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# Facilitating a transition to a circular economy in construction projects: intermediate theoretical models based on the theory of planned behaviour

Michael Atafo Adabre [a], Albert P. C. Chan [a], Amos Darko [a] and Mohammad Reza Hosseini [b]

[a]Building and Real Estate Department, Hong Kong Polytechnic University, Hong Kong, Hong Kong; [b]School of Architecture and Built Environment, Deakin University, Geelong, Australia

**ABSTRACT**

A transition to a circular economy (CE) is a sociotechnical phenomenon that relies on adopting innovative methods and technologies, as well as changes in behaviour across the construction supply chain. Although a lot of ground has been covered on developing methods and technologies, there is little research on stakeholders' change of behaviour. Informed by an underlying framework, the theory of planned behaviour, a comprehensive literature review discusses several conceptual models to establish the interrelationships between barriers and drivers to managing a transition to CE – and their underlying causes. The findings offer a comprehensive point of reference for identifying factors that affect CE adoption, and lay a solid foundation for future research into CE adoption and managing a CE transition where the intermediate theories presented can be validated through empirical research.

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Circular economy; sustainability transition; indicators; barriers; drivers; waste management

## Introduction

The construction industry consumes 30% of the world's raw materials, 12% of its land, 25% of its water resources, and 40% of its energy (Bilal et al., 2020). It also generates more than three billion tonnes of construction and demolition (C&D) waste annually (Akhtar & Sarmah, 2018). These challenges have stemmed policy evolutions towards sustainable development, which aims to realize economic, social and environmental goals (Adabre et al., 2022; Adabre & Chan, 2020; Adabre et al., 2020; Debrah et al., 2022; Chen et al., 2022); instead of focusing exclusively on a linear economy concept that emphasizes the production, distribution and consumption of resources without regard for their 'after consumption' period (Çimen, 2021). This approach sees most facilities demolished after their life span and new facilities constructed with virgin materials, thereby depleting resources and generating large volumes of waste. Cleaner production and enhanced linear concept models are much needed to address these issues.

Currently, cleaner production focuses on cost-effective strategies for environmental improvement, however, this approach could exclude or underestimate less cost-effective strategies that deliver superior environmental outcomes. Such criticisms have partly contributed to the evolution of industrial ecology, which integrates forecasting and backcasting approaches (Van Berkel et al., 1997). Industrial ecology adopts a systemic view of design and manufacturing stages to avoid or reduce environmental impacts attributed to a product's manufacture, use and disposal. An extension of industrial ecology is the cradle-to-cradle (C2C) concept that seeks to substitute wasteful or harmful toxic materials with natural materials that are decomposable or have an infinite life, however, the C2C concept is technically not justifiable as 100% efficiency in recycling to ensure materials' extended use cannot be guaranteed. Further, C2C is more focused on the technical aspects of sustainability and less so on the importance of users, communities, and other actors and dynamics in a sociotechnical system (Reike et al., 2018). The circular economy (CE) concept, relying on the basic principles of C2C for material circulation, reuse, recycling and remanufacturing in a closed-loop system for sociotechnical development, emerged to address these shortcomings (Ceschin & Gaziulusoy, 2016; Chauhan et al., 2021; El Haggar, 2007).

The CE concept is a continuous loop of resource use, reuse, repair and recycling (Akhimien et al., 2020; Antwi-Afari et al., 2021; Wang et al., 2018). In CE, waste is managed as a resource that is continually circulated within an economy (Elgie et al., 2021). CE considers the afterlife span of a product and is therefore superior to the linear economy concept, with Suárez-Eiroa et al. (2019) lauding CE as a better means to

**CONTACT** Amos Darko amos.darko@connect.polyu.hk

achieving sustainable development goals. Other studies recognize sustainable development as a subset of CE, arguing that CE offers benefits beyond sustainable development (Pomponi & Moncaster, 2017). The latter view considers CE as a goal, not a tool. Despite this disparity, there is consensus that CE is an effective strategy for waste control and management, and this emerging concept has been adopted in various fields, including construction (Tazi et al., 2021).

Due to a growing interest in its purported advantages, there has been a resurgence of publications on CE adoption. Some of these have focused on indicators for tracking progress on CE development (Akhimien et al., 2020; Parchomenko et al., 2019), while others have centred on barriers and risks (Donner et al., 2021; Tura et al., 2019) or on drivers (Gusmerotti et al., 2019; Pizzi et al., 2021). A review of the extant literature reveals that past research has almost entirely focused on technical aspects and technological advancement of CE. Nonetheless, as an innovation to the domain, CE co-evolves with sociopolitical dimensions influenced by stakeholders, including consumers, community or citizens, business entities, project supervisors (consultancy) and governments (Walker et al., 2021). Accordingly, studies (Prendeville et al., 2018; Sauermann et al., 2020) have concluded that CE transition is invariably of a sociotechnical nature – it involves new knowledge and technologies as well as changes in behaviours (Sauermann et al., 2020). Solely focusing on the technological aspects of a sociotechnical challenge is, therefore, unlikely to achieve effective CE transition (Ceschin & Gaziulusoy, 2016). Developing a model to drive effective behaviour change requires the integration of measures for assessing the extent of behaviour adoption as well as the behavioural controls – the attitudes and subjective norms/social pressures that influence behaviour adoption (Ajzen, 1991). An integrated model is missing from the available literature, exposing a knowledge gap that this research aims to address.

The study employs the theory of planned behaviour (TPB) as its underlying framework and a comprehensive literature review informs the development of a model to guide the adoption of – and transition to – CE. The model serves as the basis for establishing interrelationship between CE constructs (i.e. indicators, barriers and drivers) and their underlying factors. It is envisaged that the study findings will inspire policymakers and practitioners to promote CE adoption in the construction industry, and the model seeks to provide them with a checklist of various factors that could influence the adoption of CE to improve decision-making on resource allocation. Moreover, by establishing interrelationships between the indicators, barriers and drivers, the findings could provide a new lens that enables policymakers to see how these underlying factors are interrelated within the CE system and where change strategies should be implemented to drive CE promotion. Theoretically, the review findings contribute to the literature on CE by shifting attention from the sociotechnical-oriented discourse on CE adoption to a systems perspective of the transition journey. The new direction offered through this paper is novel to the field, providing fertile ground for future research on the topic.

## Theoretical basis and framework: TPB

There is broad consensus in the literature that CE transition is influenced by the behaviour of key stakeholders (Islam et al., 2021; Sauermann et al., 2020). This study relies on TPB as a suitable theoretical framework. Developed by Ajzen (1991), TBF forms the basis for establishing a conceptual model for CE. TPB asserts that undertaking a certain behaviour can be explained by three main constructs: personal attitude (What are the drivers for CE transition?); subjective norms (What are the societal impacts or influence on CE transition?) and perceived behavioural control (What are the barriers to CE transition?) (Ham et al., 2015). Personal attitude links the CE transition to specific outcomes or attributes (i.e. reduced depletion of natural resources, reduced $CO_2$ emissions, reduced C&D waste generation, longevity of construction materials, etc.). These attributes are known as indicators for assessing the level of CE development (Rincón-Moreno et al., 2021). With regard to the increasing level of C&D waste generation and changes in climatic conditions, the existing literature has assessed antecedent CE indicators as positive (Bilal et al., 2020) which means a transition to CE is globally considered urgent and desirable.

Subjective norm refers to the belief that an important person or group of people will approve and support a particular behaviour (Ham et al., 2015). Relating this to CE transition, subjective norms could be community or neighbourhood comments that persuade consumers of products or materials. The influence could be positive (i.e. drive consumers towards the adoption of CE) or negative (i.e. inhibit adoption of CE). A number of previous studies have revealed that the impact of subjective norm is weaker than attitude on behaviour adoption. It has been rationalized that consumers' attitude is partly influenced by their community or neighbourhood and consequently, most studies have been conducted with little regard to community influence. However, a study by Sauermann et al. (2020) on citizen science defended the importance of community engagement in any sustainability transition such as CE. The subjective norm can be categorized into two concepts: descriptive norms and social norms. Descriptive norms refer to real activities and behaviours that others are undertaking, while social norms refer to other people's perceptions of how an individual should behave (Ham et al., 2015). Thus, subjective norms include consumer perceptions of peer pressure from other citizens or groups of people (e.g. community or neighbourhood) that motivate them to act or behave (or not) in a certain manner (Ajzen, 1991). With regards to the degree of compliance, subjective norms could either be social norms or moral norms. Social norms demand conditional compliance from individuals and are prompted by expectations: (1) what individuals think others believe they ought to do or what they believe others expect from them (normative) and (2) what individuals have observed in the behaviour of others in similar situations (empirical). Comparatively, moral norms demand unconditional compliance from individuals and are prompted by an emotional response of disapproval for non-compliance (Miliute-Plepiene et al., 2016).

The perceived behavioural control refers to people's perception of the ease or difficulty of performing a particular behaviour (Ajzen, 1991), often reflecting experience in addition to anticipated impediments and obstacles. It includes the perception of one's own abilities and sense of control over a situation as a combination of locus of control (belief about the amount of control that a person has) and self-efficacy (perceived ability to perform a task) (Ham et al., 2015). As for transition to CE, perceived behavioural control could be influenced by factors such as risks or barriers which decrease the probability of – or hinder effective – CE transition. Together, these three constructs – attitude towards behaviour, subjective norms and perceived behavioural control – determine the intention and behaviour of key stakeholders towards CE transition. Therefore, in accordance with the TPB framework explored in the literature review, CE adoption is determined by intentions shaped by CE indicators, barriers and drivers delineated as 'perceived behavioural control', 'subjective norms' and 'attitude towards behaviour' (Figure 1). Factors on 'subjective norms' could be barriers or drivers, depending on their influence on CE.

