Kong Polytechnic University, Hong Kong; albert.chan@polyu.edu.hk (A.P.C.C.); y.yang@brookes.ac.uk (Y.Y.)
[2] Department of Construction Management, University of Washington, Seattle, WA 98195, USA; adarko@uw.edu
[3] Department of the Built Environment, Birmingham City University, Birmingham B4 7XG, UK; drdavidedwards@aol.com
[4] Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg 2092, South Africa
[5] Department of Construction Studies, SD Dombo University of Business and Integrated Development Studies, Wa P.O. Box 64, Ghana; sissahaque@ubids.edu.gh
* Correspondence: 17902405r@connect.polyu.hk; Tel.: +852-66450743

Abstract: Ensuring optimum utilisation of the Earth's finite resources engenders the circular economy (CE) concept which has attracted the attention of policymakers and practitioners worldwide. As a bifurcated strategy which involves both scientific knowledge, advanced technologies and behavioural changes, the CE transition is sociotechnical in nature. Yet, prolific studies focus on scientific knowledge and technologies alone, while studies on promoting CE practices or built environment stakeholders' behaviour are limited. Using Stakeholder Theory, a comprehensive literature review on CE drivers was conducted. Through a questionnaire survey of professionals, key drivers identified were deployed to develop a 20-driver model for CE transition in the built environment. The model is relevant to policymakers and practitioners because it highlights essential drivers for optimum resource allocation. Moreover, the findings apprise policymakers of the drivers that pertain to key stakeholders (i.e., professional and higher educational institutions, society and clients, government and firms), thus stating the requirements for driving each stakeholder to achieve this sociotechnical transition.

Keywords: circular economy; sociotechnical transition; sustainability; drivers; stakeholder theory; waste reduction

check for updates

Citation: Adabre, M.A.; Chan, A.P.C.; Darko, A.; Edwards, D.J.; Yang, Y.; Issahaque, S. No Stakeholder Is an Island in the Drive to This Transition: Circular Economy in the Built Environment. *Sustainability* **2024**, *16*, 6422. https://doi.org/10.3390/su16156422

Academic Editor: Adriana Del Borghi

Received: 5 June 2024
Revised: 18 July 2024
Accepted: 24 July 2024
Published: 26 July 2024

1. Introduction

Globally, the construction industry is a major consumer of the Earth's finite resources viz.: 30% of raw materials, 40% of energy and 25% of water. Besides these consumptions, discharge of anthropogenic greenhouse gas and construction and demolition waste have negatively contributed to changes in climatic conditions. These changes are evinced in the heat island effect, global warming, shifts in rainfall patterns and deteriorating conditions in human (and environmental) health [1]. Studies have attributed these challenges to the predominant linear economy (LE) approach employed for most construction projects [2,3]. An LE applies a 'take-make-dispose' strategy to the Earth's limited resources, which engenders overconsumption, wastage and scarcity of resources [3]. To allay these challenges, a paradigm shift from an LE to a circular economy (CE) is needed [4–6].

The CE is "*an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals impairing reuse, and aims at eliminating waste through the superior design of materials, products, systems and business models*" [7] as cited in Mahpour ([8]

p. 216). As a bifurcated strategy (which involves scientific knowledge, as well as advanced technologies and behavioural changes), the CE transition is sociotechnical in nature [9]. Thus, besides the technological advancement to ensure a circular flow of materials within a loop, key stakeholders must embrace new behaviour and practices for adopting and sustaining CE principles towards achieving its promises. Among various principles, the three main basics of CE implementation include reduce, reuse and recycle (i.e., the 3R principles) [10,11].

The 'reduce' principle concerns using minimum input of resources (i.e., energy and raw materials) by, for example, employing better technologies, simplifying packaging and using more energy-efficient appliances ([12] p. 71). The 'reuse' principle requires multiple uses (i.e., at least twice) of materials, products or components that are not waste for the same purpose for which they were originally conceived. The 'recycle' principle encapsulates any recovery operation which reprocesses waste materials into products, materials or substances for either the original or other purposes ([12] p. 71). Effective implementation of the reduce principle, such as dematerialisation (i.e., reduction in materials usage), would minimise construction and demolition waste globally, which constitutes more than 3.00 billion tons per annum. Furthermore, adequate enforcement of the reuse principle, such as longer use of materials, will promote energy savings at the micro level (i.e., companies and consumers), meso level (i.e., construction industries and other industrial networks) and macro level (i.e., regions, cities and nations). Moreover, the recycling principle could ensure waste recovery and raw material input reduction. Collectively, the 3Rs could promote waste minimisation and mitigation of greenhouse gas emissions in the built environment.

The built environment comprises buildings and infrastructure that are constructed, operated, maintained and utilised for various purposes (e.g., habitation, work and social amenities) but ultimately support unbridled economic development within the prevailing global neoliberal economic machinations. Without adequate adoption of CE principles into the built environment, buildings and infrastructure will continue to pose negative environmental effects during and after their useful life [13]. Nonetheless, the global CE adoption remains embryonic [9]. Low adoption is partly attributed to barriers that affect various stakeholders. For instance, institutional bodies and regulatory agencies are plagued with inadequate resources for CE implementation; lax waste legislation enforcement; lack of national policy for CE; and lack of accreditation or certifications on secondary materials/products [14–17]. Prevailing CE barriers that plague project professionals and consultants (including educational institutions) include a lack of circularity in product design; inadequate knowledge and information on material quality; and a dearth of flexibility in academic curricula to reflect industrial needs regarding CE [18,19]. Concerning business stakeholders, common barriers include dysfunctional markets for recyclables; volatility in market demand; ingrained linear mindsets; and a relatively low cost of incineration compared to recycling strategies [20,21]. End users' barriers include high required customisation among end users; inadequate awareness; and end user hesitancy on new products [22,23]. Within the broader citizenry, such as communities, society or the public, inadequate public awareness and a lack of public support for the recycling markets have affected the CE markets in various industries, including the construction industry [24,25].

Considering the barriers that influence multiple stakeholders in transitioning to CE and the current incipient stage of CE worldwide [11], this study seeks to identify the drivers for promoting CE transition in the built environment. Emergent findings seek to apprise policymakers of the key stakeholders' drivers that could enable them to devise appropriate measures to influence the stakeholders for a CE transition in the built environment.

2. CE Transition

2.1. Progression to CE

Previously, industries employed preventive measures (such as cleaner production) to avoid toxic waste and emissions [26]. Despite the inherent potential for such measures to mitigate environmental problems, key underlying weaknesses with cleaner production exist (e.g., a reliance upon deterministic forecasting to mitigate environmental problems). Thus, the prevailing state of industry was taken as the starting point from which measures were devised (refer to Figure 1). Nonetheless, there are more efficient measures and strategies which require working backward (i.e., backcasting approach) [27]. Another peccadillo with cleaner production is that only cost-efficient measures are selected even though alternative (and less cost-effective) strategies could be more effective for managing environmental problems [26]. Attributed to these shortcomings, the industrial ecology concept, which adopts a hybrid approach of forecasting and backcasting, has emerged [26].

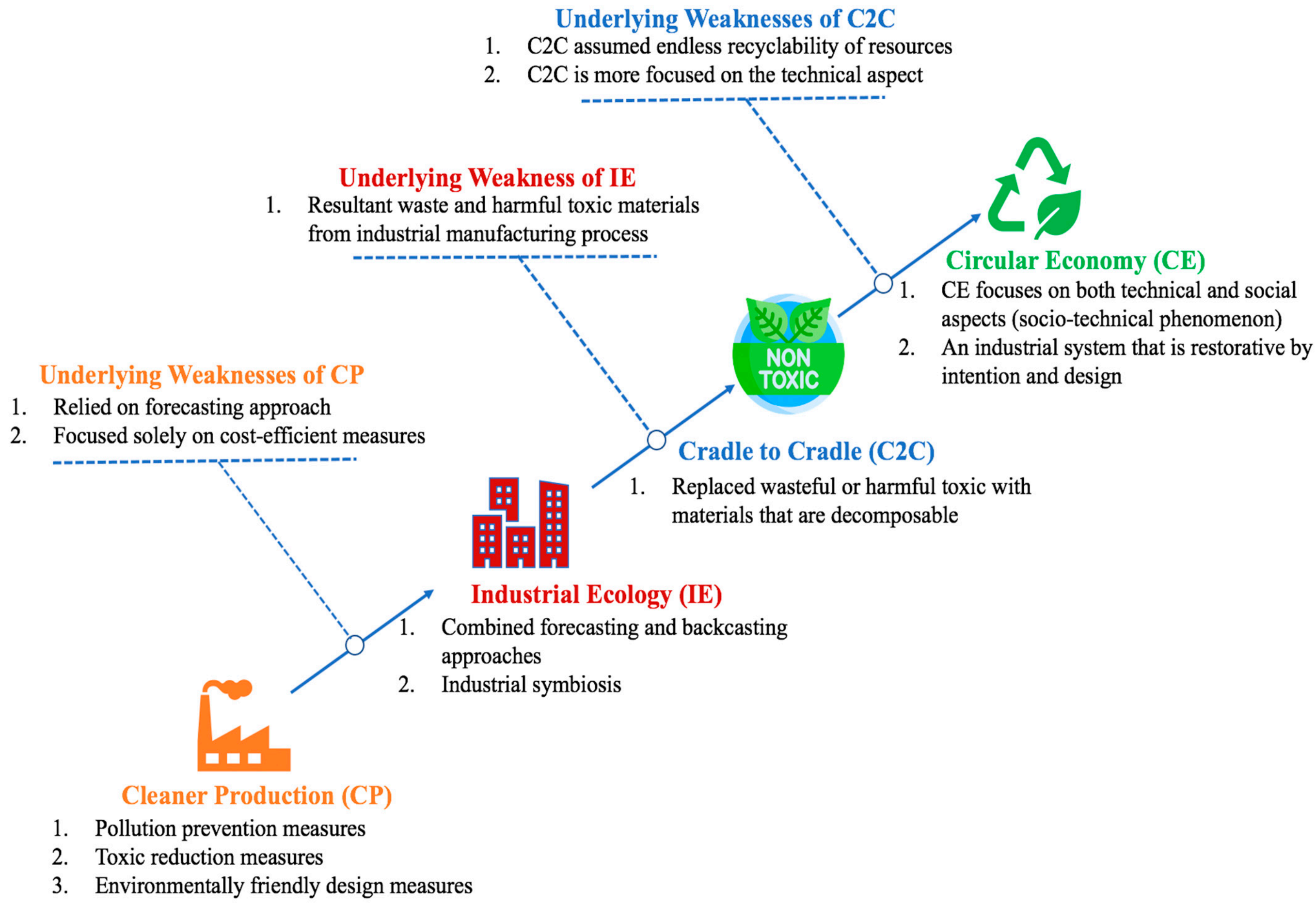

Figure 1. Progression to CE [9].

