Received: 11 October 2023 | Revised: 25 April 2024 | Accepted: 28 May 2024

DOI: 10.1002/sd.3082

RESEARCH ARTICLE

Sustainable Development | WILEY

Dismantling linear lock-ins in the Australian AEC industry: A pathway to a circular economy

M. Reza Hosseini[1] | Sanaz Memari[2] | Igor Martek[2] | Tuba Kocaturk[2] | Masoomeh Bararzadeh[3] | Mehrdad Arashpour[4]

[1]Melbourne School of Design, The University of Melbourne, Parkville, Victoria, Australia

[2]Faculty of Science, Engineering and Built Environment, School of Architecture and Built Environment, Geelong, Victoria, Australia

[3]Department of Energy Engineering, Sharif University of Technology, Tehran, Iran

[4]Department of Civil Engineering, Monash University, Clayton, Victoria, Australia

Correspondence
M. Reza Hosseini, Melbourne School of Design, The University of Melbourne, Parkville, VIC 3010, Australia.
Email: mreza.hosseini@unimelb.edu.au

Abstract

The architecture, engineering, and construction (AEC) industry has struggled in its efforts to transition to a circular economy (CE) due to lock-ins, where the industry remains entrenched in practices that resist this much-needed transition. The solutions implemented so far have been unsuccessful. This failure can largely be attributed to the prevailing paradigm, which assumes that by sequentially removing barriers transition will naturally follow. However, this assessment overlooks the "lock-in" effect of practices within the industry's linear model. A comprehensive, holistic "whole of industry" approach is essential to uncover these lock-ins. In this context, O'Brien's "three transformational spheres framework" is introduced to examine how Australia's AEC sector is deterred from transitioning to a CE by three groups of lock-ins, and provide viable recommendation to tackle them. Fifteen industry experts were interviewed, covering the three dimensions of the framework. The findings specify three levels of intervention that must be addressed in the industry and recommend an order for tackling them: first, political systems and structures; second, practical behavioral and technical responses; and finally, personal beliefs and values. This article contributes significantly to the field by outlining a comprehensive array of strategies for industry transition. Implementing these strategies in the discussed order has the potential to catalyze the long-awaited transformation of the industry. This advances the theoretical framework concerning the adoption of a CE within the AEC sector and provides a reliable reference for policymakers, practitioners, and advocates who are orchestrating this transformative journey based on circular principles.

KEYWORDS

building industry, circular construction, construction projects, decarbonization, low-carbon economy, reverse logistics, waste management

During the preparation of this work the author(s) used GPT-4 model to improve readability and language. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

1 | INTRODUCTION

The architecture, engineering, and construction (AEC) industry plays a vital role in the Australian economy, serving as the largest non-services sector and providing direct employment to approximately 1.2 million individuals. Despite its economic significance, the Australian AEC industry has faced considerable criticism due to its low resource efficiency and unsustainable practices, surpassing global averages in their adverse impacts on the environment, communities, and the economy (Shooshtarian et al., 2023).

Much of the inefficiency in material use and wasteful operations can be attributed to the linear economy model that currently dominates the construction industry (Gyimah et al., 2024). One viable approach to address these challenges in the AEC industry in Australia involves transitioning toward a circular economy (CE) model (Rodrigo et al., 2024). The essence of the CE paradigm lies in effectively managing available resources. This includes extending the lifespan of materials and minimizing waste generation through the adoption of efficient design practices, offering a solution to these predicaments (Osobajo et al., 2022; Wuni, 2023). The CE paradigm advocates for a production and consumption system centered on sharing, leasing, reusing, repairing, refurbishing, and recycling materials and products for as long as possible, thereby extending their life cycle (European Parliament, 2022; Stefan et al., 2022). Specifically, within the AEC context, a CE entails an economic system that replaces the traditional "end-of-life" concept, focusing on reducing, reusing, recycling, and recovering materials throughout the production, distribution, and consumption processes, aiming to maintain a closed-loop approach and minimize the reliance on new natural resources (Ghisellini & Ulgiati, 2020a).

Throughout the Australian landscape, the momentum for a CE has surged, driven by a growing awareness of the critical significance of environmental sustainability (GBCA, 2021; Halog et al., 2021; Parry-Husbands et al., 2021). The benefits of adopting a CE within the AEC context are widely acknowledged by both practitioners and researchers, with a shared recognition of its potential to drive the AEC industry toward sustainable practices (GBCA, 2021; Levitzke, 2020). In reality, neither the widespread adoption of CE nor the envisaged systematic transition within the AEC industry has occurred (Horne et al., 2023; Shooshtarian et al., 2023).