## Research methods

### *Literature review process*

The review's purpose is to identify the indicators, potential barriers and drivers of CE to inform the development of a model to guide the adoption of – and transition to – CE. The literature search was limited to peer-reviewed articles written in English and published between 2006 and 2021. A study by Kristensen and Mosgaard (2020) confirmed that major publications on CE appeared after 2006. The search process focused on titles, abstracts and keywords within the Scopus and Web of Science (WoS) databases, and Google Scholar was deployed to complement this coverage. 'Circular economy' was the key search term used in the literature review process, together with other keywords, including 'criteria' or 'indicator', 'variables', 'measure', 'barriers', 'drivers', 'index', 'quantity' and 'parameter'.

### *Identifying CE indicators*

Indicators are qualitative or quantitative measures of a phenomenon (Parchomenko et al., 2019). Also referred to as criteria or metrics, they must be measurable, comparable, replicable, and responsive to fluctuations in the phenomenon's development. They can help policymakers and other stakeholders to understand and interpret results, reveal trade-offs between policy measures, and formulate clear policy targets (Kardung et al., 2021). Moreover, they are important for identifying drivers or enablers of CE (Parchomenko et al., 2019; Pacurariu et al., 2021). The literature review on CE indicators was conducted using the following search string: [ALL ('Circular economy' OR 'Circularity') AND ('Indicator' OR 'Indicators' OR 'Criteria' OR 'Measures')) AND DOCTYPE (ar) AND PUBYEAR > 2006 AND PUBYEAR < 2022 AND (LIMIT-TO (LANGUAGE, 'English'))]. On 4th August 2021, a total of 2980 articles – 1527 and 1453 respectively – were retrieved from Scopus and WoS. The papers were then combined and scrutinized manually to remove duplications and/or other materials that were not relevant to CE indicators. A total of 24 articles were identified as important and formed the basis of a literature review on CE indicators. A list of the indicators identified in the study is provided in Table 1. Some indicators could be integrated as a composite measure of the attributes of CE. Such a measure is called an index or primary indicator if expressed as a single score (Li et al., 2010). The indicators also could be integrated as composite or secondary indicators, i.e. the disaggregated components of composite indicators as shown in Table 1 (Kosajan et al., 2018; Papageorgiou et al., 2021).

### *Identifying barriers to CE*

CE development could be hampered by barriers or unfavourable behavioural controls (Urbinati et al.,

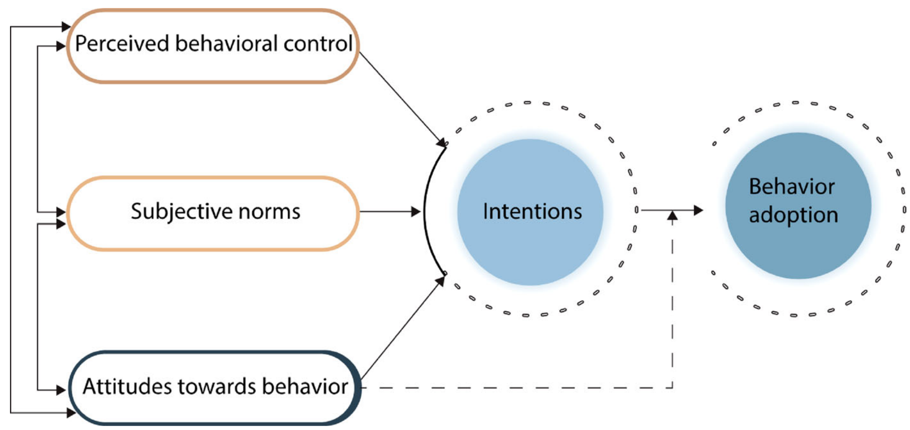


**Figure 1.** TPB on adoption of behaviour (Ajzen, 1991).

2021). Barriers prevent stakeholders from adopting practices or behaviours that support a shift towards CE. This could lead to low indicator performance scores, implying low-level progress on CE development. Recently published literature on CE barriers was identified using the following search string: [ALL ('circular economy' OR 'circularity') AND ('barriers' OR 'challenges' OR 'obstacles')) AND DOCTYPE (ar) AND PUBYEAR > 2006 AND PUBYEAR < 2022 AND (LIMIT-TO (LANGUAGE, 'English'))]. A search of Scopus and WoS on 4th August 2021 retrieved 2662 and 1674 articles respectively. The articles were manually controlled to remove repetitions and articles that were not focused predominantly on CE barriers. In total, 22 relevant articles were identified which formed the basis of a literature review on critical barriers to CE. A barrier to CE transition was deemed critical based on how frequently it appeared in the retrieved articles. Only barriers that occurred at least twice in a minimum of two manuscripts were considered potential critical barriers (Table 2).

## *Identifying CE drivers*

Existing literature calls on various names for positive reinforcement, namely 'promoters', 'enablers', 'motivators', 'enhancers', 'success factors' and 'levers' (Scipioni et al., 2021), however, in other studies, the general term 'drivers' is used (Haselsteiner et al., 2021; Smol et al., 2021). The various terms were used to source relevant articles that discussed the identification of potential critical drivers for CE transition. Publications were retrieved using the following search string: [ALL ('circular economy' OR 'circularity' AND ('drivers' OR 'success factors' OR 'enablers' OR 'promoters' OR 'motivations' OR 'enhancers' OR 'levers')) AND DOCTYPE (ar) AND PUBYEAR > 2006 AND PUBYEAR < 2022 AND (LIMIT-TO (LANGUAGE, 'English'))]. A total of 1903 and 458 articles respectively were retrieved from Scopus and WoS on 4th August 2021. The articles were then combined and scrutinized to remove repetitious articles and/or others that were not focused on CE drivers. The remaining 32 articles formed the basis of a literature review, and a driver's importance for CE transition was assessed on how frequently it appeared in the journal articles. Only drivers that occurred at least twice in two or more manuscripts were considered as potential critical drivers (Table 3).

## *A model for CE transition*

The model illustrated in Figure 2 captures the interrelationships between various stakeholders and their influence on resource use for CE. Many studies on CE are focused on government and industry (i.e. the business entities) because legislative and government bodies are currently the main actors driving CE development (Kalmykova et al., 2018). Similarly, Prendeville et al. (2018, p. 172) observed that the literature, to date, is dominated by a business-focused narrative, 'raising questions about the placement of CE within a broader urban sustainability agenda'. As clearly stated by Kalmykova et al. (2018, p. 188) 'while the role of citizens and communities is revered, there appears to be mismatch in how these stakeholders are included in building a circular city'. Consequently, the autonomy of users and communities or citizens has been eroded in CE and this could adversely affect the intended outcome of a CE transition. CE can only be attained if different stakeholders work together towards their common goals (indicators Table 1) (Wijkman, 2019). This requires effective governance with an inclusive mindset of working consumers, communities and solution providers

**Table 1.** CE indicators.

| Primary indicators | Secondary indicators | Direction of indicators for CE | References/sources |
|---|---|---|---|
| Longevity of CE products | Recycling efficiency rate | Positive | Parchomenko et al. (2019); Kristensen and Mosgaard (2020) |
| | Residence time/lifetime extension | Positive | Parchomenko et al. (2019); Rincón-Moreno et al. (2021) |
| | Refurbishment rate | Positive | Franklin-Johnson et al. (2016); Kristensen and Mosgaard (2020) |
| | Product, components and material retention rate | Positive | Parchomenko et al. (2019); Cottafava and Ritzen (2021) |
| Modularity | Upgradability | Positive | Finch et al. (2021); del Mar Alonso-Almeida et al. (2021); Wuni and Shen (2022) |
| | Adaptability | Positive | Suárez-Eiroa et al. (2019); Finch et al. (2021) |
| | Disassembly efficiency/designed for material recovery | Positive | Kristensen and Mosgaard (2020); Kardung et al. (2021); Cottafava and Ritzen (2021) |
| | Designed for building flexibility | Positive | Akhimien et al. (2020); Cottafava and Ritzen (2021) |
| Functional independence | Designed for attachment and trust | Positive | Mesa et al. (2018); Suárez-Eiroa et al. (2019) |
| or functional variety | Upgradability | Positive | Suárez-Eiroa et al. (2019); Finch et al. (2021) |
| | Adaptability | Positive | Mesa et al. (2018); Finch et al. (2021) |
| | Servitization (i.e. product service system) | Positive | Kristensen and Mosgaard (2020); Zhang et al. (2020) |
| Cascading resource use | Highest utility and value (i.e. up-cycling) | Positive | Ellen MacArthur Foundation (2012); Mair and Stern (2017) |
| | Resource reusability or resource-efficiency | Positive | Akhimien et al. (2020); Kristensen and Mosgaard (2020) |
| | Resource productivity or process efficiency | Positive | Parchomenko et al. (2019); Cottafava and Ritzen (2021) |
| | Repairability (availability of repair manuals or spare parts or product designed for maintenance) | Positive | Kristensen and Mosgaard (2020); del Mar Alonso-Almeida et al. (2021) |
| | Recovery rate of waste (i.e. for energy) | Positive | Kristensen and Mosgaard (2020); Rincón-Moreno et al. (2021) |
| | Recyclability | Positive | The Ellen MacArthur Foundation (2012); Mair and Stern (2017) |
| | Remanufacture | Positive | The Ellen MacArthur Foundation (2012); Mair and Stern (2017) |
| | Disposal | Negative | The Ellen MacArthur Foundation (2012); Mair and Stern (2017) |
| Regenerative design | Energy efficiency | Positive | Kalmykova et al. (2018); Gusmerotti et al. (2019) |
| | Design for material reuse/durability (reusability or resource-efficiency) | Positive | Akhimien et al. (2020); Rincón-Moreno et al. (2021); Cottafava and Ritzen (2021) |
| | Adaptability | Positive | Cole et al. (2013); Suárez-Eiroa et al. (2019) |
| | Co-evolution | Positive | Cole et al. (2013); Suárez-Eiroa et al. (2019) |
| | Co-creation and co-production (i.e. participatory design) | Positive | Prendeville et al. (2018); Salmenperä et al. (2021) |
| Eco-efficiency | Recycled material value/resale value | Positive | Akhimien et al. (2020); Finch et al. (2021) |
| | End-of-life management/end-of-life recycling input rates | Negative | Kristensen and Mosgaard (2020); Rincón-Moreno et al. (2021) |
| | Residence time/lifetime extension | Positive | Parchomenko et al. (2019); Rincón-Moreno et al. (2021) |
| | Additional process/resource input | Negative | Parchomenko et al. (2019); Kristensen and Mosgaard (2020) |
| | Recyclability/re-manufacturable | Positive | Akhimien et al. (2020); del Mar Alonso-Almeida et al. (2021) |
| | Waste generation rate | Negative | Parchomenko et al. (2019); Kristensen and Mosgaard (2020) |
| | Emissions to air | Negative | Allwood et al. (2011) |
| | Emissions to water | Negative | Allwood et al. (2011) |
| | Servitization (i.e. product service system) | Positive | Kristensen and Mosgaard (2020); Zhang et al. (2020) |
| | Energy efficiency | Positive | Reike et al. (2018); Gusmerotti et al. (2019) |
| Eco-design | Designed for energy efficiency | Positive | Kalmykova et al. (2018); Gusmerotti et al. (2019) |
| | Designed for minimum resource input | Negative | Knight and Jenkins (2009) |
| | Designed for emissions minimization | Negative | Knight and Jenkins (2009) |
| | Designed for minimum waste generation | Negative | Parchomenko et al. (2019); Kristensen and Mosgaard (2020) |
| | Designed for minimum use of hazardous materials | Negative | Knight and Jenkins (2009) |
| | Designed for upgrade | Positive | Suárez-Eiroa et al. (2019); Finch et al. (2021) |
| | Designed for recovery (i.e. material or components) | Positive | Kristensen and Mosgaard (2020); Kardung et al. (2021) |
| | Designed for disassembly | Positive | Knight and Jenkins (2009) |
| | Designed for waste recovery | Positive | |