The industrial ecology concept employs a system perspective for the design and manufacture of products to avoid environmental effects caused by the manufacturing processes, use and disposal of products [9,28]. A paradigm of industrial ecology is industrial symbiosis, in which industries within a system network utilise waste from any other industry as a resource in that system [29,30]. Notwithstanding improvements made by the industrial ecology, key challenges were still evinced in the resultant waste and harmful toxic materials from industrial manufacturing processes. Therefore, the cradle-to-cradle (C2C) concept is an extension of the industrial ecology and seeks to reduce environmental impact by replacing wasteful materials or harmful toxic materials with materials that are natural and decomposable [29].

C2C assumes that such materials will ensure their endless utilisation within a system. Thus, "*the cradle-to-cradle philosophy reflects the idea of endless recyclability of resources*" ([31] p. 2). However, there is no material that can guarantee such a period of recycling and utilisation [9]. Moreover, the C2C concept is heavily focused on technical industry-centric aspects and pays less attention to end users and communities. Therefore, relying on the C2C core principles of recycling and reuse with an integration of various stakeholders (i.e., end users/clients, communities/societies, business sectors and policymakers), an all-embracing stakeholder management approach for efficient resource utilisation emerged [32–35]. This paragon is the CE (refer to Figure 1).

2.2. Stakeholder Theory

Stakeholder theory is both a management approach and a corporate governance technique that conceptualises an organisation as a collection of individuals or groups who have a vested interest in the organisation/business. It focuses on the humanistic perspective of a business on achieving business goals via human cooperation and entails stakeholder engagement and value creation for them [36,37]. Value is created with and for the stakeholders. Thus, the stakeholders are co-creators of the CE and beneficiaries of it. This is depicted in Figure 2 by double arrow lines, where the arrow at the end of a line towards 'CE in the Built Environment' depicts the value creation (i.e., CE) and the arrow at the beginning of a line pointing towards the stakeholders depicts the benefits derived from the value created. A combined effort and collective responsibility of all the stakeholders are required to create benefits for them [38]. Thus, a transition and advancement to a CE in the built environment requires a collective effort of all stakeholders in the built environment, hence the relevance of assessing CE transition from the perspective of the stakeholder theory.

Figure 2. Multi-stakeholders' relationships and contributions to the CE in the built environment [9].

2.3. No Stakeholder Is an Island

Freeman [39] states that a stakeholder refers to *"any group or individual who can affect or is affected by the achievement of an organisation's objective"*. The prominent CE models entail three CE operating levels with limited stated stakeholders at these levels: namely, micro-level for firms; meso-level for eco-industry parks and symbiosis; and macro-level for governments ([40] p. 1). Additionally, the ReSOLVE framework (an acronym for regenerate, slow, optimise, loop, virtualise and exchange) relates to the three CE levels as short-term processes (operational level) and mid-term processes (tactical level). The specific target stakeholders of the ReSOLVE framework are firms. Although Ma and Hao [41] confirmed the relevance of these stakeholders, their study provided an extension to the list of stakeholders. According to Ma and Hao [41] on construction and demolition waste management, five key stakeholders were identified, namely, clients, designers, contractors, C&D waste treatment companies and governments. Nonetheless, some key stakeholders are missing in these lists. *"It could be argued that academia also has a role for operating the CE as academia may be considered an additional operation level"* ([40] p. 4). Indeed, the triple helix model (3HM) identified academia as a key stakeholder among government and firms. Properly informed, empowered and supported university researchers (in academia) serve as the foundation for a successful CE transition that is based on a bedrock of scientific and technological knowledge. Notwithstanding the relevance of the 3HM to highlighting key stakeholders, it is arguably considered an incomplete model. Therefore, extending on the 3HM, van Bueren et al. [40] developed the Quintuple Helix Model (eco-5HM). Two operations and stakeholder levels, namely, society and environment (ecosystem), were added to the three levels of the 3HM. The media, culture, norms, values and behaviours constitute the system of a society which could contribute to CE through co-evolution, cooperating to create more shared opportunities and other sustainability behaviour. On the human actors of society and the ecosystem, it was stated that they could be represented by non-governmental organisations (NGOs).

Although the list of stakeholders in a study cannot be exhaustive, studies concerning CE often include at least one of the identified stakeholders in the eco-5HM provided by van Bueren et al. [40]. For instance, in Volk et al. [42], stakeholders are classified into four groups: namely, public authorities; clients and owners; planners and construction companies; and recycling, demolition and disposal companies and construction materials manufacturers. Marcon et al. [43] identified these inveterate stakeholders in their study: namely, governments; community and customers; companies or corporations; and universities. They (ibid) further broadly classified the stakeholders into two groups *viz.*: primary stakeholders; and secondary stakeholders based on the level of direct involvement in CE transition. Similarly, van Langen et al. [44] surveyed three groups of stakeholders: namely, researchers; economists; and administrators. It was found that researchers advocated for a more holistic top-down approach to CE. However, both economists and administrators suggested a bottom-up approach under the guidance of civil society (i.e., companies and citizens/consumers). Nevertheless, these views—top-down and bottom-up approaches (refer to Figure 2)—complement each other since a successful CE transition requires actors from both approaches. Indeed, Coenen et al. ([45], p. 1) stated: *"As long as bottom-up innovations regarding circularity are not stimulated, much potential is lost in the transition to circular practices. Furthermore, a mere top-down approach is often criticised for its inability to encompass the perspective and values of all stakeholders involved"*—as conceptualised in Figure 2.

2.4. Driving the Stakeholders to a CE

Stakeholders play an essential role in CE transition and advancement because they drive one another towards a CE. Marcon et al. [43] highlighted the importance of the government and regulation in driving CE via national/public policies on waste and waste collection; changes in legislation to facilitate CE transition; fines for practices that do not conform to CE; and incentives (i.e., tax incentives or tax reductions) for companies that have adopted CE practices. Society and clients could exert pressure on companies to adopt

CE during the procurement of goods and services. Nonetheless, this hegemonizing and controlling impact of society and clients hinges on their awareness of CE practices and their benefits. An uninformed society is unable to exert pressure on or influence companies for CE transition. On awareness creation, professional institutions and higher educational institutions (HEIs—including universities) play a crucial role in *"training thinkers, including materials on sustainability in the curriculum and creating complementary training and updating courses on the topic"* ([43] p. 3522). Companies can promote innovation, drive CE transition and ultimately engender greater CE. It is no gainsay that each stakeholder group drives the others towards a CE. Nonetheless, the prioritisation of the stakeholders, the drivers and the interrelationships among the drivers for a circular built environment is underexplored.

3. Research Methodology

3.1. Research Methods

Two research methods were employed. First, a comprehensive literature synthesis (detailed in Section 2) was conducted to identify the key drivers (see Table 1) for a CE transition. To retrieve pertinent literature (including CE, stakeholders and drivers), the Scopus database was searched using relevant keyword terminologies. The search string was TITLE-ABS-KEY ((“Circular Economy” OR “Circularity”) AND (“Stakeholders”) AND (“Drivers” OR “Enablers” OR “Strategies”) AND (“Built Environment” OR “Construction”)) AND PUBYEAR > 2005 AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”)). In total, 120 articles were retrieved. The search was complemented by another search using Google Scholar. A total of 25 articles were identified as relevant and therefore formed the foundation of this literature review. Second, the identified drivers were deployed via a structured questionnaire survey to secure primary data to elucidate the phenomenon under investigation. The questionnaire was structured in three main parts. Part 1 focused on soliciting the demographic data of respondents. Demographic details collected were job title, professional membership, years of construction research and/or industry experience, core business of respondents’ organisation and knowledge on CE through research and/or hand-on experience. Part 2 focused on the barriers to adopting CE practices. Twenty barriers were provided, and respondents were asked to rate the importance of each statement (barrier) using the following 5-point Likert scale: 1 = Not important; 2 = Slightly important; 3 = Moderately important; 4 = Important and 5 = Very important. Part 3 investigated CE drivers. Twenty drivers were listed, and respondents were asked to indicate their level of agreement on the importance of the drivers using the following 5-point Likert scale: 1 = Strongly disagree, 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree.

Table 1. Stakeholders' Drivers for CE Transition in the Built Environment.

Code	Stakeholders	Driver Categories	Underlying Drivers	References
S1	Government	Regulatory Drivers		
S12			National policy on CE	Ababio et al. [46]; Mies and Gold [47]
S13			Government funding support for CE, i.e., start-ups	Marcon et al. [43]; Ma and Hao [41]
S14			Support for market penetration of innovative projects through labelling, awards, certification, and standards	Ma and Hao [41]; van Bueren et al. [40]; Wuni [48]
S15			Promoting reuse, recycling and facilities maintenance centres and tax breaks for shops (i.e., public C&D waste treatment companies)	Marcon et al. [43]; Baah et al. [49]
S16			Building design assessment for circularity prior to permit approval (i.e., circular permit)	Campbell-Johnston et al. [15]; Adabre et al. [50]; Adabre et al. [9]
S17			Establishing CE rating systems	Adabre et al. [9]
S18			Promotion of standardisation and compatible components	Ma and Hao [41]; Tapia et al. [51]; Cruz Rios et al. [52]
S2	Firms (i.e., Designers and Contractors)	Corporate Drivers		
S21			Promoting servitised business models (i.e., providing function instead of product)	Coenen et al. [45]; Giorgi et al. [53]
S22			Integration of circularity into business strategy and goals (i.e., reverse logistics)	van Bueren et al. [40]; Hartwell et al. [54]
S23			Collaboration and information sharing among business entities	Mies and Gold [47]; Ho et al. [55]; Senaratne et al. [56]; Meath et al. [57]
S24			Promotion of modular construction and design	Ma and Hao [41]; Karaca et al. [58]; Senaratne et al. [56]
S25			Designing and constructing buildings in layers	Coenen et al. [45]; Gerding et al. [59]; Guerra and Leite [60]
S26			Flexible and adaptable design and construction	Coenen et al. [45]; Kaya et al. [61]; Ma and Hao [41]
S3	Professionals and HEIs	Professional Institutions and HEI Drivers		
S31			Promotion of skill development/expertise relevant to CE	Marcon et al. [43]; van Bueren et al. [40]
S32			Information dissemination (i.e., provision of manual/guidelines on dismantling or disassembling facilities/components)	Ramos et al. [62]; Ho et al. [55]; van Bueren et al. [40]; Gillott et al. [63]
S33			Research and development on CE promotion in the construction industry	Marcon et al. [43]; van Bueren et al. [40]; Shooshtarian et al. [64]
S4	Society and Clients	Society and Clients' Drivers		
S41			Access to incentives to facilitate CE transition or subsidies on CE products or materials	Ho et al. [55]; Ma and Hao [41]
S42			CE awareness among clients (evinced in aligning norms to CE regulations)	Mollaei et al. [65]; Baah et al. [49]; Mies and Gold [47]; Coenen et al. [45]
S43			Access to facility operation and maintenance (O&M) and disassembling guidelines	Adabre et al. [50]
S44			Circular procurement	Ma and Hao [41]; van Bueren et al. [40]

3.2. Data Collection

Potential respondents to the questionnaire were sourced from the 2023 membership list of the Ghana Institute of Architects (GIA). From the membership list, 534 architects were listed as registered architects in good standing. Through one of the authors, an architect, the questionnaires were administered via email to only architects who (1) had knowledge of or experience with CE; and (2) were willing to participate in the survey. Respondents were first contacted via phone calls to secure informed consent [66–70] and to verify the two stated criteria before emailing the questionnaires to them. Seventy-five questionnaires were administered via email. Thirty-four questionnaires were received. However, four questionnaires were not properly answered and were therefore considered unsuitable for further statistical analysis. Correspondingly, the response rate was 40%. The low response could be attributed to the current incipient state of the CE concept in the Ghanaian construction industry. Nonetheless, a sample size of 30 was suitable for statistical analysis because a sample size of 30 met the central limit theory, which stated that this sample size was adequate for statistical analysis [71]. Moreover, the sample size was deemed adequate for fuzzy synthetic evaluation (FSE) analysis adopted in this present research [72].