Examining the literature on transitions, the issue primarily stems from the characteristics of the existing industrial system, which originated in a period marked by abundant resources and a smaller global population. Initially regarded as unproblematic, the system's inadequacies have become apparent as global demands have increased (Gyimah et al., 2024; Wuni, 2023). Despite growing recognition of the advantages of transitioning to a CE, potent forces including economic interests, political factors, behavioral dynamics, lobbying, and advocacy persistently uphold the status quo. Such individual constraints, although potentially surmountable in isolation, collectively reinforce each other, resulting in a system-level lock-in effect (Peralta et al., 2020; Sopjani et al., 2020); they are exacerbated by practical, political, and personal contexts that favor linear practices and deter potential adopters from embracing and implementing a CE approach (Bilal et al., 2020; Horne et al., 2023; Van Bueren et al., 2022); and, they collectively perpetuate the dominance of linear practices, complicate change, and impede the transition to a CE (Aminoff & Sundqvist-Andberg, 2021). This persistent endurance of dominant practices, despite the emergence of superior alternatives, is termed as lock-in (Arthur, 1989; Goldstein et al., 2023). Lock-in refers to a situation where existing technologies, practices, or systems become entrenched, making it difficult to transition to more sustainable alternatives. This can include factors, such as existing infrastructure, regulations, and established supply chains that favor linear practices (Nagatani & Helbing, 2004; Nasir et al., 2017). The adverse impact of the lock-in concept, hindering widescale adoption of CE and perpetuating linear practices, has been increasingly evident across various industries (Aminoff & Sundqvist-Andberg, 2021; Greer et al., 2021).

Past research has recognized the importance of investigating the issue of slow progress in sustainability-related phenomena from the perspective of linearity lock-ins (Aminoff & Sundqvist-Andberg, 2021; Goldstein et al., 2023). The impact of lock-in and established linear practices as formidable barriers to a CE adoption in the Australian AEC context is also well documented for the Australian AEC context (Horne et al., 2023; Shooshtarian et al., 2023; Van Bueren et al., 2022). A review of the now available literature, however, fails to identify any scholarly work that has attempted to promote circularity through tackling lock-ins in the Australian AEC sector. In essence, though there are many studies that justify the necessity of a transition to a CE, research on informing "how" a transition to a CE in Australia should take place is scarce (Ghisellini & Ulgiati, 2020a, 2020b; Marino & Pariso, 2020; Melles, 2021).

To address this gap, this study aims to harness the frameworks of constraints and lock-ins to tackle the prevailing linear paradigm. More specifically, this study is an attempt to investigate individual constraints and how they form system-level lock-ins in the context of the Australian AEC industry that prevent the uptake of new innovations that can facilitate a transition to a CE. The objectives are formulated as follows: (1) identify the factors that impede the adoption and diffusion of technological innovations conducive to facilitating a transition to CE; (2) investigate how these constraints interact and contribute to the formation of system-level lock-ins within the socio-technical system of the AEC sector; (3) provide viable remedies aimed at addressing the system-level lock-ins.

The approach taken by this article is novel, as it is one of the first of its kind in the AEC context to demonstrate the theoretical and practical relevance of understanding lock-ins in a transition to a CE. This addresses a gap identified in recent studies (Shooshtarian et al., 2023). In this regard, O'Brien's (2018) "three transformational spheres framework" is utilized as the theoretical framework. It provides a steppingstone and sound basis for future research into the field from the perspective of system-level lock-in phenomena. For the world of practice, this article acts as a point of reference for policy makers and industry practitioners, who aspire to advocate the adoption of a CE within the Australian AEC domain, illuminating perspectives as well as a blueprint for other countries and settings.

The structure of this article proceeds, as follows. Having provided an introductory background, it proceeds to the contextual background in which the mechanism by which linear industry practices have stymied the transition to a more desired circular economy, is explained. Section 3 introduces O'Brien's framework as the theoretical lens by which the problem of breaking "lock-in" practices is examined. A description of the research method follows; the interview design, sampling, and data collection. Section 5 offers an analysis of interview findings, and specifically highlights salient recommendations made by experts for a transition to circularity. Section 6 extracts those recommendations and juxtaposes them against identified challenges in a discussion on what a successful implementation of recommendations might entail. Specifically, of the three generic "lock-in" classes identified, it appears evident that these be tackled in a sequenced order of priorities: political, practical, and personal, respectively. The article ends with concluding remarks.

2 | CONTEXTUAL BACKGROUND

The regional boundaries assessment for Australia offers a sobering picture, revealing high pressures on ecosystem processes despite its low population density. Climate change has already exerted pressure on societal and economic production processes, manifesting through bushfires, droughts, floods, and the deterioration of Australia's Great Barrier Reef (Van Bueren et al., 2022). Striving toward self-sufficiency and "closing the loop" for all major processes is considered an effective solution, offering three bottom line benefits, along with regional resilience and stability for Australia (Melles, 2021; Van Bueren et al., 2021, 2022). This can be translated into circling flows and economic processes that are not part of the linear economy and take responsibility for regulating the three bottom lines of sustainability, namely, a CE (Kevin van Langen et al., 2021; Van Bueren et al., 2021). The circular economy seeks to decouple resource extraction from economic growth to enhance resource efficiency. It contrasts with the linear economic model by emphasizing closed resource loops. A broader perspective highlights the importance of slowing material flows in both somewhat circular and predominantly linear economies. The most comprehensive view advocates optimizing resource use across all economic activities, not just those with high material consumption. This perspective is prevalent in modeling assessments and literature reviews, including this one (Kevin van Langen et al., 2021; McCarthy et al., 2018).