(*Continued*)

**Table 1.** Continued.

| Primary indicators | Secondary indicators | Direction of indicators for CE | References/sources |
|---|---|---|---|
| | | | Kristensen and Mosgaard (2020); Rincón-Moreno et al. (2021) |
| | Designed for recycling | Positive | Knight and Jenkins (2009) |
| Cleaner production | Waste generation rate | Negative | Parchomenko et al. (2019); Kristensen and Mosgaard (2020) |
| | Emissions to air | Negative | Allwood et al. (2011) |
| | Emissions to water | Negative | Allwood et al. (2011) |
| | Resource input reduction | Negative | Reike et al. (2018) |
| Material efficiency | Upgradability | Positive | Allwood et al. (2011); Finch et al. (2021) |
| | Repairability | Positive | Allwood et al. (2011); Kristensen and Mosgaard (2020) |
| | Re-sale | Positive | Akhimien et al. (2020); Finch et al. (2021) |
| | Light-weighting | Positive | Allwood et al. (2011); Parchomenko et al. (2019) |
| | Material/product replacement | Negative | Allwood et al. (2011); Parchomenko et al. (2019) |
| | Remanufacture | Positive | Moraga et al. (2019); Kalmykova et al. (2018) |
| | Reusability | Positive | Allwood et al. (2011); Rincón-Moreno et al. (2021) |
| | Lifetime extension/design for longer life | Positive | Allwood et al. (2011); Franklin-Johnson et al. (2016) |
| | Use-for-longer | Positive | Allwood et al. (2011); Parchomenko et al. (2019) |
| | More intense use | Positive | Allwood et al. (2011); Parchomenko et al. (2019) |
| | Dematerialization (i.e. material reduction) | Negative | Allwood et al. (2011); Reike et al. (2018) |
| | Material/product design differentiations (as opposed to standardization) | Negative | Allwood et al. (2011) |

(i.e. experts and business entities). Different frameworks have been established to enhance this systemic approach to CE. These frameworks include resource flow analysis, doughnut economics and user-driven circularity. Resource flow analysis identifies the resources that flow in and out of a system, from their origin to their final destination (Wijkman, 2019).

Doughnut economics establishes a framework for delivering life's essential needs without exceeding the ecological limit of the planet (Raworth, 2017) by engaging multiple stakeholders such as governments, businesses and experts, albeit with limited attention on users or potential customers (Wijkman, 2019). Building on this gap, the user-driven circularity framework begins with users as its main focus to influence behaviour in a system, since users are the customers and consumers of products and services. Based on the previous frameworks outlined and prior study undertaken by Velenturf et al. (2019), a model is developed (Figure 2) to establish interrelationships between the categories of barriers and drivers identified during the literature review.

The model begins with the community or society as the broadest stakeholder group in a CE transition. The community's or public's needs and values provide direction for government policies which could be achieved and enhanced through community engagement at the onset of a project or program. Policies can then be formulated and translated into solutions through research and concept design by the solution providers (project experts and contractors/business entities). The concept designs can be refined and validated through users' engagement (via co-production and co-design). This approach will ensure that circular products are first accepted by the community and then by the users. The community, through social norms, could positively influence users or consumers on the acceptance of CE products. As shown in Figure 2, the model moves beyond the consumer being treated as a user of CE products to a broader category of stakeholders, such as the community or citizens, due to the impact of subjective norms (i.e. descriptive norms, social norms and moral norms as discussed on TPB) on a CE transition (Sauermann et al., 2020; Witjes & Lozano, 2016). The direction of the arrow line from the community to consumers depicts the influence of subjective norms from the community on consumers concerning the adoption CE practices. In this model, two complementary interventions for CE have been deployed, namely the bottom-up and top-down interventions. The bottom-up entails a network of business entities, consumers and communities (or citizens) who devise effective solutions for CE while the top-down intervention encompasses policymakers (e.g. governments and consultants or experts) who stimulate bottom-up networks through research and development policies (Prendeville et al., 2018).

Stakeholders make up and control the production-consumption system, which also is embedded in the broader biophysical environment. The biophysical environment may not be controlled by humans, but it can be influenced by human activities related to waste generation and emission (Velenturf et al., 2019). Different stakeholders can influence resource utilization as follows: (a) the government controls the use of resources

**Table 2.** Potential critical barriers to CE transition.

| Barrier categories | Underlying barriers | Code | References/sources |
|---|---|---|---|
| Institutional and regulatory barriers | Inadequate resources for CE at the municipalities/regional level | B01 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Lax waste legislation enforcement | B02 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Lock-ins created by earlier solutions such as investments in waste incineration | B03 | Mahpour (2018); Salmenperä et al. (2021) |
| | Lack of circular requirements in public procurement | B04 | Mahpour (2018); Salmenperä et al. (2021) |
| | Secondary materials markets lack support from government | B05 | Bilal et al. (2020); Salmenperä et al. (2021) |
| | Lack of environmental regulations and laws | B06 | Prendeville et al. (2018); Salmenperä et al. (2021) |
| | Lack of accreditation or certifications on secondary materials/ products | B07 | Ranta et al. (2018); Mahpour (2018) |
| | Lack of knowledge on CE among political decision-makers | B08 | Prendeville et al. (2018); Salmenperä et al. (2021) |
| | Variations in regulations among different regions | B09 | Ranta et al. (2018); Tura et al. (2019) |
| | Old practices, e.g. in raw material procurement in the C&D sector | B10 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Lack of national regulation for CE | B11 | Ranta et al. (2018); Fernando (2019) |
| Project-level barriers | Virgin materials are cheap compared to recycled materials (linear lock-in) | B12 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Lack of circularity in product design | B13 | Mahpour (2018); Salmenperä et al. (2021) |
| | Inadequate indicators for holistically assessing CE (i.e. economic and social benefits) | B14 | Prendeville et al. (2018); Sauermann et al. (2020) |
| | Lack of knowledge and information on material quality | B15 | Moktadir et al. (2018); Campbell-Johnston et al. (2019) |
| | Low return on products' quality/variation in output quality due to process | B16 | Ethirajan et al. (2021); Donner et al. (2021) |
| | Variability in product performance | B17 | Ranta et al. (2018); Prendeville et al. (2018) |
| | Lack of knowledge and technical skills on CE | B18 | Mahpour (2018); Campbell-Johnston et al. (2019) |
| Business-level barriers | Lack of tools and methods for assessing (long-term) benefits of CE | B20 | Prendeville et al. (2018); Salmenperä et al. (2021) |
| | Inefficiencies of logistics in waste collection | B21 | Hosseini et al. (2015); Charef and Emmitt (2021) |
| | Lower cost of incineration than recycling strategies | B22 | Mahpour (2018); Salmenperä et al. (2021) |
| | Inadequate processors/refiners of waste-based materials | B23 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Lack of collaboration or network support among business entities | B24 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Inclination to manage cost and time rather than C&D waste | B25 | Mahpour (2018); Salmenperä et al. (2021) |
| | High investment cost and time needed to break even | B26 | Tura et al. (2019); Urbinati et al. (2021) |
| | Rapid changes in market | B27 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Dysfunctional markets for recyclables | B28 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Business secrecy hindrances to collaboration or data exchange | B29 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Business competition in developing new waste-based products | B30 | Prendeville et al. (2018); Salmenperä et al. (2021) |
| | Difficulties in finding finance for start-ups | B31 | Tura et al. (2019); Campbell-Johnston et al. (2019) |
| | Lack of incentives for CE | B32 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Conservative construction industry/high organizational inertia | B33 | Tura et al. (2019); Salmenperä et al. (2021) |
| | New concept fatigue/silo thinking and fear of risks (risk aversion) | B34 | Mahpour (2018); Salmenperä et al. (2021) |
| | Strong industrial focus on linear models (ingrained linear mindset) | B35 | Campbell-Johnston et al. (2019); Urbinati et al. (2021) |
| | Lack of data accessibility on waste | B36 | Prendeville et al. (2018); Charef et al. (2021) |
| | Uncertainty in material resale value | B37 | Ethirajan et al. (2021); Charef et al. (2021) |
| | Uncertainty after implementing CD waste management | B38 | Ethirajan et al. (2021); Donner et al. (2021) |
| | Lack of waste advisory activities to integrate CE practices and business models | B39 | Campbell-Johnston et al. (2019); Salmenperä et al. (2021) |
| | Inadequate digitization tools for forecasting consumer behaviour | B40 | Salmenperä et al. (2021); Donner et al. (2021) |
| Community-level barriers | Lack of public awareness | B41 | Mahpour (2018); Bilal et al. (2020) |
| | Limited large scale pilot study on technology for awareness | B42 | Charef et al. (2021); Prendeville et al. (2018) |
| | Poor environmental perceptions or beliefs | B43 | Siringo et al. (2020); Charef et al. (2021) |
| | Negative social or peer pressure | B44 | Siringo et al. (2020); Charef et al. (2021) |
| | Limited participation of communities in CE products | B45 | Sauermann et al. (2020); Velenturf and Purnell (2021) |
| | Lack of public support for strengthening recycling markets | B45 | Tura et al. (2019); Salmenperä et al. (2021) |
| Consumer-level barriers | Customers' preference for new construction materials | B46 | Charef and Emmitt (2021); Salmenperä et al. (2021) |
| | High required customization | B47 | Mahpour (2018); Urbinati et al. (2021) |
| | Lack of customer awareness | B48 | Tura et al. (2019); Bilal et al. (2020) |
| | Consumers' hesitancy regarding new kinds of product (i.e. reuse products) | B49 | Charef and Emmitt (2021); Ethirajan et al. (2021) |
| | Lack of spare parts for repairs and maintenance among consumers | B50 | Kalmykova et al. (2018); del Mar Alonso-Almeida et al. (2021) |
| | Limited participation of consumers in CE products | B51 | Sauermann et al. (2020); Velenturf and Purnell (2021) |
| | Inconvenience of waste storage for recycle planning among consumers | B52 | Mahpour (2018); Salmenperä et al. (2021) |
| | Consumers' perception of CE products as a trade-off for price/ performance | B53 | Ranta et al. (2018); Charef and Emmitt (2021) |