3.3. Data Analysis

Prior to statistical analysis, the reliability and the consistency of the questionnaire data were tested through the Cronbach's coefficient alpha using the IBM Statistical Package for Social Sciences (SPSS) Version 20 statistical software. If the alpha value is >0.70, the questionnaire data are considered reliable, consistent and suitable for subsequent statistical analysis. A Cronbach's coefficient alpha of 0.893 was obtained, which was over the 0.70 threshold and therefore implied adequate reliability and satisfactory internal consistency of the questionnaire data. Therefore, further descriptive statistical analyses were conducted to determine the mean scores of the drivers.

A key limitation of the mean score analysis is subjectivity and biases attributed to survey participants' responses [4]. Therefore, for objectivity in prioritisation of the driver categories, the FSE technique was employed for statistical analysis of the data [5,50]. Six steps were established for conducting the FSE analysis. First, a list of the underlying drivers was established for each driver category. Using the regulatory driver category as an example, the list was created as follows: S1 = {S11, S12, S13 . . . S1N}. N indicates the number of underlying drivers in the category. Second, the FSE created labels for the set of grade alternative. Thus, labels were created for the 5-point Likert scale as L_1 = strongly disagree, L_2 = disagree, L_3 = neutral, L_4 = agree, and L_5 = strongly agree. Third, the weighting of each driver was calculated based on the mean scores with the aid of an equation (i.e., $W_i = \frac{M_i}{\sum_{B=1}^{K} M_i}$, $0 < W_B < 1$, and $\sum_{B=1}^{K} W_i = 1$). Equation variables are explained as follows: W_i is the weighting of an underlying driver; M_i is the mean score of an underlying driver, and $\sum W_i$ is the total of the mean scores of all underlying drivers within a driver category. The weighting of each driver category was determined in likewise manner. Fourth, the fuzzy evaluation matrix (R_i) was established for each of the driver categories. Fifth, the FSE indices for each driver category were determined via an equation: D = $W_i{}^{\circ}R_i$, where "°" is the fuzzy composition operator. Sixth, the fuzzy indices were normalised as $\sum_{i=1}^{5}$ D × L to obtain the objective levels of importance (OL) of each driver category.

The underlying drivers interrelate or interact with one another. The interrelation was illustrated through a causal-loop diagram. The causal-loop diagram has been deployed previously [41] as a qualitative technique to show the interrelations among variables. Therefore, the interactions were qualitatively depicted through a causal-loop diagram by using Version 7.3.5 of Vensim, a simulation software tool.

4. Results

4.1. Respondents' Backgrounds

Table 2 reports the respondents' backgrounds and shows that 57% of the respondents indicated that they had >6–10 years of work experience in the Ghanaian construction industry. Concerning business of organization, 60% of respondents indicated that they worked in private institutions, while 37% worked in government institutions. The respondents' backgrounds provided credence that the respondents were abreast of the Ghanaian construction industry and could provide suitable data concerning the drivers required to promote a CE in the sector.

Table 2. Respondents' Backgrounds.

Job Title, Professional Membership, Years of Experience and Business of Organisation	Number of Responses	Percent
Job Title		
Architect	27	90
Others	3	10
Professional membership		
Ghana Institute of Architects	30	100
Others		
Years of experience		
0–5 years	5	17
6–10 years	17	57
11–19 years	8	27
Business of organisation		
Government institution	11	37
Private institution	18	60
Others	1	3

4.2. Results of FSE

In conducting the FSE, two levels (namely levels one and two) were established. Level one comprises the four driver categories viz.: regulatory drivers, corporate drivers, professional and HEI drivers; society and clients' drivers. These categories are represented as S1, S2, S3 and S4, respectively. Level two consists of the underlying drivers of each driver category, which serve as input variables for level one. Therefore, in conducting the FSE, analysis of level two was conducted first, followed by that of level one. The driver categories and their underlying drivers are expressed as follows:

S1 = {S11, S12, S13, S14, S15, S16, S17, S18}

S2 = {S21, S22, S23, S24, S25, S26}

S3 = {S31, S32, S33}

S4 = {S41, S42, S43, S44}

4.2.1. Estimating the Weightings of Level Two Variables

Weightings of the level two drivers were estimated using the following Equation (1):

$$W_s = \frac{M_s}{\sum_{s=1}^{k} M_s},\ 0 < W_s < 1,\ \text{and} \sum_{s=1}^{k} W_s = 1 \quad (1)$$

W_s is the estimated weighting of an underlying driver within a driver category, which is obtained by dividing the mean score (M_S) by the total of all mean scores of a driver category. Using the regulatory driver, for example, particularly the underlying driver 'National policy on CE', its weighting will be estimated as follows:

$$W_s = \frac{4.333}{4.333 + 4.400 + 4.133 + 4.500 + 3.933 + 4.133 + 4.433} = \frac{4.333}{29.865} = 0.145$$

4.2.2. Estimating the Weightings of Level One Variables

Likewise, the weighting of each driver category was estimated by summing all the mean scores of its underlying drivers to obtain the mean of the driver category. Then, the weighting was calculated by dividing the mean of the driver category by the sum of the mean scores of all driver categories. Using a driver category—regulatory driver—as an example, its weighting was estimated as follows:

$$W_s = \frac{29.865}{29.865 + 24.234 + 13.866 + 17.657} = \frac{29.865}{85.622} = 0.349$$

The weightings of the level one and level two variables are provided in Table 3.

4.2.3. Estimating Membership Functions of Level Two: Underlying Drivers

The membership function of an element indicates the extent to which the element belongs to a fuzzy set; its values vary between zero and one. Membership functions of level two are derived from the participants' evaluation of the fundamental drivers in the survey. Each membership function consists of five components due to the utilisation of a 5-point Likert scale (L_1 = strongly disagree, L_2 = disagree, L_3 = neutral, L_4 = agree, L_5 = strongly agree). The example chosen to demonstrate the derivation of the membership function will focus on the underlying driver 'National policy on CE' within the category of 'Regulatory Drivers'. To illustrate, the distribution of responses regarding the underlying driver's importance was examined as follows: none (0%) strongly disagreed, 7% of respondents disagreed, 13% remained neutral, 20% of respondents agreed, and 60% strongly agreed. If $S1_{1RD1}$ is considered as the proportion of responses for each rating related to the underlying driver, then the membership function (MF_{1RD1}) for 'National policy on CE' can be represented using Equation (2):

$$MF_{1RD1} = \frac{S11_{1RD1}}{R_1} + \frac{S11_{2RD1}}{R_2} + \frac{S11_{3RD1}}{R_3} + \frac{S11_{4RD1}}{R_4} + \frac{S11_{5RD1}}{R_5} \tag{2}$$

$$MF_{1RD1} = \frac{S11_{1RD1}}{\text{strongly disagree}} + \frac{S11_{2RD1}}{\text{disagree}} + \frac{S11_{3RD1}}{\text{neutral}} + \frac{S11_{4RD1}}{\text{agree}} + \frac{S11_{5RD1}}{\text{strongly agree}}$$

$$MF_{1RB1} = \frac{0.00}{R_1} + \frac{0.07}{R_2} + \frac{0.13}{R_3} + \frac{0.20}{R_4} + \frac{0.60}{R_5}$$

Since the "+" symbol in the FSE analysis indicates a symbolic representation instead of an arithmetic addition [73], the membership function can also be expressed as Equation (3):

$$\mathrm{MF}_{1RD1} = (0.00, 0.07, 0.13, 0.20, 0.60) \tag{3}$$

The membership functions (as shown in Table 4) of the other underlying drivers are obtained in the same manner.

Table 3. Mean Scores and Relative Weightings of CE Drivers.

Code	Stakeholders	Driver Categories and Underlying Drivers	Mean	Weightings of Drivers (W_B)	Total Mean of Each Category (M_c)	Weighting of Each Category (W_C)
S1	Government	Regulatory Drivers			29.865	0.349
S11		National policy on CE.	4.333	0.145		
S12		Government funding support for CE (i.e., start-ups)	4.400	0.147		
S13		Support for market penetration of innovative projects through labelling, awards, certification, and standards	4.133	0.138		
S14		Promoting reuse, recycling and facilities maintenance centres and tax breaks for shops (including public C&D waste treatment companies)	4.500	0.151		
S15		Building design assessment for circularity prior to permit approval (i.e., circular permit)	3.933	0.132		
S16		Establishing CE rating systems	4.133	0.138		
S17		Promotion of standardisation and compatible components	4.433	0.148		
S2	Firms (i.e., Designers and Contractors)	Corporate Drivers			24.234	0.283
S21		Promoting servitised business models (i.e., providing function instead of product)	3.700	0.153		
S22		Integration of circularity into business strategy and goals (i.e., reverse logistics)	4.100	0.169		
S23		Collaboration and information sharing among business entities	4.300	0.177		
S24		Promotion of modular construction and design	4.167	0.172		
S25		Designing and constructing buildings in layers	3.867	0.160		
S26		Flexible and adaptable design and construction	4.100	0.169		
S3	Professional and HEIs	Professional Institutions and HEI Drivers			13.866	0.162
S31		Promotion of skill development/expertise relevant to CE	4.700	0.339		
S32		Information dissemination (i.e., provision of manual/guidelines on dismantling or disassembling facilities/components)	4.633	0.334		
S33		Research and development on CE promotion in the construction industry	4.533	0.327		
S4	Society and Clients	Society and Clients' Drivers			17.657	0.206
S41		Incentives to facilitate CE transition or subsidies on CE products or materials	4.357	0.247		
S42		CE awareness among clients (evinced in aligning norms to CE regulations)	4.733	0.268		
S43		Access to facility operation and maintenance (O&M) and disassembling guidelines	3.867	0.219		
S44		Circular procurement	4.700	0.266		
Total mean and total weighting values					85.622	1.00

Table 4. Weightings and Membership Functions of CE Drivers.