In contrast to Europe, where measures to transition toward a CE have gained considerable momentum and been mandated (Ciliberto et al., 2021; Ghisellini & Ulgiati, 2020a; McCarthy et al., 2018), Australia has proceeded with more caution due to its much smaller dispersed population centers and reliance on materials extraction through mining (Levitzke, 2020). Despite this, there is consensus on the effectiveness of a CE and the necessity of a transition to CE in Australia (Halog et al., 2021); therefore, coalitions and networks of research organizations, government and nongovernment actors, consultancies, and niche actors have become active, with an explicit goal to promote the adoption of a CE in Australia (ACE Hub, 2020; Melles, 2021; PwC Australia, 2021; Rynne, 2020).

The adoption of CE practices in Australia is projected to yield substantial benefits compared to business as usual. It is estimated that by 2025, the implementation of CE can generate an additional $23 billion, and by 2047–48 it can contribute up to $210 billion to the GDP; so too, this transition is anticipated to create approximately 17,000 full-time job equivalents (Rynne, 2020). Other modeling approaches show that Australia could generate $1860 billion in direct economic benefits over 20 years and save 165 million tons of CO_2 annually by 2040 (PwC Australia, 2021). This concerted effort is also evident in the context of the Australian AEC sector, as discussed next.

2.1 | Circular economy in the Australian AEC context

The AEC sector has witnessed an unprecedented interest in CE, driven by numerous national and international organizations worldwide. This growing interest has led to an increased focus on conducting research on adopting a CE across the AEC context (Atapattu et al., 2024), including within the Australian AEC context (Shooshtarian et al., 2021).

First attempts aligned with the concept of CE within the Australian AEC industry were informed by the principals of waste management, where the sole focus was increasing the rate of waste diverted from landfill and internalizing a culture of managing waste in AEC-related projects (Crawford et al., 2017; Udawatta et al., 2015). The focus and intention was increasing the rate of reuse and recovery of construction materials and products, though recycling was given top priority among other approaches of managing waste (Kabirifar, Mojtahedi, Changxin Wang, & Tam, 2021). That said, the adverse impacts of rigidity of traditional practices and established attitudes—a shorthand for lock-ins—was identified as a major barrier toward a widespread adoption of waste management (Kabirifar, Mojtahedi, & Wang, 2021; Teo & Loosemore, 2001; Udawatta et al., 2018).

In years after 2013, the concept of "reverse logistics" that shows noticeable commonality with a CE gained momentum; a stream of research studies in the Australian AEC context focused on identifying the barriers that hinder closing the loop for construction and building materials at the end of their first service life (Chileshe et al., 2015, 2018). All these highlighted the role of established regulatory, economic and personal perceptions formed by linear practices as major barriers to adopting reverse logistics, echoing the need for tackling system-level lock-ins in the Australian AEC context (Rameezdeen et al., 2016).

The restriction of waste imports by China, along with the ban on certain foreign waste materials and stricter limits, heightened pressure on Australian landfill sites (Kabirifar, Mojtahedi, & Wang, 2021; Pandey & Shukla, 2019). As a result, the growing volume of construction and demolition waste has become an additional burden. To address this issue and divert waste from landfills, a transition from the

linear model of "resources-products-waste" to a CE model of "resources-products-waste-renewable resources" has gained momentum (Halog et al., 2021; Hossain et al., 2020; Urbinati et al., 2017). The Senate's Environment and Communications References Committee highlighted the urgency of establishing a CE in Australia, as demonstrated in the 2018 report titled "Never waste a crisis: the waste and recycling industry in Australia." The committee recommended that the Australian Government prioritize the adoption of CE principles, emphasizing the efficient use, collection, recovery, and reutilization of materials within the country (Commonwealth of Australia, 2018, p. 5). Despite the widely recognized advantages of adopting a CE in the sector, anecdotal evidence and past research indicate that neither widespread adoption nor the intended systematic change has been observed (Shooshtarian et al., 2021, 2023). In the context of the AEC industry, the gap between intention and implementation has largely been attributed to system-level barriers and entrenched linear practices that impede necessary changes, making a transition costly, risky, and unjustified (Horne et al., 2023; Shooshtarian et al., 2023; Wijewickrama et al., 2021).

2.2 | Linear lock-ins

'Drivers and barriers' is the common language used to explain why the Australian AEC industry has failed to transition to one more sustainable, predicated on a CE (Rodrigo et al., 2024; Shooshtarian et al., 2023). The implication here is that the mere identification of barriers implies that their removal will lead to a resolution of all associated issues. A legacy of this approach is that when a list of barriers is identified, and the result even years later is that the industry continues in its inefficient, wasteful, and outdated unsustainable practices, to assume that there are yet more barriers to be removed. And, subsequent research generally finds new barriers, upholding that assumption. The list of substantive barriers has grown to more than eighty (Brenda Mutanu & Nicholas, 2018; Pasqualotto et al., 2023; Singh et al., 2022). There is also the view that additional barriers accrue to particular AEC sectors, such as mining or infrastructure (Upadhyay et al., 2021), or to particular AEC methods or are unique to particular countries (Gyimah et al., 2024).