through policies [(1) in Figure 2]; (b) consultancy and business entities oversee 'take-make', i.e. design and construction resource use decisions [delineated as (2) and (3)]; and resource use-storage-disposal is undertaken by consumers and the community but controlled by governments through legislation and regulations.[-delineated as (4), (5) and (6)]. Materials and resources that are unsuitable for production and consumption move into the biophysical environment and are recycled, while materials or resources that legislation and regulations deem suitable for production and consumption are reused, rather than discarded under a traditional linear economy (Kalmykova et al., 2018). Therefore governments make decisions concerning use, reuse, recycling and disposal to 'balance' resource inputs and outputs (Franklin-Johnson et al., 2016). For CE, resources in the production-consumption system keep circulating at a high rate and do not enter the biophysical environment unless they are biological nutrients (Kalmykova et al., 2018).

Although CE seeks to eliminate waste, it is worth noting that a 100% circular process is impossible to achieve because leakages (Corona et al., 2019) indicate waste is generated during the CE production and consumption process. These leakages refer to material losses due to challenges in attaining optimum resource use. Waste generated by production is either recycled or reused as raw materials for subsequent production. Likewise, any end-of-life waste is either reused or recycled in accordance with government rules and regulations.

## Discussion of findings: various categories

### *Indicators of CE*

Indicators are measures that provide scores on the level of circularity of a product or component or building facility. The literature review discovered multiple lists of indicators (Table 1) that could be used to measure CE. In prior studies, these were categorized into subgroups using different classification criteria. For example, using the burden- or value-criterion, Figge and Hahn (2004) classified indicators based on their impact on shaping behaviour or tracking performance. Furthermore, Heisel and Rau-Oberhuber (2020) asserted that indicators could be classified to assess CE development during the construction phase (goal: 100% secondary material resources), the use phase (goal: functional lifespan longer than average lifespan) and the end-of-life phase (goal: 100% recoverable content). More broadly, Saidani et al. (2019) established 10 categories of CE indicators that employed various criteria including 'level of implementation (i.e. micro, meso and macro), CE loop (i.e. maintain, reuse, remanufacture, recycle), performance (intrinsic, impacts), perspectives of circularity (actual, potential) that are taken into account, or their degree of transversality (generic, sector-specific)'. Franklin-Johnson et al. (2016) established a longevity metric for assessing the impact of corporate entities on CE. Three secondary indicators were used to measure longevity, namely recycling efficiency rate, residence time/lifetime extension and refurbishment rate (Table 1). Furthermore, secondary indicators such as recycled material value/resale value; recyclability/re-manufacturable; resource productivity or process efficiency; energy efficiency; additional process input; and end-of-life management are essential for evaluating the economic viability of reused products. Environmental impacts relative to the economic activities of business entities can be evaluated using primary indicators including eco-efficiency, eco-design, cleaner production and material efficiency, however, indicators for evaluating the performance of other actors (i.e. governments, consultants, users and communities) have not been adequately explored in prior studies.

In assessing the contribution of users and the community to CE, it is essential to rely on indicators that measure satisfaction levels with regard to CE products. Corporate entities could therefore be informed about the performance of their products, which could serve as feedback for performance improvement. Indicators for assessing progress in CE transition among users and communities could include modularity (i.e. upgradability, adaptability); functional independence (i.e. attachment and trust in CE product, upgradability and adaptability, servitization); cascading resource use (i.e. repairability, highest utility and value); and material efficiency (i.e. repairability, resale, remanufacture, reusability, more intense use). Some indicators could oppose one another and CE development, for example, the indicator 'material or product replacement' opposes desirable CE indicators such as 'attachment and trust in CE product', 'use-for-longer' and 'more intense use'.

Notwithstanding the extensive studies on CE indicators, other key indicators have not received much attention in the literature, among them social indicators such as CE product aesthetics; CE product quality; employment generated by CE activities, and community/citizen satisfaction attributable to circularity promotion (Corona et al., 2019). Some of the less discussed indicators are economic measures, viz price affordability of recycled products/secondary products; consumer expenditure on repairs and maintenance of products; and replacement rate of products or components (Bressanelli et al., 2021; Çimen, 2021). Most

**Table 3.** Potential critical drivers for CE transition.

| Drivers categories | Underlying drivers | Code | References/sources |
|---|---|---|---|
| Institutional & regulatory Drivers | Availability and access to new technologies (digital platforms) and innovations | D01 | Tura et al. (2019); Bressanelli et al. (2021) |
| | Taxations on virgin input resources | D02 | Tura et al. (2019); Kardung et al. (2021) |
| | Revenue via penalties on non-compliance to enable municipalities | D03 | Kalmykova et al. (2018); Bilal et al. (2020) |
| | Penalties on non-compliance and incentives for compliance | D04 | Tura et al. (2019); Bilal et al. (2020) |
| | Availability of funds and budgets for local self-government on CE | D05 | Bilal et al. (2020); Ilić and Nikolić (2016) |
| | Partnerships with public authorities to help innovative businesses overcome potential legal obstacles to innovation | D06 | Ilić and Nikolić (2016); del Mar Alonso-Almeida et al. (2021) |
| | Government support via tax credit and duty relaxation for CE products | D07 | Kardung et al. (2021); Urbinati et al. (2021) |
| | Government support funds for start-ups | D08 | Tura et al. (2019); Urbinati et al. (2021) |
| | Waste legislation on source-separation | D09 | Gusmerotti et al. (2019); Kardung et al. (2021) |
| | National legislation and policy on CE | D10 | Kardung et al. (2021); Cottafava and Ritzen (2021) |
| | Support for market penetration of innovative projects through labelling, awards, certification and standards | D11 | Ranta et al. (2018); del Mar Alonso-Almeida et al. (2021) |
| | Ensuring landfill restrictions including landfill taxes | D12 | Miliute-Plepiene et al. (2016); Ranta et al. (2018) |
| | Including CE requirements in public procurement and internal CE audits | D13 | Zhang et al. (2020); Salmenperä et al. (2021) |
| | Promoting reuse and repair centres, and tax breaks for shops | D14 | Kalmykova et al. (2018); del Mar Alonso-Almeida et al. (2021) |
| | Harmonization and interpretation of regulations | D15 | Kalmykova et al. (2018); Salmenperä et al. (2021) |
| | Committed political leadership and vision for CE | D16 | Prendeville et al. (2018); Velenturf and Purnell (2021) |
| | Circular permit | D17 | Campbell-Johnston et al. (2019); Zhang et al. (2020) |
| | Enforcing compliance with legal requirements on CE | D14 | Ranta et al. (2018); Bilal et al. (2020) |
| Project-level drivers | Technical assistance for CE projects | D13 | del Mar Alonso-Almeida et al. (2021); Kardung et al. (2021) |
| | R&D (research includes proof of concept, experiments and pilot scales) | D15 | Kardung et al. (2021); del Mar Alonso-Almeida et al. (2021) |
| | Promotion of skills development/expertise relevant to CE | D16 | Tura et al. (2019); del Mar Alonso-Almeida et al. (2021) |
| | Promotion of deconstructed design processes and competencies | D17 | Heisel and Rau-Oberhuber (2020); Cottafava and Ritzen (2021) |
| | Illustration of the economic benefits of CE | D18 | Heisel and Rau-Oberhuber (2020); Salmenperä et al. (2021) |
| | Increased dialogue and cooperation among key players | D19 | Kalmykova et al. (2018); Salmenperä et al. (2021) |
| | Addressing technical and social aspects of CE | D20 | Sauermann et al. (2020); Bressanelli et al. (2021) |
| | Increased information sharing on $CO_2$ saving and financial savings attributed to CE (circular design and circular material choices) | D21 | Tura et al. (2019); Heisel and Rau-Oberhuber (2020) |
| | Promotion of experimental approaches to CE (i.e. living lab or circular centres) | D22 | Prendeville et al. (2018); Velenturf and Purnell (2021) |
| | Effective monitoring of CE implementation | D23 | Campbell-Johnston et al. (2019); Bilal et al. (2020) |
| | Improved management of environmental awareness/public education on CE | D24 | Bilal et al. (2020); Urbinati et al. (2021) |
| Business-level drivers | Potential for reducing resource constraints and prevention of adverse environmental impact | D25 | Tura et al. (2019); Kardung et al. (2021) |
| | Potential for increasing efficiency by reducing costs and enhancing profit | D26 | Gusmerotti et al. (2019); Tura et al. (2019) |
| | Potential for improving corporate image | D27 | Gusmerotti et al. (2019); Tura et al. (2019) |
| | Prospect of acquiring a competitive advantage | D28 | Gusmerotti et al. (2019); Salmenperä et al. (2021) |
| | Potential for reducing company dependence on raw materials | D29 | Gusmerotti et al. (2019); Tura et al. (2019) |
| | Potential for reducing environmental impact of companies (environmental protection) | D30 | Gusmerotti et al. (2019); Tura et al. (2019) |
| | Enhanced information availability on waste-related data | D31 | Kalmykova et al. (2018); Salmenperä et al. (2021) |
| | Potential for reducing price volatility and resource scarcity effects on companies | D32 | Salmenperä et al. (2021); Urbinati et al. (2021) |
| | Prospect of new business and opportunities | D33 | Salmenperä et al. (2021); Blasi et al. (2021) |
| | Promoting servitized business models (providing function instead of product) | D34 | Zhang et al. (2020); Bressanelli et al. (2021) |
| | Promotion of reverse logistics in traditional supply chains | D35 | Tura et al. (2019); Bressanelli et al. (2021) |
| | Collaboration and information sharing among business entities | D36 | Kalmykova et al. (2018); Tura et al. (2019) |
| | Integration of circularity into business strategy and goals | D37 | Tura et al. (2019); Campbell-Johnston et al. (2019) |
| | Prospect of differentiating and improving business brand | D38 | Ranta et al. (2018); Tura et al. (2019) |
| | Extended responsibility of producer on CE | D39 | Miliute-Plepiene et al. (2016); Ranta et al. (2018) |
| Community-level drivers | Public awareness generation | D41 | Ilić and Nikolić (2016); Bilal et al. (2020) |
| | Positive mindset on CE products by providing positive examples | D42 | Prendeville et al. (2018); Salmenperä et al. (2021) |
| | Co-creation of CE products with community (engaging with diverse stakeholders) | D43 | Kalmykova et al. (2018); Prendeville et al. (2018) |
| | Positive social or peer pressure (social norms) | D44 | Siringo et al. (2020); Salmenperä et al. (2021) |
| | Strong environmental beliefs | D45 | Siringo et al. (2020); Salmenperä et al. (2021) |
| | Moral norms | D46 | Siringo et al. (2020); Salmenperä et al. (2021) |