Code	Stakeholders	Driver Categories and Underlying Drivers	Weight	Membership Function for Level 2	Membership Function for Level 1	Weight (W_C)
S1	Government	Regulatory Drivers			0.00, 0.05, 0.14, 0.28, 0.53	0.349
S11		National policy on CE.	0.145	0.00, 0.07, 0.13, 0.20, 0.60		
S12		Government support fund for CE start-ups	0.147	0.00, 0.03, 0.07, 0.37, 0.53		
S13		Support for market penetration of innovative projects through labelling, awards, certification, and standards	0.138	0.00, 0.07, 0.20, 0.27, 0.47		
S14		Promoting reuse, recycling and facilities maintenance centres and tax breaks for shops (including public C&D waste treatment companies).	0.151	0.00, 0.03, 0.07, 0.23, 0.67		
S15		Building design assessment for circularity prior to permit approval (i.e., circular permit).	0.132	0.03, 0.10, 0.17, 0.30, 0.40		
S16		Establishing CE rating systems	0.138	0.00, 0.07, 0.20, 0.27, 0.47		
S17		Promotion of standardisation and compatible components	0.148	0.00, 0.00, 0.13, 0.30, 0.57		
S2	Firms (i.e., Designers and Contractors)	Corporate Drivers			0.01, 0.04, 0.20, 0.41, 0.34	0.283
S21		Promoting servitised business models (i.e., providing function instead of product)	0.153	0.00, 0.07, 0.33, 0.43, 0.17		
S22		Integration of circularity into business strategy and goals (i.e., reverse logistics)	0.169	0.00, 0.03, 0.17, 0.47, 0.33		
S23		Collaboration and information sharing among business entities	0.177	0.00, 0.00, 0.13, 0.43, 0.43		
S24		Promotion of modular construction and design	0.172	0.00, 0.03, 0.20, 0.33, 0.43		
S25		Designing and constructing buildings in layers	0.160	0.03, 0.07, 0.23, 0.37, 0.27		
S26		Flexible and adaptable design and construction	0.169	0.03, 0.03, 0.13, 0.40, 0.40		
S3	Professional and HEIs	Professional Institutions and HEI Drivers			0.00, 0.00, 0.03, 0.31, 0.66	0.162
S31		Promotion of skill development/expertise relevant to CE	0.339	0.00, 0.00, 0.00, 0.30, 0.70		
S32		Information dissemination (i.e., provision of manual/ guidelines on dismantling or disassembling facilities/components)	0.334	0.00, 0.00, 0.07, 0.23, 0.70		
S33		Research and development on CE promotion in the construction industry	0.327	0.00, 0.00, 0.03, 0.40, 0.57		
S4	Society and Clients	Society and Clients' Drivers			0.01, 0.04, 0.07, 0.36, 0.52	0.206
S41		Incentives to facilitate CE transition or subsidies on CE products or materials	0.247	0.00, 0.04, 0.04, 0.46, 0.46		
S42		CE awareness among clients (evinced in aligning norms to CE regulations)	0.268	0.00, 0.00, 0.00, 0.27, 0.73		
S43		Access to facility operation and maintenance (O&M) and disassembling manuals	0.219	0.03, 0.10, 0.17, 0.37, 0.33		
S44		Circular procurement	0.266	0.00, 0.03, 0.10, 0.35, 0.52		
Total mean and total weighting values					85.622	1.00

4.2.4. Determining Membership Functions at Level One: Driver Categories

Equation (4) can be utilised to establish the membership functions of the driver categories once the membership functions of the underlying drivers have been estimated.

$$D_s = Ws^\circ Ms \tag{4}$$

where W_s = weightings of an underlying driver within a category; and M_s stands for the fuzzy evaluation matrix. Using the driver category 'Regulatory drivers' as an example, the expression for the fuzzy evaluation matrix MB is as follows:

$$M_S = \begin{bmatrix} MF_{1RD11} \\ MF_{1RD12} \\ MF_{1RD13} \\ MF_{1RD14} \\ MF_{1RD15} \\ MF_{1RD16} \\ MF_{1RD17} \end{bmatrix} = \begin{bmatrix} S11_{1RD1} & S11_{1RD2} & S11_{1RD3} & S11_{1RD4} & S11_{1RD5} \\ S12_{2RD1} & S12_{2RD2} & S12_{2RD3} & S12_{2RD4} & S12_{2RD5} \\ S13_{3RD1} & S13_{3RD2} & S13_{3RD3} & S13_{3RD4} & S13_{3RD5} \\ S14_{4RD1} & S14_{4RD2} & S14_{4RD3} & S14_{4RD4} & S14_{4RD5} \\ S15_{5RD1} & S15_{5RD2} & S15_{5RD3} & S15_{5RD4} & S15_{5RD5} \\ S16_{6RD1} & S16_{6RD2} & S16_{6RD3} & S16_{6RD4} & S16_{6RD5} \\ S17_{7RD1} & S17_{7RD2} & S17_{7RD3} & S17_{7RD4} & S17_{7RD5} \end{bmatrix}$$

The calculation of the membership function for each driver category is conducted using a matrix format, as exemplified in Table 4.

4.2.5. Determining the Objective Level of Importance of the Driver Categories

Through Equation (5), the objective level of importance (OLI) of each category of drivers is obtained after determining the membership functions at level one. For instance, the determination of the objective level of importance for the 'Regulatory drivers' is calculated as follows:

$$OLI_{S1} = D_{S1} \times L_n = (D_{S11}, D_{S12}, D_{S13}, D_{S14}, D_{S15}) \times (L_1, L_2, L_3, L_4, L_5) \tag{5}$$

where $D_{S1} = (D_{S11}, D_{S12}, D_{S13}, D_{S14}, D_{S15})$ is the membership function for level one (as shown in Table 5) and $L_n = (1, 2, 3, 4, 5)$ entails the 5-point Likert scale employed in this study. Therefore, the OLI_{RB} of the 'Regulatory drivers' (see Table 5) was calculated as follows:

$$OLI_{RB} = (0.00,\ 0.05,\ 0.14,\ 0.28,\ 0.53) \times (1,\ 2,\ 3,\ 4,\ 5) = 4.288$$

Table 5. FSE Indices of Stakeholders' Drivers for CE.

Code	Stakeholders	Categories of CE Drivers	Ranking of Drivers	
			FSE Index	**Rank**
S1	Government	Regulatory Drivers	4.288	3
S2	Firms (i.e., Designers and Contractors)	Corporate Drivers	4.003	4
S3	Professional Institutions and HEIs	Professionals and HEI Drivers	4.624	1
S4	Society and Clients	Society and Clients' Drivers	4.347	2

The objective levels of importance of the other three driver categories (see Table 5) were calculated as follows:

$$OLI_{S2} = (0.01,\ 0.04,\ 0.20,\ 0.41,\ 0.34) \times (1,\ 2,\ 3,\ 4,\ 5) = 4.003$$

$$OLI_{S3} = (0.00,\ 0.00,\ 0.03,\ 0.31,\ 0.66) \times (1,\ 2,\ 3,\ 4,\ 5) = 4.624$$

$$OLI_{S4} = (0.01,\ 0.04,\ 0.07,\ 0.36,\ 0.52) \times (1,\ 2,\ 3,\ 4,\ 5) = 4.347$$

5. Discussions of Results

5.1. Prioritization of CE Drivers

The FSE value for each of the driver categories and the stakeholder groups is above four (see Table 5 for aggregated results), which implies that each group of stakeholders is important towards achieving CE in the construction industry. Nonetheless, the driver category concerning professional and HEIs ranks as the most important with an FSE value of 4.624. Professional institutions and HEIs play the most crucial role since the highly rated underlying drivers (i.e., all rated above 4.5) pertain to the professional institutions and higher educational institution stakeholders. These underlying drivers include 'promotion of skill development/expertise relevant to CE'; 'information dissemination (i.e., provision of manuals/guidelines on dismantling or disassembling facilities/components)' and 'research and development on CE promotion in the construction industry'. The high ranking of these drivers is reasonable because they create awareness among clients and society. Additionally, the government relies on these highly ranked drivers to make effective and efficient policies or regulations concerning CE transition in the construction industry. Apart from influencing society, clients and the government concerning CE transition, professionals and HEIs could also facilitate the efforts of firms (i.e., designers and contractors) in the CE transition through facilitating the development of new products and circular business models [74]. Thus, the stakeholder category of professional institutions and HEIs influences the decisions of the other key stakeholders such as society and clients, governments, and firms (i.e., designers and contractors). The driver category of the stakeholder group 'society and clients' is ranked second. This is reasonable because society and clients are key stakeholders for circular procurement and the alignment of norms to circular practices. The government is the third-ranked stakeholder. Government's policies and regulations are important to facilitate CE transition by shaping the market conditions [41]. Such regulations are, therefore, effective if they are formulated using evidence-based data (i.e., credible information, research and development on CE and clients' awareness of CE). However, government's policies are likely to be ineffective if not supported by scientific and technological knowledge provided by the professionals and HEIs. The corporate driver category that pertains to 'firms (i.e., designers and contractors)' is the lowest ranked. This could imply that designers and contractors will be automatically influenced to adopt CE practices once the other three stakeholders (i.e., professionals and HEIs, society and clients, and governments) embrace CE practices [41].

Based on the ranking of the driver categories in this study, an effective transition to CE involves scientific and technological knowledge on CE by the professionals and HEIs, followed by CE awareness creation and fostering a culture of circularity among society and clients by the professionals and HEIs. At this juncture, CE regulation and policies by government (supported by scientific knowledge) are required to shape the market conditions to facilitate CE transition. Finally, CE business implementation frameworks or models (developed by the professionals and HEIs) are pivotal for the firms (i.e., designers and contractors).

5.1.1. CE Awareness among Clients

'CE awareness among clients' ranked first out of the 20 underlying drivers. This concurs with the study of Marcon et al. [43] that revealed that without an informed client/consumer, a CE business model and policy implementation could fail. The perception of CE products as low quality and performance trade-offs by consumers has partly contributed to the prevailing low CE policy implementation by policymakers and practitioners [12]. Due to lack of information and awareness creation, some clients still adopt practices that do not promote circularity in the built environment. For example, some clients prefer river sand to crushed sand or manufactured sand for construction. However, between these two, there is minimal or no wastage with crushed sand.