The difficulty, however, is that the industrial system is itself unsustainable, and attempts at remedying its constituent parts piecemeal does not equate to a reinvention of a new industry (Langston & Zhang, 2021). The current AEC in Australia is built on specific codes, that recognize specific building practices, utilizing specific materials, delivered through established supply chains, in order to deliver building projects of a recognizable type, life-expectancy and cost, for a conservative, risk-averse clientele (Loosemore et al., 2023). Transitioning to more sustainable materials, which can be reused, as one example for adopting a CE, will be met with a regulatory environment unprepared to authorize their use, tradespeople unfamiliar with their installation, supply chains unable to deliver such materials, not to mention customers reluctant to accept their inclusion in pricy capital investments (Martek et al., 2019).

"Barriers," as such, are not what is preventing an otherwise viable AEC industry from becoming a sustainable, CE. The problem goes deeper. The industry is itself ossified in an entrenched system incapable of being anything other than it is—a linear economy predicated on the mantra of "build-use-demolish-repeat." This realization has attracted the terminology "locked-in" (Goldstein et al., 2023). While concepts, such as "constraints and barriers" emphasize specific obstacles hindering an industry's transition, "locked-in" refers to the systematic inertia across the entire system, which resistant change (Aminoff & Sundqvist-Andberg, 2021).

Rather than think of what it is that is holding back the AEC industry from becoming a CE as merely an extensive list of barriers, examination of the structural dependencies between a range of interacting dynamics offers a more promising approach. This "locked-in" list, like the barriers paradigm that preceded it, has been preliminarily identified in the literature. That list includes: lack of economic incentives (Atapattu et al., 2024), existing infrastructure (Svingstedt & Corvellec, 2018), technological developments (Corvellec et al., 2013), organizational inertia (Aida et al., 2021), social and cultural factors (Ylä-Mella et al., 2022), and, political and institutional factors (Cecere et al., 2014). Nevertheless, this remains a fledgling research domain, with the concept of "locked-in" yet to be investigated in the realm of Australia's AEC industry. Consequently, this study aims to delve into this concept. The mechanism for that investigation is O'Brien's (2018) "three Transformational Spheres framework," as described in the following section.

3 | THEORETICAL LENS

The analytical model employed for data analysis was the "three transformational spheres framework" (O'Brien, 2018; O'Brien & Sygna, 2013). This framework (see Figure 1) consists of three related and interacting spheres of transformation: the practical, political, and personal spheres. The "Personal" sphere refers to the individuals internal value systems and world-views that would inform his/her motivations and incentives for adopting transformation. That is, without the "buy-in" of the actors involved, hope for change with be resisted. The "Political" sphere refers to the role of government in directing and facilitating change. Policy and regulations must be suitably and comprehensively crafted and implemented to reshape industry if indeed there is to be change. The "Practical" sphere refers to the technical level of implementation. The right tools, procedures and training must be made available. The practical sphere lies at the heart of the model, encompassing tangible actions, interventions, and strategies that directly contribute to the desired outcome. Complementing this, the political sphere encompasses the systems and structures that shape and govern these actions, while the personal sphere encompasses subjective beliefs and worldviews that influence individual and collective behaviors.

This framework is particularly suited for investigating a transition toward a circular economy (CE) in several respects. First, as illustrated in Figure 1, it acknowledges the multilevel and multiphase nature of