(*Continued*)

**Table 3.** Continued.

| Drivers categories | Underlying drivers | Code | References/sources |
|---|---|---|---|
| Consumer-level drivers | Socio-demographic factors (i.e. age, gender, educational level and monthly income influence user's desire to return waste product) | D48 | Botelho et al. (2016); Kardung et al. (2021) |
| | Subsidies on CE products or materials | D49 | Tura et al. (2019); Salmenperä et al. (2021) |
| | Consumer awareness creation | D52 | Ilić and Nikolić (2016); Bilal et al. (2020) |
| | Development of contextual knowledge on resource use | D53 | Prendeville et al. (2018); Velenturf and Purnell (2021) |
| | Development of circular household waste plan | D54 | Prendeville et al. (2018); Velenturf and Purnell (2021) |
| | Availability of information on product maintenance and repairs (repair manuals) | D55 | Kalmykova et al. (2018); del Mar Alonso-Almeida et al. (2021) |

of the CE indicators discussed in the literature are therefore focused on environmental impact assessment.

Indicators for measuring the contribution of consultants or experts to CE could be evaluated by various design criteria (Allwood et al., 2011). Relevant primary and secondary indicators could include modularity (i.e. design for material recovery or disassembly efficiency, design for building flexibility); functional independence (i.e. design for attachment and trust); regenerative design (i.e. energy-efficient design, design for material reuse, co-evolution, participatory designs); material efficiency (i.e. design for longer life, dematerialization, design for remanufacture and standardization in design); and eco-design (i.e. design for energy efficiency, design for material recovery and recycling). Although circular products are designed for repetitive use, it is worth noting that such products could be discarded if they are perceived as obsolescent, i.e. if they do not satisfy consumers' desire for fashionable products or social status emulation, or meet their ephemeral needs (Ceschin & Gaziulusoy, 2016). Participatory design through co-production and co-design with users, and adaptive designs for co-evolution, are essential to ensure 'emotionally durable design' and 'design for user-

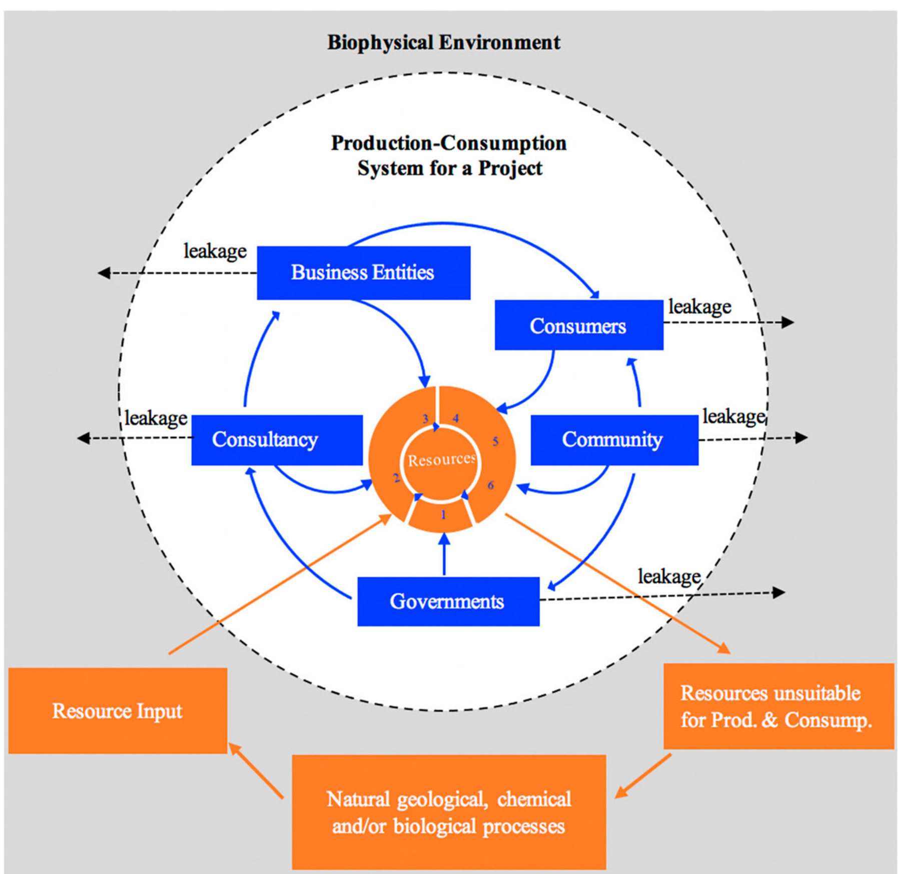


**Figure 2.** Model for CE transition (interrelationship and influence of various stakeholders on resource utilization for CE), adapted from Velenturf et al. (2019). *Note 1 – decision making on use, reuse, recycle (governed by rules and regulations); 2–3 – take-make (i.e. design and construction); 4–5–6 – use-store-dispose.

product attachment'. Design for user-product attachment could also lead to 'design for sustainable behaviour' among consumers because this encourages behaviour that ensures circularity. Culture and consumer values also are pivotal in user-product attachment designs. Contextual product designs are desideratum in CE transition (Ceschin & Gaziulusoy, 2016).

### Barriers to CE transition

The review findings on CE barriers (Table 2) exposed the 'behavioural controls' that could hinder circular behaviour. Barriers sourced from inefficiencies or inadequate regulations, grouped under *institutional and regulatory barriers*, could be managed appropriately by governments; barriers that could adversely influence project experts to shy away from adoption of circular behaviour and practices are referred to as *project-level barriers*; those that influence the community (citizens) and users are respectively labelled *community-level barriers* and *consumer-level barriers*; and barriers that influence business entities are classified as *business-level barriers*.

'Institutional and regulatory barriers' (Table 2 and Figure 3) could hinder CE adoption by local and regional governments, and national and international agencies (Ghisellini & Ulgiati, 2020). 'Lack of circular requirements in public procurement' and 'old practices in raw material procurement' are barriers to the procurement process, with most criteria for procurement of goods and services still related to criteria typical of a linear economy. Criteria on the reduction and recovery of C&D waste are often inadequate or lacking at the preparatory stages of the procurement process, as are criteria for addressing the use of circular products or secondary materials. Even where these criteria are available, they are mostly ambiguous in terms of minimum requirements for circular products or secondary materials (Zhang et al., 2020). Procurement-related barriers, coupled with 'low price of virgin materials or products', have partly contributed to 'inadequate support for [the] recycling market'. Inadequate financial support/incentives from the governments for start-ups' and 'low resources in municipalities' are monetary barriers that further hinder government contributions to CE and could likely be attributed to financial burdens on government budgets. 'Less stringent waste legislations' also have culminated in high organizational inertia at the corporate level. For instance, although waste sorting is a step towards effective recycling, Poon et al. (2013) revealed that 'legislations requiring on-site sorting of C&D waste backed by charges' did not yield any change in behaviour among construction companies, which still prefer to pay C&D waste disposal charges to comply with on-site sorting requirements. This organizational inertia can be attributed to governments' non-responsiveness to 'inadequate space for waste storage and recycling plan[s]', 'inadequate C&D waste management' and 'lock-in created by investment in earlier linear solutions'. Therefore, 'institutional and regulatory barriers' constrain the choices of other stakeholders towards achieving circular behaviour for sustainable CE (Velenturf & Purnell, 2021).