Awareness creation plays an essential role for clients' contributions to CE in the built environment [75,76]. Changes in client behaviour regarding a CE hinge on their awareness and education [77]. Consumer demand for CE products is required for the viability of a business entity that produces CE products. Such demand could be promoted by awareness creation through adequate information dissemination via seminars, conferences and workshops. Information dissemination should focus on the importance of CE in creating eco-friendly products and ensuring optimum utilisation of Earth's finite resources. Consequently, potential clients can be persuaded to adopt practices and behavioural changes that are environmentally friendly by the palpable advantages of such practices. This has a psychological effect that encourages other potential clients to belong to a group that promotes green consumerism or pro-environmental behaviour. 'Feeling environmentally virtuous' and justification for 'future self-indulgent behaviour' could therefore influence clients' demand for and purchase decisions concerning CE products [78]. Moreover, through co-creation, clients can gain awareness and contribute to CE product value creation by engaging in a dialogue with other stakeholders in the down-stream (raw materials) and up-stream (building/infrastructure owners) supply chain. This leads to the motivation of clients through their recognition as contributors and not as end users of prescribed products.

5.1.2. Circular Procurement

'Circular procurement' is the second-ranked driver from the stakeholder group 'society and clients'. Clients oversee construction budgets and specify or control the types of materials to be purchased and used for construction projects. Designers and contractors, therefore, follow these specifications and may not be able to employ circular practices if the clients are not convinced and do not approve such practices. However, once clients are informed and are willing to adopt CE practices, they could promote circular procurement. Tender documents could be revised to promote this practice. For example, instead of focusing solely on the financial capabilities and technical capabilities of tenderers during contractor selection, tender documents could include CE criteria as part of the selection criteria. Thus, among the tender requirements, tenderers could submit documents on CE strategies to be adopted to reduce construction and demolition waste (i.e., reuse and recycling, dematerialisation strategies). Moreover, these CE criteria could be given higher weights to promote diligence by the tenderers on devising CE strategies. Furthermore, clients could ensure that purchased products are designed for disassembly to promote reuse.

5.1.3. Promotion of Skill Development/Expertise Relevant to CE

'Promotion of skill development/expertise relevant to CE' within the stakeholder category professional institutions and HEIs also ranked second out of the 20 underlying drivers. The CE concept is relatively new, and it requires acquisition of skills, competencies and knowledge by professionals to meet the needs of a circular built environment. Professional institutions and HEIs are the key stakeholders for training and developing programs to enable professionals to acquire new capabilities and skills relevant to CE. HEIs can help cultivate designers and contractors with these skills. Through training and development, young professionals could gain essential CE insights, skills, and capabilities for tackling CE implementation challenges [79–82]. HEIs can achieve effective training and development through (1) restructuring of curriculums to incorporate CE competencies and (2) the adoption of appropriate educational approaches and methodologies for instilling CE competencies. Architectural programs/curriculums could be structured to ensure that the following competencies are gained by young professionals, viz: design for reuse, design for recovery, design for disassembly; design for dematerialization, circular business models/frameworks and circular system thinking. Regarding educational methodologies and approaches (i.e., passive and active learning methodologies), active learning methodology encourages working in teams, critical thinking and system thinking, which are vital skills for CE [83]. As emphasized in this study, CE implementation entails multi-stakeholders. Therefore, through active learning methodologies, young professionals could acquire the skills and competencies thereof to work with different stakeholders for a circular built environment. Professional institutions could also play a vital role in the development of CE professionals. Continuous development programs (CPD) organized by professional institutions could focus on CE competencies. Furthermore, courses and examinations for membership in professional institutions (e.g., project management professionals, chartered institutes of builders) should be restructured to instil and test the acquisition of CE capabilities.

5.1.4. Information Dissemination

'Information dissemination' ranked fourth out of the 20 underlying drivers, and it belongs to the stakeholder category professional institutions and HEIs. HEIs play a pivotal role in the transition to a CE in the built environment. They are the decisive enablers of a change in mindset, norms, values and practices of the society and clients of both the present and future generations. Six key areas have been highlighted concerning practical application of CE by HEIs, namely, teaching, research, campus management, student-led projects, influence and leadership [7]. HEIs could ensure CE transition through their educational programs and campus practical sustainable behaviour/activities. HEIs could also promote service-learning programs. With such programs, students can carry out tasks that benefit community/society; this has the benefit of both influencing student behaviour and promoting a connection/relationship between society and HEIs. Through workshops, fieldtrips and situated learning, HEIs can collaborate, engage stakeholders and transfer knowledge to influence society and clients' behaviour for a CE.

HEIs could also facilitate the efforts of firms (i.e., designers and contractors) in the CE transition. *"They can develop practical activities to support the creation of new products and the development of circular business models"* ([74], p.3). Most firms are still fixated on linear economy business models due to the difficulty in implementing CE. However, HEIs can assist firms by providing them with cost-effective business frameworks for CE implementation. For information dissemination between HEIs and firms, workshops, seminars and conferences are strategies for collaboration and knowledge transfer. Funding schemes provided by firms to HEIs could promote collaboration between them when both sides realise the benefit of partnerships. Such funds could be used for training students ('at cost') for the firms and for conducting research on business models for CE implementations, etc. Additionally, HEIs could also be perceived as organisations that could lead by example by applying CE principles or practices [84–88]. Firms that are locked into linear thinking often cite lack of practical cases of CE projects and their benefits as a barrier to CE adoption. However, through experimentation, HEIs could allay the barrier thereof by building a business case for CE implementation. Switching service instead of purchasing product is a key CE procurement strategy that could be adopted by HEIs. A typical case of this is the pay-per-lux, which promotes energy efficiency while reducing electrical waste and cost.

5.1.5. Research and Development on CE Promotion in the Construction Industry

'Research and development on CE promotion in the construction industry', in the stakeholder category of professionals and HEIs, ranked fifth out of the 20 underlying drivers. Research and development to promote longevity of construction materials is vital for CE. Concrete is among the predominantly used construction materials. And research on increasing its lifespan could significantly improve CE. For such research and development activities by higher educational institutions, supportive funding and grants from government-related organizations are essential [89]. The private sector could also be encouraged to invest in R&D activities. For example, enterprises that conduct research with designated universities could be offered cash rebates for approved research expenditures. Further, tax deductions for qualified research expenditures could be provided to enterprises. Moreover, funding to support commercialization of R&D results on CE should be encouraged to promote technology transfer.

5.1.6. Promoting Reuse, Recycling and Facilities Maintenance Centres and Tax Breaks for Shops

'Promoting reuse, recycling and facilities maintenance centres and tax breaks for shops' ranked sixth, from the stakeholder category of government. Demolition of old buildings occurs frequently in Ghana [90]. This leads to high construction and demolition waste, which mostly emanates from concrete and bricks that could be reused or recycled for subsequent construction. However, reuse or recycling of C&D waste is plagued with barriers such as high cost and lack of confidence concerning the suitability of reused or recycled construction materials [91]. Nonetheless, if the government provides reuse and recycling centres, these barriers could be mitigated. The centres could conduct tests and check on the suitability of recycled construction materials to increase confidence in the use of recycled construction materials. To achieve this, tax incentives could be offered by the government to construction companies that establish such centres. This could increase the number of centres and therefore help lower the cost of recycling construction and demolition waste. Moreover, societal awareness of the need to use recycled construction materials could improve the availability of customers for recycled materials. Thus, societal awareness could improve the use of recycled construction materials. Additionally, facility maintenance centres established by the government could be appropriate for providing subsidised costs and free training to households and potential facility managers to promote building maintenance and longevity. This could engender a social benefit of CE in terms of job creation.

The reuse of materials could be promoted by adopting practices such as Building as Material Bank (BAMB) and Building Material Passport (BMP) for building assets. Most construction facilities also store their own materials. Therefore, an aggregation of a huge number of building assets implies a huge volume of building materials that can be reused or recycled. Such materials are low-carbon as well as eco-friendly. Thus, with BAMB, construction facilities are considered as temporary material storage. BAMB is facilitated by BMP, which is a set of data and indicators that describe characteristics of materials or systems with the aim of giving them value for recovery and reuse [92,93]. BMP of typical construction materials such as steel and wood could provide essential information to stakeholders in the industry value chains for material recovery and reuse. To achieve this, BMP should contain key attributes: namely, quality of components and conditions of use; expected lifespan and expected end-condition under defined conditions of use; valuation of use, recovery and reuse; directions for dismantling and disassembly; directions for maintenance; directions for repair and renovation; take-back options by manufacturers and marketplaces for materials, i.e., industrial symbiosis markets [94–99].

5.2. Integration of the Underlying Drivers to Develop a 20-Driver Model for CE Transition

Implementing CE is a holistic endeavour which entails the collaboration of all stakeholders via driving one another towards CE. Drivers of a particular group of stakeholders interrelate with drivers of the other categories of stakeholders. The interactions among the underlying drivers are depicted through a causal loop diagram as shown in Figure 3. The causal loop diagram has been deployed previously [41] as a qualitative technique to show the interrelations among variables.

All 20 underlying drivers (see Table 3) have mean values above the average mean (3.5) and are therefore considered key drivers for developing a 20-driver model for CE transition in the built environment, as shown in Figure 3. The stakeholders 'professional institutions and HEIs' are the most important stakeholders. This is because their underlying drivers influence at least one driver of the other groups of stakeholders. For instance, concerning the interrelation between 'society and client' and 'professional institutions and HEIs', information dissemination from professionals and HEIs 'promotes CE awareness among clients' and 'access to facility operations, maintenance and disassembling guidelines' [100–103]. Furthermore, among the stakeholders 'professional institutions and HEIs', 'government' and 'firms: designers and contractors', research and development on CE promotion in the construction industry by the professional institutions and HEIs provides the foundation for research-backed policies for government implementation [104–107]. Such research also proffers knowledge to the firms on how CE principles could be integrated into the business strategies and goals of the firms for circular business models. Moreover, between 'professional institutions and HEIs' and 'firms: designers and contractors', promotion of skill development/expertise relevant to CE by professional institutions and HEIs could influence circular construction practices such as 'modular construction and design', 'designing and construction of buildings in layers' and 'flexible and adaptable design and construction' by the firms. These interrelationships are depicted in Figure 3.