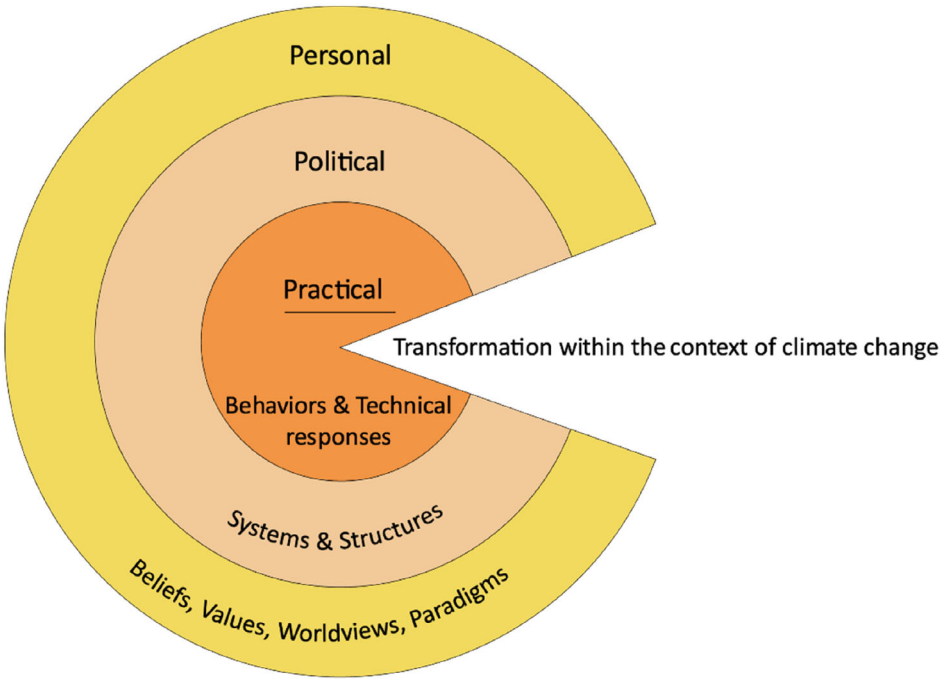

FIGURE 1 The three transformational spheres framework.

any sustainability transformation by incorporating three dimensions that provide a heuristic approach to understanding the complexity and scope of transformations required (Herrfahrdt-Pähle et al., 2020). Second, the framework's value lies in its recognition that impediments to transition are neither independent nor incremental. O'Brien's framework emphasizes the interdependent and holistic nature of all elements impacting a system and identifies the three layers through which change must be collectively realized (O'Brien, 2018). Third, this framework can deepen the understanding of long-term change in complex systems by studying innovation systems, which identify barriers to the success of novel environmental solutions. While it considers worldviews, paradigms, and other sociocultural constructs, the inherent aggregation and abstraction of these elements may detach the analysis from the perspectives of individual actors (Wojtynia et al., 2023). As such, the findings were interpreted and synthesized through the lens of three spheres of transformation, enabling a comprehensive analysis of the data and providing a deeper understanding of the dynamics at play in a transition to a CE in the AEC context.

4 | RESEARCH METHODS AND DESIGN

4.1 | Research approach

This study sought to elucidate the intricacies of linear lock-ins within the Australian AEC context. In such an investigation, the subject matter is inherently abstract, comprising subjective constructs that are context-specific and experientially oriented. This aligns with a relativist ontology, as defined within the constructivist paradigm, which underscores the contextual nature of reality (Guba & Lincoln, 1994). Furthermore, lock-ins have received limited attention within the AEC context. Addressing any little-understood phenomenon necessitates an exploratory inquiry utilizing qualitative methods to unveil the authentic experiences, perceptions, and practices of individuals involved in the subject of this study (Neuman, 2006). One of the most effective means of uncovering the experiences and practices of experts in their natural context is through conducting interviews, which is the most commonly employed method for data collection in qualitative research studies (du Toit & Mouton, 2012). Conducting interviews with experts was therefore the chosen method for this study, as discussed next.

4.2 | Sampling and data collection

To recruit potential interviewees, a "purposive sampling" strategy was used. The "purposive sampling" approach was employed to identify and select professionals with substantial experience in implementing, managing, and consulting on the transition to a CE within the AEC context. This sampling method was chosen because it allows researchers to meet research objectives concerning access to relevant knowledge and experience, while also ensuring that experts are available and willing to participate (Rowley, 2012). Interviewees were selected through prominent companies and individuals associated with professional groups dedicated to CE, such as the Australian Circular Economy Hub and companies participating and presenting in the Circularity Conference in 2022. Additionally, profiles of members of sustainability consultancy firms and active participants in CE-related professional networks, such as LinkedIn, were reviewed. LinkedIn, which enables users to showcase their skills and expertise, has proven to be a dependable source for assessing the qualifications of experts. A total of 27 potential candidates were ultimately identified as experts

TABLE 1 Details of interviewees.

No.	Role and qualifications	Organization category	Description
Interviewee #1	Director	Private sector firms (specialized)	A company with over 30 years of experience of contracting sustainable projects
Interviewee #2	Senior associate	Consultancies and design firms	One of Australasia's largest design firms, with more than 770 talented designers and active in a wide range of project types
Interviewee #3	Senior project manager, project delivery and property	Government and public sector entities	State government
Interviewee #4	Associate, sustainability and energy services consultant, certified passive house consultant	Consultancies and design firms	Small consultancy active in providing consultancy on a change to a CE
Interviewee #5	Sustainability advisor	Private sector firms (specialized)	A large property investment firm and developer with commitment to sustainable properties
Interviewee #6	Owner and designer	Independent designers and sole traders	A sole trader, active in designing closed-loop, symbiotic and regenerative architecture
Interviewee #7	Sustainability manager	Other	A large multinational consultant with offices in all Australian cities
Interviewee #8	Architect/director/principal, passive house certified designer, circular economy adviser	Consultancies and design firms	Small consultancy active in providing consultancy on a change to a CE
Interviewee #9	Sustainable design engineer	Consultancies and design firms	A small design company with experts from varied backgrounds who all share a commitment to sustainable design, with projects across Australia and Malaysia
Interviewee #10	Senior sustainability and resilience consultant	Other	A large multinational consultant with offices in all Australian cities
Interviewee #11	Energy and sustainability consultant	Consultancies and design firms	A large employee-owned engineering consultancy that operates in all mainland regions of Australia
Interviewee #12	Sustainability expert	Private sector firms (specialized)	A medium-size company active firms and government to inspire empower sustainable change through circular principle
Interviewee #13	Regional sustainability manager for two states	Construction and contracting firms	One of the largest contractors in Australia
Interviewee #14	Principal sustainability consultant	Consultancies and design firms	A global multidisciplinary consultant company active in low-carbon design and circular economy
Interviewee #15	Circular economy consultant	Other	A large multinational consultant with offices in all Australian cities