'Consumer-level barriers' are the behavioural controls that could negatively influence user adoption of CE. Most 'consumer-level barriers' can be attributed to a lack of consumer participation in CE research and co-production in CE products (Velenturf & Purnell, 2021). As a socio-technical sustainability strategy, CE entails social and policy structure, as well as scientific knowledge and innovation (Sauermann et al., 2020), yet most scientific inquiries have focused on technical aspects with disregard for social dimensions. Consumer views on CE products are mostly neglected in designing products for circularity (Sauermann et al., 2020). As a result, barriers such as 'lack of awareness on CE' and 'lack of knowledge on material quality' have been identified in most studies (Allwood et al., 2011; Ranta et al., 2018). Such unmanaged barriers could bring about others: 'lack of contextual knowledge on circular products', 'consumer hesitancy on new kinds of product (i.e. reuse products)' and 'consumer perceptions of CE products as a trade-off for performance'. Consequently, circular products including recycled products may be treated as inferior goods on quality (Allwood et al., 2011).

'Business-level barriers' restrict suppliers (i.e. principal contractors, trade contractors, and material or product contractors/suppliers) from contributing to CE development. Most corporate barriers are CE market uncertainties which often create high organizational reluctance to embrace a CE transition (Mansikkasalo et al., 2014). An organization that intends to enter the CE market for recycling C&D waste faces many uncertainties, viz 'potential competition with existing companies'; 'possibility of low demand for recycled products'; 'volatility of consumer behaviour on replacing recycled products with fashionable products'; 'intermittent supply of C&D waste as input for new products'; and 'unavailability of expertise on C&D waste recycling'.

Furthermore, on disposing C&D waste, Poon et al. (2013) stated that most contractors do not comply with onsite sorting despite the associated charges. 'Tight schedules in business' and 'cheaper incineration than on-site sorting' were identified as some of the reasons for contractors' conservative attitude towards C&D waste management (Hossain et al., 2017). Sharing of information and knowledge on the development of new CE solutions also is rare due to competition between companies and patents on intellectual property. This affects industrial symbiosis as business entities cannot trade waste resources between themselves without effective collaboration.

'Project-level barriers' obstruct CE adoption among project experts. Professionals at the project level are mostly concerned with project management and realizing project goals (i.e. completion within a stipulated time, cost and quality standard). Therefore, anything that could be counterproductive to achieving these objectives is unlikely to be adopted. Key underlying barriers in the project-level category include 'virgin materials are cheap compared to recycled materials (linear lock-in)'; 'inadequate indicators for holistically assessing CE (i.e. economic and social benefits)'; 'lack of knowledge and information on material quality'; 'returned products' low quality/variation in output quality due to process'; and 'variability in product performance' (Table 2 and Figure 3). These could lead to a lack of interest and 'inadequate knowledge among the professionals', which could cause other barriers such as 'lack of circularity in product design'.

'Community-level barriers' hinder citizen or community adoption of circular behaviour. The main underlying barriers in this category are 'lack of public awareness'; 'limited large scale pilot study on technology'; and 'limited participation of communities in CE'. These barriers could lead to subjective norms such as 'poor environmental perceptions or beliefs'; 'negative social/peer pressure'; and 'lack of public support for strengthening recycling markets'. These affect the marketability of CE products. As the community is a major consumer of CE products and a source of creative ideas to address societal problems, 'lack of community engagement' could adversely affect business co-invention and co-creation of an emerging CE market (Ceschin & Gaziulusoy, 2016).

## Interrelationships of barriers

### *Interrelationships: barrier categories*

In a socio-technical system, stakeholders do not exist in isolation (Connolly, 2017). Barriers impacting on one category of stakeholders could result in barriers that affect other stakeholders (Marle et al., 2013; Urbinati et al., 2021). Campbell-Johnston et al. (2019) concluded that 'institutional and regulatory barriers' are mostly established as the causal variables that drive other barrier categories. Therefore, in Figure 3 the causal influences among barriers are indicated by the lines connecting the categories. Apart from the well-noted causal influence of 'institutional and regulatory barriers', the remaining barriers also could influence one another: 'project-level barriers' could influence 'consumer-level barriers'; and both 'consumer-level barriers' and 'project-level barriers' could influence 'business-level barriers' because all three barrier categories influence the CE market. The numerical values (1–5) in Figure 3 represent the five categories of CE barriers. The dotted lines connect 'institutional and regulatory barriers' to the other four barrier categories, demonstrating the potential relationships between them. The solid lines with the letter 'a' in a circle connect the other four categories, along with 'institutional and regulatory barriers', to show the potential influence that the barrier categories have on each another.

### *Interrelationships: individual barriers*

Figure 4 demonstrates the cause–effect relationship between individual barriers. For instance, 'business secrecy' can be caused by 'lack of collaboration among business entities'; 'business competition in developing new waste-based products'; 'high investment cost and time needed to break-even'; and 'conservative construction industry'. 'Dysfunctional markets for recyclables' can be caused by 'lack of public support to recycling market'; 'inadequate digitisation tools for forecasting consumer behaviour'; 'rapid changes in market'; 'lack of government support for secondary materials market'; and 'lack of spare parts for repair and maintenance'. 'Dysfunctional market for recyclables', in turn, can lead to a 'conservative construction industry'. Similarly, 'lack of incentives for CE' can be attributed to several underlying barriers, viz 'difficulties in finding financing for start-ups'; 'lack of accreditation or certification of CE products'; 'inadequate resources for CE at the municipal level'; and 'lack of political commitment to increase waste recycling'. 'Lack of incentives for CE' could trigger 'high investment cost and time needed to break-even' and 'business competition in developing new waste-based product'. Moreover, 'customers' preference for new construction materials' could be ascribed to 'low returned product quality'; 'high required customisation'; and 'lack of knowledge and information on material quality'. 'Customers' preference for new construction materials' could induce 'new concept fatigue' and 'conservative construction industry' among business entities.

## Drivers for a CE transition

Five driver categories were established, namely 'institutional and regulatory drivers'; 'project-level drivers';

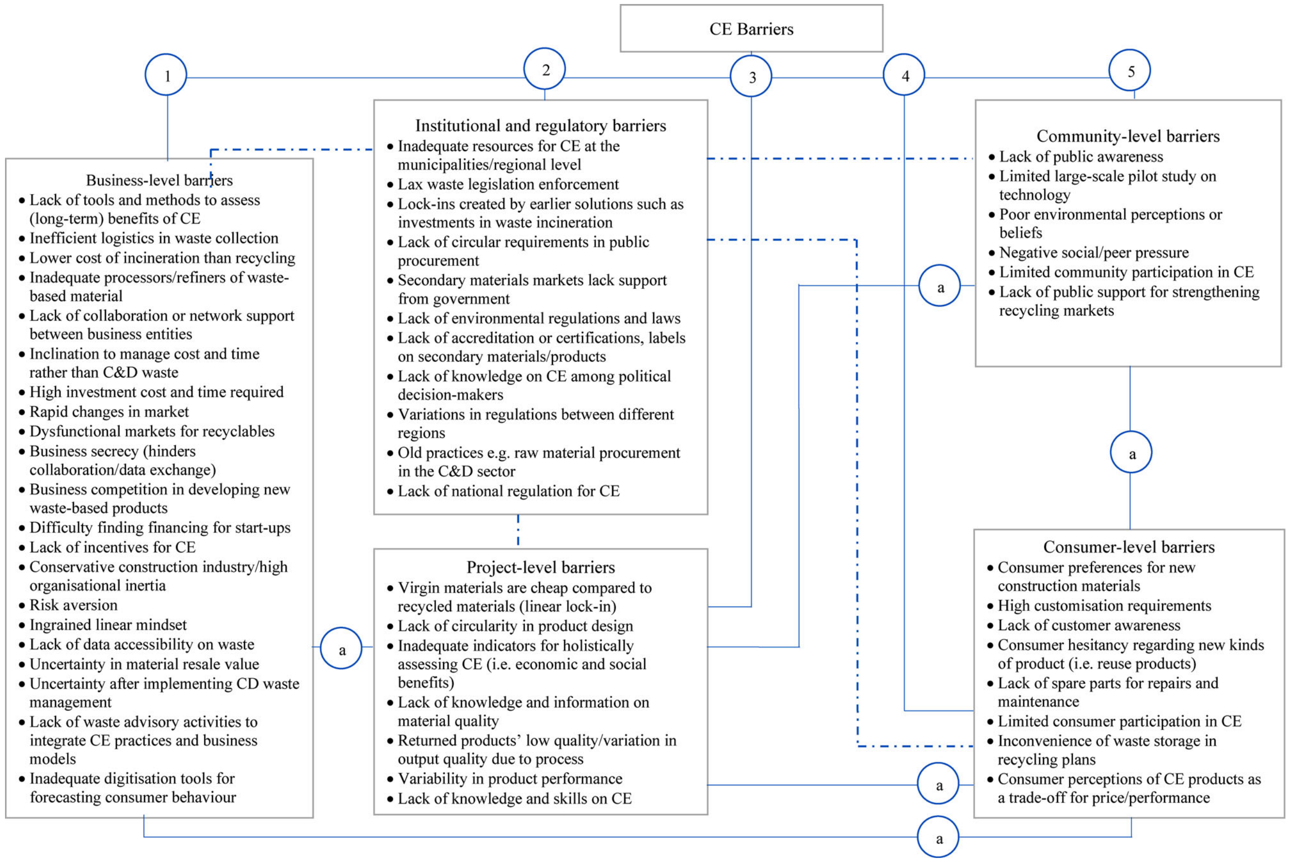


**Figure 3.** Interrelationships between barrier categories.

'consumer-level drivers'; 'community-level drivers'; and 'business-level drivers' (Table 3).