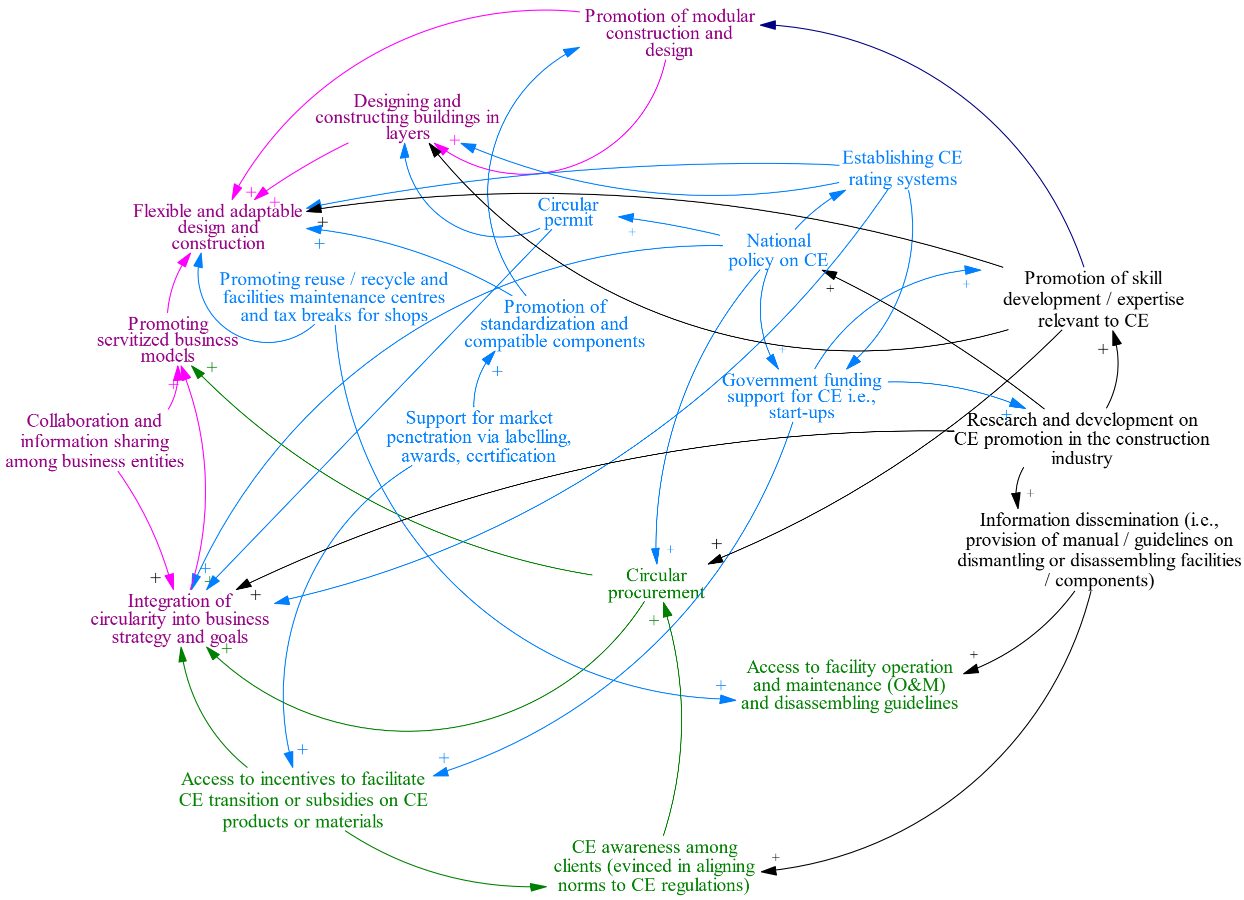

Figure 3. A 20-driver model for CE transition in the built environment.

6. Conclusions

In this study, a 20-driver model was developed for CE transition in the built environment. Informed by stakeholder theory, a review of the extant literature was conducted. Drivers identified from the literature review were grouped under four key stakeholder categories viz.: professionals and HEIs; society and clients; government; and firms (i.e., designers and contractors). Through a questionnaire survey, professionals' views were solicited on key drivers from the review findings. The data were analysed through FSE, and analysis results revealed that the stakeholder category 'professionals and HEIs' has the most influence among the other stakeholders and is therefore the most important category of stakeholders for promoting CE in the built environment. The next important category of stakeholders is 'society and clients', followed by 'government' and 'firms: designers and contractors'. It is not surprising that 'society and clients' ranks higher in terms of importance than the government. This is because CE awareness among society and clients should take precedence over regulation on CE. Without an informed society and clients, regulations on CE are likely to fail. Thus, an informed society and clients are precursors to an effective and efficient implementation of CE policies by the government. Moreover, the government is only instrumental in facilitating a CE transition in the built environment by shaping the market conditions.

The stakeholders interrelate with one another through their underlying drivers. For instance, through 'research and development on CE strategies', 'promotion of skills/expertise relevant to CE in the built environment' and 'information dissemination', the 'professionals and HEIs' can inform 'society and clients' on CE practices. They also can provide information to the government for effective and efficient development and implementation of national policies on CE. Furthermore, the professional institutions and HEIs can provide scientific and technological knowledge which could enable firms to integrate CE practices into their businesses. These interrelations were depicted using a causal loop diagram.

The essence of the classifications of drivers depicts the multi-stakeholders required for transitioning to a CE in the built environment. The classifications also reveal that transitioning from the prevailing LE to CE requires a systemic approach in which key stakeholders collaborate effectively to ensure such change. Moreover, the classifications imply that a CE is achieved through a mixture of top-down and bottom-up approaches. The government, professional institutions and HEIs constitute the stakeholders for a top-down approach, while society, clients and firms (i.e., designers and contractors) constitute the stakeholders for a bottom-up approach to CE. Both approaches complement each other for a successful CE transition in the built environment. Emergent findings are relevant for specifying the roles, responsibilities and strategies to influence each group of stakeholders for a CE transition in the built environment. The findings could also serve as a guide for policymakers (i.e., governments, NGOs, project professionals and educational institutions) on optimum resource allocations among stakeholders. Although each stakeholder has a role to play, the underlying drivers indicate that the professional and HEI drivers are the precursors for instigating CE among the other stakeholders.

Notwithstanding the essence of this study, there are some limitations which are worth recommending for further study to enhance the CE literature. Empirical studies could investigate interrelationships among the stakeholders and indicators of CE towards assessing the impact of each stakeholder on a CE. Finally, within each stakeholder category, interrelationships among the drivers could be evaluated to identify cause and effect drivers.

Author Contributions: Conceptualization, M.A.A.; Methodology, S.I.; Writing—original draft, M.A.A.; Writing—review & editing, A.P.C.C., A.D., D.J.E., Y.Y. and S.I.; Supervision, A.P.C.C. and A.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author. The data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Roberts, C.; Edwards, D.J. Post-occupancy evaluation: Identifying and mitigating implementation barriers to reduce environmental impact. *J. Clean. Prod.* **2022**, *374*, 133957. [CrossRef]
2. Illankoon, I.C.S.; Tam, V.W.; Le, K.N.; Shen, L. Key credit criteria among international green building rating tools. *J. Clean. Prod.* **2017**, *164*, 209–220. [CrossRef]
3. Çimen, Ö. Construction and built environment in circular economy: A comprehensive literature review. *J. Clean. Prod.* **2021**, *305*, 127180. [CrossRef]
4. Adabre, M.A.; Chan, A.P. Towards a sustainability assessment model for affordable housing projects: The perspective of professionals in Ghana. *Eng. Constr. Archit. Manag.* **2020**, *27*, 2523–2551. [CrossRef]
5. Adabre, M.A.; Chan, A.P.; Edwards, D.J.; Osei-Kyei, R. To build or not to build, that is the uncertainty: Fuzzy synthetic evaluation of risks for sustainable housing in developing economies. *Cities* **2022**, *125*, 103644. [CrossRef]