in CE, and specifically in advising and consulting in industry transition to CE. Thus, these 27 were invited to participate, with 15 experts agreeing to be interviewed (refer to Table 1 for details). The sample size was considered adequate, aligning with the argument made by Bazeley (2013) that data saturation can typically be achieved after interviewing more than six participants. To enhance the generalizability of the findings, a criterion of "demographic heterogeneity" among experts was employed. This criterion aimed to ensure that experts with diverse demographic attributes and varied professional experiences were interviewed, thus encompassing a wide range of perspectives and facets related to the topic. However, the primary focus remained on identifying information-rich experts, which was crucial for ensuring the validity and reliability of the study's results (Rowley, 2012).

The interviews for the study were organized into two distinct stages, each employing different methodologies. In the first stage, a PowerPoint presentation was utilized to ensure all participants had a clear understanding of the concept of "lock-ins" and the objectives of the study. This stage included a question-and-answer session to address any ambiguities or concerns. The second stage involved semi-structured interviews conducted primarily through online video meetings, each lasting between 30 and 44 min. During these interviews, participants responded to questions about specific lock-ins they encountered while integrating CE principles into their businesses and projects. An initial list of potential lock-ins was prepared beforehand, based on a comprehensive review of relevant literature from Australia and beyond. Participants were then invited to modify this list by adding or removing items, elaborating on each, providing examples, and

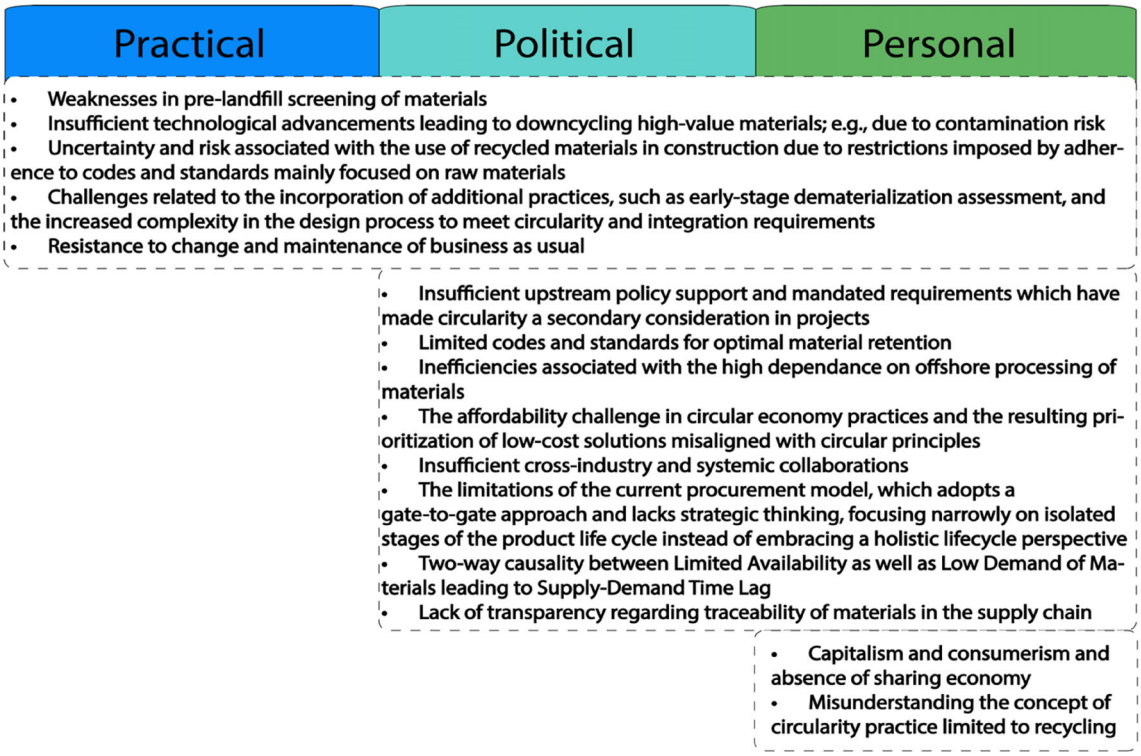

FIGURE 2 Model of linear lock-ins based extracted from the interviews.

discussing potential solutions and recommendations to overcome these challenges.

4.3 | Data analysis

Data from interviews were analyzed using a two-cycle coding method. Initially, "question-based coding" was applied in the first cycle, which involved coding responses to each question separately. This inductive approach allowed for a detailed breakdown of the data, facilitating initial exploration and categorization.