The 'institutional and regulatory drivers' (Table 3) are policies that can be stipulated or implemented by governments – local and regional, national and international – to drive CE transition among other stakeholders. Most drivers are financial. Financial resources are essential at local, regional and national levels to enable government actors to implement CE strategies and may include awareness creation, R&D policies including pilot scales, and the development of a sustainable public procurement plan. Financial resources also could be raised through negative reinforcement, viz. 'penalties for non-compliance' on waste segregation among bottom-up stakeholders. Policies on C&D waste management could be enforced by ensuring that C&D waste disposal charges serve as penalties (Poon et al., 2013). Governments can lessen their financial burden through partnerships with the private sector, for example 'tax and duty relaxation for recycled products', or 'soft loans or low-interest loans' strategies.

For procurement-related legislation or policies, criteria should address the use of circular products or secondary materials (Zhang et al., 2020) that require contractors to implement measures for C&D waste reduction and recovery. Furthermore, mandatory requirements should specify a minimum percentage of secondary materials/products to be used in projects. This could link consumption, via sustainable public procurement, to production, via sustainable business models, with compliance enhanced through 'harmonisation and interpretations of regulations', i.e. what constitutes circular products, what practices are considered relevant for CE, and which secondary materials or products are deemed suitable for use or reuse in projects. Sustainable public procurement will motivate companies or business entities to redesign business models for corporate sustainability (Witjes & Lozano, 2016; Zhang et al., 2020).

'Business-level drivers' that promote a functional CE market by motivating CE product suppliers and other stakeholders to induce circular practices and behaviour among corporate bodies at various levels: micro, meso and macro. For instance, 'acquisition of a competitive advantage'; 'potential for improving corporate image'; and 'reduced company dependence on raw materials' could propel a company towards CE practices and behaviour, however, these drivers must be financially feasible in the long term. For example, economically-viable drivers such as 'potential for increasing efficiency

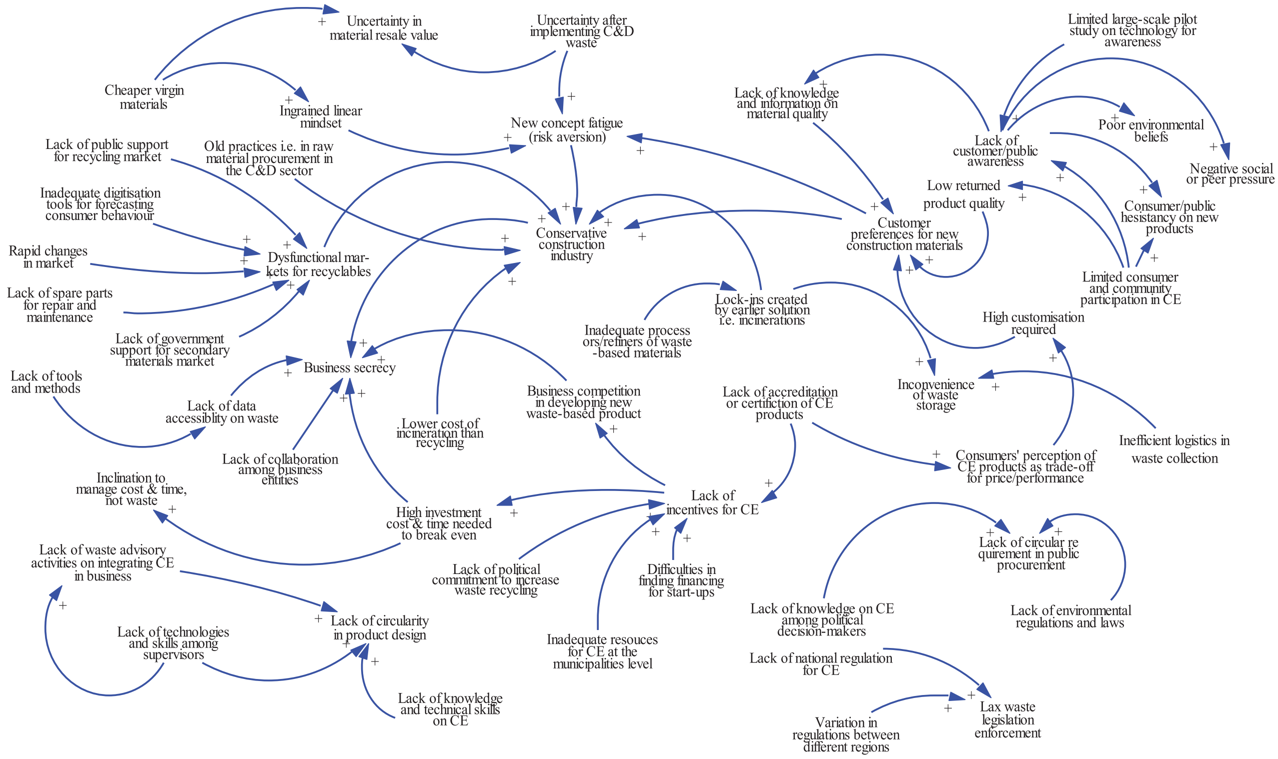


**Figure 4.** Conceptual interrelationships between individual barriers to CE.

via reducing costs and enhancing profits' and 'potential for acquiring a competitive advantage' could further inspire the intrinsic drive of corporate institutions towards a CE transition. 'Organisational collaboration among the business entities' could prevent a monopoly and encourage business stakeholders into the CE market. This could be achieved through 'better sharing of waste-related data'. Moreover, 'promoting servitized business models (product-service-systems)' could improve CE transition. In product-service systems, business stakeholders sell services to consumers and ownership of the product resides with the producer. This could economically motivate producers to make products that last for as long as possible in addition to providing efficient service to consumers (Ceschin & Gaziulusoy, 2016). Thus, product longevity could be achieved at the corporate level. Business entities also could promote CE by advertising the environmental benefits of CE products so that consumers may be more willing to buy such products (Bei & Simpson, 1995; Mansikkasalo et al., 2014).

'Project-level drivers' influence CE experts to promote a transition to CE. CE experts provide specialist services or expertise to project owners during a project's preliminary stages, and could supervise and coordinate corporate activities on behalf of the owner to ensure compliance with project specifications during the project execution stage. Therefore, third parties should be trained in relevant CE skills which would enable supervisors to ensure projects are built as designed in accordance with CE requirements. Supervisors also must be familiar with CE legal requirements to ensure supplier compliance. Academic organizations could play a key role in promoting technology and innovation, skill acquisition and training relevant to a CE transition. To motivate demand for CE products, academic institutions or third-party organizations should generate awareness of CE products' environmental benefits and quality aspects (Bei & Simpson, 1995).

'Consumer-level drivers' influence the consumption, storage and disposal of resources by users. Adequate environmental awareness could strengthen support and influence consumers' willingness to pay for products that are circular and environmentally friendly. Socio-demographic factors including level of education or awareness could further reinforce pro-environmental behaviour such as eco-friendly disposal of household waste (Islam et al., 2021). Therefore, ensuring that primary and secondary education curricula are structured to inform students about CE is crucial for an effective transition.

*Community-level drivers* include community beliefs and activities, collectively referred to as subjective norms, which could influence individuals in a