6. Thirumal, S.; Udawatta, N.; Karunasena, G.; Al-Ameri, R. Barriers to Adopting Digital Technologies to Implement Circular Economy Practices in the Construction Industry: A Systematic Literature Review. *Sustainability* **2024**, *16*, 3185. [CrossRef]
7. Ellen MacArthur Foundation, 2016. Circular Economy—UK, Europe, Asia, South America & USA. Ellen MacArthur Foundation. Available online: http://www.ellenmacarthurfoundation.org/circulareconomy (accessed on 4 June 2024).
8. Mahpour, A. Prioritizing barriers to adopt circular economy in construction and demolition waste management. *Resour. Conserv. Recycl.* **2018**, *134*, 216–227. [CrossRef]
9. Adabre, M.A.; Chan, A.P.; Darko, A.; Hosseini, M.R. Facilitating a transition to a circular economy in construction projects: Intermediate theoretical models based on the theory of planned behaviour. *Build. Res. Inf.* **2023**, *51*, 85–104. [CrossRef]
10. Eikelenboom, M.; Long, T.B.; de Jong, G. Circular strategies for social housing associations: Lessons from a Dutch case. *J. Clean. Prod.* **2021**, *292*, 126024. [CrossRef]
11. Charef, R.; Ganjian, E.; Emmitt, S. Socio-economic and environmental barriers for a holistic asset lifecycle approach to achieve circular economy: A pattern-matching method. *Technol. Forecast. Soc. Chang.* **2021**, *170*, 120798. [CrossRef]
12. Ranta, V.; Aarikka-Stenroos, L.; Ritala, P.; Mäkinen, S.J. Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe. *Resour. Conserv. Recycl.* **2018**, *135*, 70–82. [CrossRef]
13. Joensuu, T.; Edelman, H.; Saari, A. Circular economy practices in the built environment. *J. Clean. Prod.* **2020**, *276*, 124215. [CrossRef]
14. Kirchherr, J.; Piscicelli, L.; Bour, R.; Kostense-Smit, E.; Muller, J.; Huibrechtse-Truijens, A.; Hekkert, M. Barriers to the circular economy: Evidence from the European Union (EU). *Ecol. Econ.* **2018**, *150*, 264–272. [CrossRef]
15. Campbell-Johnston, K.; Ten Cate, J.; Elfering-Petrovic, M.; Gupta, J. City level circular transitions: Barriers and limits in Amsterdam, Utrecht and the Hague. *J. Clean. Prod.* **2019**, *235*, 1232–1239. [CrossRef]
16. Salmenperä, H.; Pitkänen, K.; Kautto, P.; Saikku, L. Critical factors for enhancing the circular economy in waste management. *J. Clean. Prod.* **2021**, *280*, 124339. [CrossRef]
17. Oluleye, B.I.; Chan, D.W.; Olawumi, T.O.; Saka, A.B. Assessment of symmetries and asymmetries on barriers to circular economy adoption in the construction industry towards zero waste: A survey of international experts. *Build. Environ.* **2023**, *228*, 109885. [CrossRef]
18. Prendeville, S.; Cherim, E.; Bocken, N. Circular cities: Mapping six cities in transition. *Environ. Innov. Soc. Transit.* **2018**, *26*, 171–194. [CrossRef]
19. Sauermann, H.; Vohland, K.; Antoniou, V.; Balázs, B.; Göbel, C.; Karatzas, K.; Mooney, P.; Perelló, J.; Ponti, M.; Samson, R.; et al. Citizen science and sustainability transitions. *Res. Policy* **2020**, *49*, 103978. [CrossRef]
20. Hosseini, M.R.; Rameezdeen, R.; Chileshe, N.; Lehmann, S. Reverse logistics in the construction industry. *Waste Manag. Res.* **2015**, *33*, 499–514. [CrossRef]
21. Tura, N.; Hanski, J.; Ahola, T.; Ståhle, M.; Piiparinen, S.; Valkokari, P. Unlocking circular business: A framework of barriers and drivers. *J. Clean. Prod.* **2019**, *212*, 90–98. [CrossRef]
22. Kalmykova, Y.; Sadagopan, M.; Rosado, L. Circular economy—From review of theories and practices to development of implementation tools. *Resour. Conserv. Recycl.* **2018**, *135*, 190–201. [CrossRef]
23. del Mar Alonso-Almeida, M.; Rodriguez-Anton, J.M.; Bagur-Femenías, L.; Perramon, J. Institutional entrepreneurship enablers to promote circular economy in the European Union: Impacts on transition towards a more circular economy. *J. Clean. Prod.* **2021**, *281*, 124841. [CrossRef]
24. Velenturf, A.P.; Purnell, P. Principles for a sustainable circular economy. *Sustain. Prod. Consum.* **2021**, *27*, 1437–1457. [CrossRef]
25. Wuni, I.Y.; Shen, G.Q. Developing critical success factors for integrating circular economy into modular construction projects in Hong Kong. *Sustain. Prod. Consum.* **2022**, *29*, 574–587. [CrossRef]
26. Van Berkel, R.; Willems, E.; Lafleur, M. The relationship between cleaner production and industrial ecology. *J. Ind. Ecol.* **1997**, *1*, 51–66. [CrossRef]
27. Vergragt, P.J.; Quist, J. Backcasting for sustainability: Introduction to the special issue. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 747–755. [CrossRef]
28. Brandão, R.; Edwards, D.J.; Hossieni, M. Reza., André, M.S.; Alcebiades, M. A reverse supply chain conceptual model for construction and demolition waste. *Waste Manag. Res.* **2021**, *39*, 1341–1355. [CrossRef]
29. Neves, A.; Godina, R.; Azevedo, S.G.; Matias, J.C. A comprehensive review of industrial symbiosis. *J. Clean. Prod.* **2020**, *247*, 119113. [CrossRef]
30. Paquin, R.L.; Howard-Grenville, J. The evolution of facilitated industrial symbiosis. *J. Ind. Ecol.* **2012**, *16*, 83–93. [CrossRef]
31. Anastasiades, K.; Goffin, J.; Rinke, M.; Buyle, M.; Audenaert, A.; Blom, J. Standardisation: An essential enabler for the circular reuse of construction components? A trajectory for a cleaner European construction industry. *J. Clean. Prod.* **2021**, *298*, 126864. [CrossRef]
32. El Haggar, S. Sustainability of industrial waste management. In *Sustainable Industrial Design and Waste Management: Cradle-to Cradle for Sustainable Development*; Elsevier Academic Press: Amsterdam, The Netherlands, 2007; Chapter 10; pp. 307–369. [CrossRef]
33. Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Des. Stud.* **2016**, *47*, 118–163. [CrossRef]

34. Reike, D.; Vermeulen, W.J.; Witjes, S. 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. *Resour. Conserv. Recycl.* **2018**, *135*, 246–264. [CrossRef]
35. Ünal, E.; Urbinati, A.; Chiaroni, D.; Manzini, R. Value Creation in Circular Business Models: The case of a US small medium enterprise in the building sector. *Resour. Conserv. Recycl.* **2019**, *146*, 291–307. [CrossRef]
36. Freeman, R.E.; Phillips, R.; Sisodia, R. Tensions in stakeholder theory. *Bus. Soc.* **2020**, *59*, 213–231. [CrossRef]
37. Freudenreich, B.; Lüdeke-Freund, F.; Schaltegger, S. A stakeholder theory perspective on business models: Value creation for sustainability. *J. Bus. Ethics* **2020**, *166*, 3–18. [CrossRef]
38. Shah, M.U.; Bookbinder, J.H. Stakeholder theory and supply chains in the circular economy. In *Circular Economy Supply Chains: From Chains to Systems*; Emerald Publishing Limited: Bingley, UK, 2022; pp. 129–148.
39. Freeman, E. *Stakeholder Management: Framework and Philosophy*; Pitman: Mansfeld, Germany, 1984.
40. van Bueren, B.J.; Argus, K.; Iyer-Raniga, U.; Leenders, M.A. The circular economy operating and stakeholder model "eco-5HM" to avoid circular fallacies that prevent sustainability. *J. Clean. Prod.* **2023**, *391*, 136096. [CrossRef]
41. Ma, W.; Hao, J.L. Enhancing a circular economy for construction and demolition waste management in China: A stakeholder engagement and key strategy approach. *J. Clean. Prod.* **2024**, *450*, 141763. [CrossRef]
42. Volk, R.; Müller, R.; Reinhardt, J.; Schultmann, F. An integrated material flows, stakeholders and policies approach to identify and exploit regional resource potentials. *Ecol. Econ.* **2019**, *161*, 292–320. [CrossRef]
43. Marcon, M.; Provensi, T.; Sehnem, S.; Campos, L.M.; Queiroz, A.A.F.S.L. The internalisation of the circular economy and ESG in Brazilian B Corps from the perspective of the Stakeholder Theory. *Sustain. Dev.* **2023**, *31*, 3513–3527. [CrossRef]
44. van Langen, S.K.; Vassillo, C.; Ghisellini, P.; Restaino, D.; Passaro, R.; Ulgiati, S. Promoting circular economy transition: A study about perceptions and awareness by different stakeholders groups. *J. Clean. Prod.* **2021**, *316*, 128166. [CrossRef]
45. Coenen, T.B.; Haanstra, W.; Braaksma, A.J.; Santos, J. CEIMA: A framework for identifying critical interfaces between the Circular Economy and stakeholders in the lifecycle of infrastructure assets. *Resour. Conserv. Recycl.* **2020**, *155*, 104552. [CrossRef]
46. Ababio, B.K.; Lu, W.; Ghansah, F.A. Transitioning from green to circular procurement in developing countries: A conceptual framework for Ghana's construction sector. *Build. Res. Inf.* **2023**, *51*, 798–815. [CrossRef]
47. Mies, A.; Gold, S. Mapping the social dimension of the circular economy. *J. Clean. Prod.* **2021**, *321*, 128960. [CrossRef]
48. Wuni, I.Y. Drivers of circular economy adoption in the construction industry: A systematic review and conceptual model. *Build. Res. Inf.* **2023**, *51*, 816–833. [CrossRef]
49. Baah, C.; Agyabeng-Mensah, Y.; Afum, E.; Kumi, C.A. Do circular economy practices accelerate CSR participation of SMEs in a stakeholder-pressured era? A network theory perspective. *J. Clean. Prod.* **2023**, *394*, 136348. [CrossRef]
50. Adabre, M.A.; Chan, A.P.; Edwards, D.J.; Mensah, S. Evaluation of symmetries and asymmetries on barriers to sustainable housing in developing countries. *J. Build. Eng.* **2022**, *50*, 104174. [CrossRef]
51. Tapia, D.; González, M.; Vera, S.; Aguilar, C. A Novel Offsite Construction Method for Social Housing in Emerging Economies for Low Cost and Reduced Environmental Impact. *Sustainability* **2023**, *15*, 16922. [CrossRef]
52. Cruz Rios, F.; Grau, D.; Bilec, M. Barriers and enablers to circular building design in the US: An empirical study. *J. Constr. Eng. Manag.* **2021**, *147*, 04021117. [CrossRef]
53. Giorgi, S.; Lavagna, M.; Wang, K.; Osmani, M.; Liu, G.; Campioli, A. Drivers and barriers towards circular economy in the building sector: Stakeholder interviews and analysis of five European countries policies and practices. *J. Clean. Prod.* **2022**, *336*, 130395. [CrossRef]
54. Hartwell, R.; Macmillan, S.; Overend, M. Circular economy of façades: Real-world challenges and opportunities. *Resour. Conserv. Recycl.* **2021**, *175*, 105827. [CrossRef]
55. Ho, O.T.K.; Gajanayake, A.; Iyer-Raniga, U. Transitioning to a state-wide circular economy: Major stakeholder interviews. *Resour. Conserv. Recycl. Adv.* **2023**, *19*, 200163. [CrossRef]
56. Senaratne, S.; Rodrigo, N.; Almeida, L.M.; Perera, S.; Jin, X. Systematic review on stakeholder collaboration for a circular built environment: Current research trends, gaps and future directions. *Resour. Conserv. Recycl. Adv.* **2023**, *19*, 200169. [CrossRef]
57. Meath, C.; Karlovšek, J.; Navarrete, C.; Eales, M.; Hastings, P. Co-designing a multi-level platform for industry level transition to circular economy principles: A case study of the infrastructure CoLab. *J. Clean. Prod.* **2022**, *347*, 131080. [CrossRef]
58. Karaca, F.; Tleuken, A.; Pineda-Martos, R.; Ros Cardoso, S.; Orel, D.; Askar, R.; Agibayeva, A.; Güemez, E.G.; Salles, A.; Varol, H.A.; et al. Cultivating Sustainable Construction: Stakeholder Insights Driving Circular Economy Innovation for Inclusive Resource Equity. *Buildings* **2024**, *14*, 935. [CrossRef]
59. Gerding, D.P.; Wamelink, H.; Leclercq, E.M. Implementing circularity in the construction process: A case study examining the reorganization of multi-actor environment and the decision-making process. *Constr. Manag. Econ.* **2021**, *39*, 617–635. [CrossRef]
60. Guerra, B.C.; Leite, F. Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers. *Resour. Conserv. Recycl.* **2021**, *170*, 105617. [CrossRef]
61. Kaya, D.I.; Dane, G.; Pintossi, N.; Koot, C.A. Subjective circularity performance analysis of adaptive heritage reuse practices in the Netherlands. *Sustain. Cities Soc.* **2021**, *70*, 102869. [CrossRef]
62. Ramos, M.; Paiva, A.; Martinho, G. Understanding the perceptions of stakeholders on selective demolition. *J. Build. Eng.* **2024**, *82*, 108353. [CrossRef]