Subsequently, the second cycle employed "pattern coding" to abstract the analysis further by synthesizing the initial codes into a coherent scheme that aligned with the theoretical framework of the research. This method connects detailed observations to broader themes, adhering to the principles of thematic analysis through "analytic induction." This approach ensures that the analysis captures both the intricacies of individual responses and the broader thematic insights relevant to the study's objectives (Merriam, 2014).

5 | IDENTIFIED LINEAR LOCK-INS

The interviews conducted yielded consensus that the prospects for the adoption of CE practices within the Australian AEC sector are promising. However, it was also acknowledged that there exist substantial linear lock-ins that must be addressed to fully realize this potential. These barriers are comprehensively examined within the context of the "three transformational spheres framework," depicted as a model illustrating linear lock-ins (refer to Figure 2). As depicted in Figure 2, personal lock-ins encompass and influence all other lock-ins, serving as the overarching framework that impacts various aspects of the transition (see Figure 1). On the other hand, practical lock-ins primarily pertain to technological aspects and can be mitigated through advancements in technology.

5.1 | Practical lock-ins

Interviewees referred to several practical lock-ins, as illustrated in Figure 2. These included insufficient technological advancements that retains the value of materials at the end of their first use is a lock-in that contributes to a prevalence of downcycling of high-value materials. Interviewees agreed that this presents a significant obstacle that extends the dominance of linear practices. For instance, inappropriate and mostly manual separation of different materials during recycling processes can result in contaminated recycled products. These contaminants may affect the quality and safety of CE products, making it difficult for them to meet the regulatory standards and requirements. In some cases, materials are lost entirely due to weaknesses in pre-landfill screening procedures.

Interviewees agreed that a shift toward a CE necessitates designers to rethink conventional design processes, to consider the lifecycle of buildings and building materials. This expanded scope

faces new challenges and considerations that add complexity to the design process, which often results in resistance to change and a tendency to maintain business-as-usual practices. In this regard, interviewee #7 noted that:

> "our building industry is very established in such (conventional) methodologies, and it is very difficult to get expertise and skills that are required to put something together in a different way."

In addition, interviewee #13 also referred to the increased complexity and added levels of uncertainty in technical aspects and planning of projects associated with circular practices as opposed to linear ones. One includes renovation projects as compared to new construction:

> "If you knock down, you've got certainty. You spend a couple of weeks demolishing and removing a building, and then you've got it clean. Basic ground. You can do a fixed program. You can know exactly what is going to be in the end product. And you know you're not going to come across any surprises or challenges."

5.2 | Political lock-ins

The political lock-ins identified by the interviewees highlighted the importance of political will and supportive regulatory framework for CE practices. They argued that the dominance of existing codes and standards focused on raw materials creates challenges and ambiguity regarding the quality of materials produced within the CE framework, consequently, hindering their broad adoption and application in construction projects. As such, interviewee #3 noted:

> "if we're using recycled products as a possibility, some people assume that the longevity or the life of that building may be compromised."

Some interviewees believed that the existing regulatory standards do not adequately cover the unique characteristics and attributes of circular materials. For instance, according to interviewee #14:

> "one of the other things that stops us to a certain extent is, and this is a good thing in a lot of respect, but… the regulatory environment is such that we are not sure we can use those recycled goods."

On the other hand, while the industry has extensive knowledge and experience in using secondary materials and assessing their performance through testing, the use of secondary materials as a replacement still raises questions; according to the interviewee #13:

> "There's like uncertainty in the industry around exactly how it (secondary materials) will perform, the long-term performance is a bit of a question mark whereas there is a lot of knowledge on using virgin products, and we know how to test them, how to screen them. We know what the outcomes will be … But when we've come to use secondary stuff to replace some of those new products, we've had question marks around."

This was explained by the interviewees in terms of the AEC sector being traditionally a conservative industry. The AEC industry traditionally focuses on durability, with established practices that have demonstrated their long-term effectiveness. Any departure from these established practices is viewed as a potential long-term risk that could impact a project over the course of decades. The—experimental—practice of incorporating CE principles into design can have implications in the form of liability of designers and project teams. As such, interviewee #6 concluded that:

> "space for innovation is a little bit limited by that liability."

There was consensus among the interviewees that the existing regulatory gap creates uncertainty and risk, making it challenging to embrace and utilize circular materials to their full potential. Many of them pointed out that voluntary frameworks, green certificates, and incentives primarily prioritize operational emissions over embodied carbon and circularity. In essence, they raised concerns around a noticeable absence of circularity considerations within major certificates, voluntary frameworks, and incentives throughout the AEC industry. According to interviewee #7:

> "all we get basically on major projects for commodities is what are being called green commodities. But that's essentially associated with the emissions profile of those products, and not directly linked to circularity of those products."