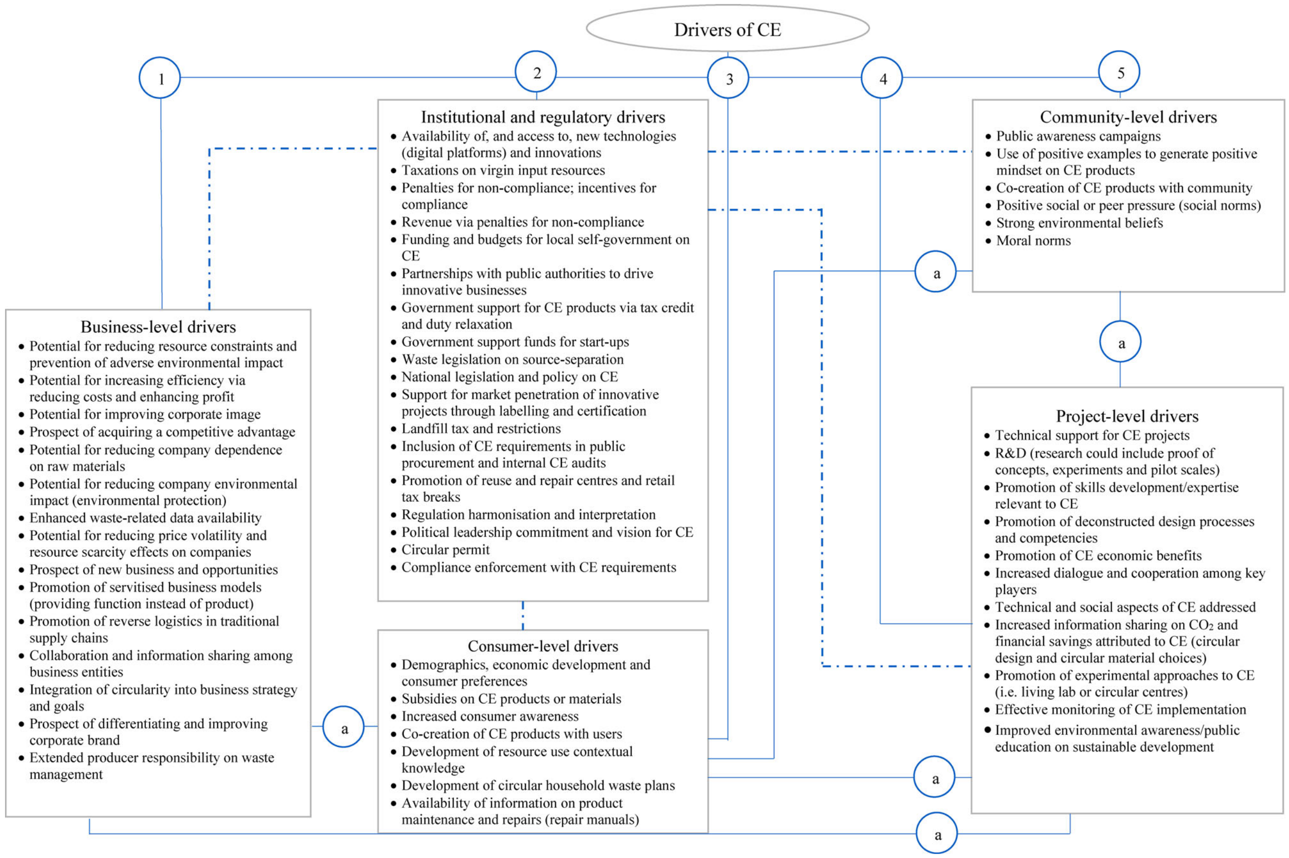


**Figure 5.** Interrelationships between CE driver categories.

community, society, region or country to adopt CE. Community beliefs, for instance, psychologically influence members. Psychological influence has more impact than technological influence on consumer engagement (Islam et al., 2021). Community engagement could influence community social norms, and community trust and acceptance can motivate consumers. Such trust can be achieved through accreditation, awards, and quality assurance of CE products (Islam et al., 2021). Community engagement also encourages co-production, adaptive governance and resilience among citizens, which is important for a successful CE transition (Velenturf & Purnell, 2021). Moreover, citizens and communities are a source of innovative ideas that ensure research activities are centred on societal problems. This could drive organizations to redesign their business models to support corporate sustainability. Public engagement and awareness camapigns also make the ethical obligation to recycle more visible in a community and could influence social norms that deliver various short-term outcomes. In the long term, social norms may not have a significant impact but could engender significant moral norms (Miliute-Plepiene et al., 2016).

## Interrelationship of drivers

### *Interrelationships: driver categories*

Various driver categories influence one another (del Mar Alonso-Almeida et al., 2021). 'Institutional and regulatory drivers' could influence other drivers, and similarly 'project-level drivers', 'business-level drivers' and 'community-level drivers' could influence 'consumer-level drivers'. 'Community-level drivers' also could influence 'business-level drivers'. For instance, moral norms and social norms (i.e. *community-level drivers*) could impact household recycling behaviour (*consumer-level drivers*) (Islam et al., 2021; Miliute-Plepiene et al., 2016). This can be achieved when norms are activated through awareness campaigns that focus on the negative environmental impacts of waste and the need to assign responsibility to consumers. Community norms also are triggered by regulations that introduce CE strategies (i.e. recycling) (Miafodzyeva & Brandt, 2013). These intrarelationships between various driver categories are illustrated in Figure 5. The numerical values (1–5) in Figure 5 represent the five categories of CE drivers. The dotted lines connect 'institutional and regulatory drivers' to the other four categories

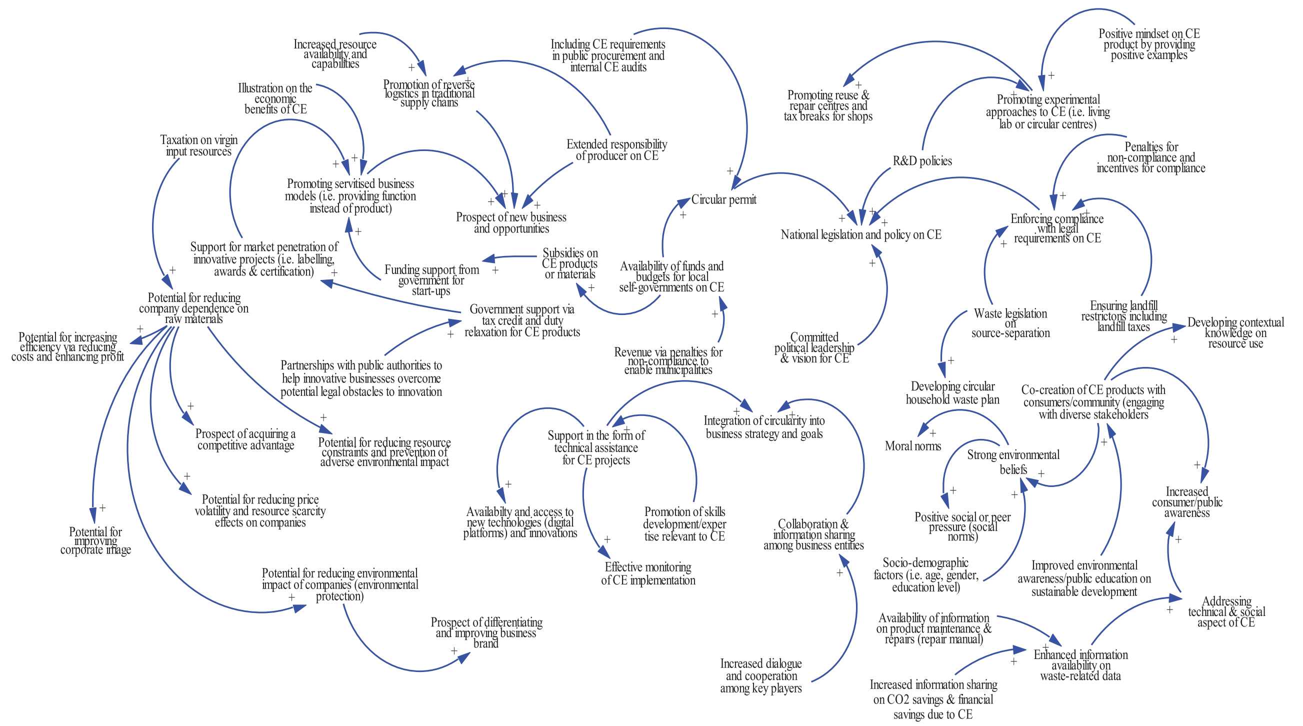


**Figure 6.** Conceptual interrelationships between individual CE drivers.

and depict potential relationships between them. The solid lines with a circled letter ‘a’ connect the four categories with the ‘institutional and regulatory driver’, and show the possible influence they could have on one another.

### *Interrelationships: individual drivers*

Individual drivers can influence each another. For instance, ‘enforcing compliance with legal requirement on CE’ could be driven by ‘ensuring landfill restrictions including landfill taxes’; ‘penalties on non-compliance and incentives for compliance’; or ‘waste legislation on source-separation’ (Figure 6). Similarly, ‘integration of circularity into business strategy and goals’ could be instigated by ‘support in the form of technical assistance for CE projects’ and ‘collaboration and information sharing among business entities’. ‘Increased consumers/public awareness’ could be achieved through ‘co-creation of CE products with consumers/community’ and ‘addressing technical and social aspects of CE’.

Through interrelationships, other drivers can be identified as constructs which could be measured by related drivers. For instance, the ‘national legislation and policy on CE’ driver could be measured by ‘circular permit’; ‘committed political leadership and vision for CE’ and ‘compliance with legal requirement on CE’.

## Conclusions

A transition to CE does not only require technological interventions but also institutional, organizational, social and behavioural change for sustainable development. Its promotion requires a systemic approach, rather than a fragmented approach; change in behaviour for CE must reach all stakeholders. Though a lot of ground has been covered in identifying the barriers, drivers and other influential factors that affect a transition to CE, this study stands out in several ways. Through the lens of the TPB as its underlying framework, findings from past research have been encapsulated in various conceptual models that not only offer a comprehensive list of influential factors, but also define associations, illustrate the direction of influence, and unearth the underlying causes related to each of the barriers, drivers, etc. In doing so, this study provides the field with intermediate theories in the form of models which can be taken as springboards for future empirical studies. In essence, the study acts as a bridge between the latest developments in the field and required empirical studies that extend the findings of available studies. A list of indicators also was presented to measure progress on circularity among governments, consultancy teams (i.e. academic institutions, practitioners), business entities, consumers and the community. The list of indicators, barriers and drivers could further serve as a checklist for decision making on interventions for circularity.

The proposed models and lists offer a point of reference for both researchers and practitioners as a comprehensive source of knowledge on various factors that affect CE adoption and influence a transition to CE. Among various practical applications, these models can be used for shaping sustainable public procurement strategies and informing policies on the procurement of products or services by government project clients through consultation with citizens to determine their needs and values. This could ensure that CE products are socially accepted by citizens in addition to meeting consumer needs.

Furthermore, through revealing conceptual interrelationships, the findings can inform decision-makers of the potential barriers and drivers that have multiplier effects on other barriers and drivers. This would enable policymakers involved in CE to see through new lenses how the categories and underlying barriers and drivers are interrelated within the CE system, and to allocate much-needed resources to address the most influential barriers and drivers that have an effect on the remainder of the network. This will inform decisions about where to implement change strategies for CE promotion.

Despite the contribution, as its major limitation, this study is a literature review where proposed relationships and models remain conceptual in nature, with no exposure to empirical data. Therefore, future empirical studies could reveal significant causal paths among the grouped or underlying barriers and drivers for CE promotion. Similarly, establishing relationships between the barriers and indicators, and between drivers and indicators, could reveal the critical barriers and drivers for an empirically validated CE model.

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No potential conflict of interest was reported by the author(s).

## ORCID

*Michael Atafo Adabre* http://orcid.org/0000-0003-2181-4401
*Albert P. C. Chan* http://orcid.org/0000-0002-4853-6440
*Amos Darko* http://orcid.org/0000-0002-7978-6039
*Mohammad Reza Hosseini* http://orcid.org/0000-0001-8675-736X

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