63. Gillott, C.; Davison, B.; Densley Tingley, D. Drivers, barriers and enablers: Construction sector views on vertical extensions. *Build. Res. Inf.* **2022**, *50*, 909–923. [CrossRef]
64. Shooshtarian, S.; Hosseini, M.R.; Kocaturk, T.; Arnel, T.; Garofano, N.T. Circular economy in the Australian AEC industry: Investigation of barriers and enablers. *Build. Res. Inf.* **2023**, *51*, 56–68. [CrossRef]
65. Mollaei, A.; Byers, B.; Christovan, C.; Olumo, A.; De Wolf, C.; Bachmann, C.; Haas, C. A global perspective on building material recovery incorporating the impact of regional factors. *J. Clean. Prod.* **2023**, *429*, 139525. [CrossRef]
66. Fisher, L.; Edwards, D.J.; Pärn, E.A.; Aigbavboa, C.O. Building design for people with dementia: A case study of a UK care home. *Facilities* **2018**, *36*, 349–368. [CrossRef]
67. Law, R.C.K.; Lai, J.H.K.; Edwards, D.J.; Hou, H. COVID-19: Research Directions for Non-Clinical Aerosol-Generating Facilities in the Built Environment. *Buildings* **2021**, *11*, 282. [CrossRef]
68. Adabre, M.A.; Chan, A.P.; Darko, A.; Osei-Kyei, R.; Abidoye, R.; Adjei-Kumi, T. Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. *J. Clean. Prod.* **2020**, *253*, 119995. [CrossRef]
69. Adabre, M.A.; Chan, A.P.; Edwards, D.J. Modeling relationship between success factors (policies) and critical success criteria (goals) for sustainable housing in developing countries. *Int. J. Constr. Manag.* **2021**, *23*, 1642–1652. [CrossRef]
70. Ohene, E.; Chan, A.P.C.; Darko, A. Prioritizing barriers and developing mitigation strategies toward net-zero carbon building sector. *Build. Environ.* **2022**, *223*, 109437. [CrossRef]
71. Ott, R.L.; Longnecker, M. *An Introduction to Statistical Methods and Data Analysis*; Cengage Learning: Belmont, CA, USA, 2016.
72. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
73. Oppong, G.D.; Chan, A.P.; Ameyaw, E.E.; Frimpong, S.; Dansoh, A. Fuzzy evaluation of the factors contributing to the success of external stakeholder management in construction. *J. Constr. Eng. Manag.* **2021**, *147*, 04021142. [CrossRef]
74. Vergani, F. Higher education institutions as a microcosm of the circular economy. *J. Clean. Prod.* **2024**, *435*, 140592. [CrossRef]
75. Smol, M.; Avdiushchenko, A.; Kulczycka, J.; Nowaczek, A. Public awareness of circular economy in southern Poland: Case of the Malopolska region. *J. Clean. Prod.* **2018**, *197*, 1035–1045. [CrossRef]
76. Pecorari, P.M.; Lima, C.R.C. Correlation of customer experience with the acceptance of product-service systems and circular economy. *J. Clean. Prod.* **2021**, *281*, 125275. [CrossRef]
77. Elzinga, R.; Reike, D.; Negro, S.O.; Boon, W.P. Consumer acceptance of circular business models. *J. Clean. Prod.* **2020**, *254*, 119988. [CrossRef]
78. Boyer, R.H.; Hunka, A.D.; Linder, M.; Whalen, K.A.; Habibi, S. Product labels for the circular economy: Are customers willing to pay for circular? *Sustain. Prod. Consum.* **2021**, *27*, 61–71. [CrossRef]
79. Wijewickrama, M.K.C.S.; Rameezdeen, R.; Chileshe, N. Information brokerage for circular economy in the construction industry: A systematic literature review. *J. Clean. Prod.* **2021**, *313*, 127938. [CrossRef]
80. Lewandowski, M. Designing the business models for circular economy—Towards the conceptual framework. *Sustainability* **2016**, *8*, 43. [CrossRef]
81. Hossain, M.U.; Ng, S.T.; Antwi-Afari, P.; Amor, B. Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. *Renew. Sustain. Energy Rev.* **2020**, *130*, 109948. [CrossRef]
82. Gupta, S.; Chen, H.; Hazen, B.T.; Kaur, S.; Gonzalez, E.D.S. Circular economy and big data analytics: A stakeholder perspective. *Technol. Forecast. Soc. Chang.* **2019**, *144*, 466–474. [CrossRef]
83. Chan, D.W.; Lam, E.W.; Adabre, M.A. Assessing the Effect of Pedagogical Transition on Classroom Design for Tertiary Education: Perspectives of Teachers and Students. *Sustainability* **2023**, *15*, 9177. [CrossRef]
84. Mendoza, J.M.F.; Gallego-Schmid, A.; Azapagic, A. A methodological framework for the implementation of circular economy thinking in higher education institutions: Towards sustainable campus management. *J. Clean. Prod.* **2019**, *226*, 831–844. [CrossRef]
85. Abdulai, S.F.; Nani, G.; Taiwo, R.; Antwi-Afari, P.; Zayed, T.; Sojobi, A.O. Modelling the relationship between circular economy barriers and drivers for sustainable construction industry. *Build. Environ.* **2024**, *254*, 111388. [CrossRef]
86. Zhang, C.; Hu, M.; Yang, X.; Miranda-Xicotencatl, B.; Sprecher, B.; Di Maio, F.; Zhong, X.; Tukker, A. Upgrading construction and demolition waste management from downcycling to recycling in the Netherlands. *J. Clean. Prod.* **2020**, *266*, 121718. [CrossRef]
87. Kardung, M.; Cingiz, K.; Costenoble, O.; Delahaye, R.; Heijman, W.; Lovrić, M.; van Leeuwen, M.; M'barek, R.; van Meijl, H.; Piotrowski, S.; et al. Development of the Circular Bioeconomy: Drivers and Indicators. *Sustainability* **2021**, *13*, 413. [CrossRef]
88. Ruiz, L.A.L.; Ramón, X.R.; Domingo, S.G. The circular economy in the construction and demolition waste sector–a review and an integrative model approach. *J. Clean. Prod.* **2020**, *248*, 119238. [CrossRef]
89. Debrah, C.; Chan, A.P.; Darko, A. Artificial intelligence in green building. *Autom. Constr.* **2022**, *137*, 104192. [CrossRef]
90. Adesi, M.; Ahiabu, M.; Owusu-Manu, D.; Boateng, F.; Kissi, E. Recyclability of Construction and Demolition Waste in Ghana: A Circular Economy Perspective. In *Applied Research Conference in Africa*; Springer International Publishing: Cham, Switzerland, 2022; pp. 106–120.
91. Brandão, R.; Edwards, D.J.; Melo, A.C.S.; Macedo, A.N. Reverse supply chain practices for construction and demolition waste in the Brazilian Amazon: A multi-stakeholder view. *J. Mater. Cycles Waste Manag.* **2023**, *25*, 2245–2261. [CrossRef]
92. Munaro, M.R.; Fischer, A.C.; Azevedo, N.C.; Tavares, S.F. Proposal of a building material passport and its application feasibility to the wood frame constructive system in Brazil. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 225, p. 012018.

93. Honic, M.; Kovacic, I.; Sibenik, G.; Rechberger, H. Data-and stakeholder management framework for the implementation of BIM-based Material Passports. *J. Build. Eng.* **2019**, *23*, 341–350. [CrossRef]
94. van Capelleveen, G.; Vegter, D.; Olthaar, M.; van Hillegersberg, J. The anatomy of a passport for the circular economy: A conceptual definition, vision and structured literature review. *Resour. Conserv. Recycl. Adv.* **2023**, *17*, 200131.
95. Guo, S.; Chen, L. Why is China struggling with waste classification? A stakeholder theory perspective. *Resour. Conserv. Recycl.* **2022**, *183*, 106312.
96. Maitre-Ekern, E. Re-thinking producer responsibility for a sustainable circular economy from extended producer responsibility to pre-market producer responsibility. *J. Clean. Prod.* **2021**, *286*, 125454. [CrossRef]
97. Salvador, R.; Barros, M.V.; Freire, F.; Halog, A.; Piekarski, C.M.; Antonio, C. Circular economy strategies on business modelling: Identifying the greatest influences. *J. Clean. Prod.* **2021**, *299*, 126918. [CrossRef]
98. Akanbi, L.A.; Oyedele, L.O.; Akinade, O.O.; Ajayi, A.O.; Delgado, M.D.; Bilal, M.; Bello, S.A. Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator. *Resour. Conserv. Recycl.* **2018**, *129*, 175–186. [CrossRef]
99. Guldmann, E.; Huulgaard, R.D. Barriers to circular business model innovation: A multiple-case study. *J. Clean. Prod.* **2020**, *243*, 118160. [CrossRef]
100. Serrano-Bedia, A.M.; Perez-Perez, M. Transition towards a circular economy: A review of the role of higher education as a key supporting stakeholder in Web of Science. *Sustain. Prod. Consum.* **2022**, *31*, 82–96. [CrossRef]
101. Wang, Y.; Zhu, Q.; Krikke, H.; Hazen, B. How product and process knowledge enable consumer switching to remanufactured laptop computers in circular economy. *Technol. Forecast. Soc. Chang.* **2020**, *161*, 120275. [CrossRef]
102. Bilal, M.; Khan, K.I.A.; Thaheem, M.J.; Nasir, A.R. Current state and barriers to the circular economy in the building sector: Towards a mitigation framework. *J. Clean. Prod.* **2020**, *276*, 123250. [CrossRef]
103. Jabbour, C.J.C.; Sarkis, J.; de Sousa Jabbour, A.B.L.; Renwick, D.W.S.; Singh, S.K.; Grebinevych, O.; Kruglianskas, I.; Godinho Filho, M. Who is in charge? A review and a research agenda on the 'human side'of the circular economy. *J. Clean. Prod.* **2019**, *222*, 793–801. [CrossRef]
104. Antwi-Afari, P.; Ng, S.T.; Hossain, M.U. A review of the circularity gap in the construction industry through scientometric analysis. *J. Clean. Prod.* **2021**, *298*, 126870. [CrossRef]
105. Whalen, K.A. Three circular business models that extend product value and their contribution to resource efficiency. *J. Clean. Prod.* **2019**, *226*, 1128–1137. [CrossRef]
106. Adabre, M.A.; Chan, A.P.; Wuni, I.Y. Modeling Sustainable Housing for Sustainable Development in Cities and Communities: The Perspective of a Developing Economy. In *Circular Economy for Buildings and Infrastructure: Principles, Practices and Future Directions*; Springer International Publishing: Cham, Switzerland, 2024; pp. 97–115.
107. Akomea-Frimpong, I.; Jin, X.; Osei Kyei, R.; Tetteh, P.A.; Tumpa, R.J.; Ofori, J.N.A.; Pariafsai, F. A review of circular economy models and success factors on public-private partnership infrastructure development. *Built Environ. Proj. Asset Manag.* **2024**, *14*, 109–126. [CrossRef]