As illustrated in Figure 2, the interviewees pointed out that the challenges associated with a lack of upstream policy support and mandated requirements have made circularity a secondary consideration in projects. Moreover, the absence of onshore manufacturing poses a hindrance to the effective management and utilization of resources. To establish a successful CE, it is crucial to adopt a localized approach that minimizes transportation costs and maximizes efficiency. As interviewee #13 highlighted:

> "I think one of the main barriers is a lack of manufacturing that happens in Australia, or where it does happen in Australia, the cost premium relative to international sources."

This shift toward localization can potentially address the current inclination toward prioritizing low-cost solutions over circular ones. As interviewee #4 elaborated on:

> "natural market forces and competitive tendering arrangements will look for the lowest cost solution for a given material. Therefore, it's natural that it will always default the lowest cost, and the lowest cost will possibly not be the product that has the greatest benefit for circular economy outcomes so I think a lock-in is fundamentally cost…"

The other significant identified lock-ins were argued to be associated with insufficient cross-industry collaboration and the prevalence of a silo approach. This fragmented approach limits the potential for synergies and deters realizing holistic solutions. One specific observation made by interviewee #5 highlighted the absence of system change scientists and economists to address this issue. Compounding the issue is the existing procurement model, which often follows a gate-to-gate approach, focusing on specific commodities and their use in isolated stages of the product life cycle rather than considering the entire lifecycle. This narrow perspective is a result of a lack of strategic planning and inhibits the integration of circularity across the entire value chain. Moreover, the interviewees also commented on the limited transparency in the traceability of CE materials within the supply chain, as a lock-in belonging to the political sphere (see Figure 2).

Furthermore, the interviewees underlined the reciprocal relationship between supply and demand as a formidable lock-in, resembling the classic conundrum of the chicken and the egg. As such, there is a time lag between demand and supply, primarily stemming from the limited availability of CE materials and practices within the supply chain. In other words, the scarcity of CE materials and practices hinders the fulfillment of demand, resulting in reduced interest and prolonging the dominance and reliance of linear practices of the market. Conversely, a lack of demand for circular products and services discourages the development and scaling up of supply chain capabilities. Breaking this lock-in presented as a cycle of limited supply and low demand is hence crucial.

5.3 | Personal lock-ins

Apart from those that were covered under other spheres, several personal lock-ins related to beliefs, values, worldviews, and paradigms that hinder a transition to a CE were discussed by most interviewees. Of these, capitalism and consumerism pose a significant lock-in to tackle. The prevailing culture of consumerism encourages individuals to prioritize the acquisition of new products over reusing or sharing existing resources. This mindset, interviewees believed, perpetuates a linear consumption pattern, where products are quickly discarded after use, leading to excessive waste generation and limited resource efficiency. As interviewee #4 highlighted,

> "there's an aspect of the circular economy in terms of the sharing economy and occupational behavioral change. So they are not very well developed at all… there's little uptake on sharing schemes in context of the circular economy."

Another challenge is the misconception of a CE, often limited to recycling alone. Interviewees were in agreement that many individuals and even businesses perceive circularity as solely recycling waste materials, overlooking the broader principles of resource conservation, product durability, and materials reuse, and regeneration just to name a few. This limited understanding rooted in many years of linear practice, hinders the comprehensive adoption of circular practices in their full potential. According to interviewee #8:

> "people think about recycling. But recycling is just the last of the worst possible way of doing what circular economy is, most costly and least desirable…."

6 | RECOMMENDATIONS TO TACKLE LOCK-INS

The analysis of the interviews revealed several key strategies and initiatives that can contribute to successfully tackling the identified lock-ins. The outcome is formulated as a set of recommendations, which are discussed below.

6.1 | Technical responses (practical)

Based on the insights gathered from the interviews, several recommendations can be put forth. First, manufacturers should initiate and scale up the incorporation of recycled materials into their production processes. This involves not only developing technical measures to identify high-quality recycled materials but also innovating in how these materials are used to maintain or enhance the final product's quality. To this end, it was recommended to emphasize manufacturer-led initiatives that catalyze industry-wide shifts to achieve these objectives as influential measures.

Second, adopting a learning-oriented approach was deemed critical. This approach should encompass continuous prototyping and testing of new ideas, which can facilitate the transition from traditional, linear production methods to circular models. Companies should create environments where experimentation is encouraged, and failures are seen as learning opportunities, thus fostering innovation in product development and manufacturing processes.

Third, interviewees emphasized a need for critical reflection on the limitations of current products to enhance their durability, reusability, and adaptability. This reflection should inform the redesign of products to make them aligned with CE principles over their lifecycle, integrating principles, such as design for disassembly. This practice is vital as it ensures products are easier to dismantle at the end of their lifecycle to facilitate the reuse and recycling of components. Additionally, it was recommended that manufacturers conduct dematerialization assessments during the early stages of design. Such assessments

can help in reducing the material footprint of products by identifying areas where materials can be minimized without compromising functionality. Employing modular construction techniques, shifting toward off-site construction, and planning for material contingency were also advised. These practices can reduce waste and enhance the efficiency of resource use.

Interviewees also agreed on the significance of adaptive reuse of buildings and the integration of recycled materials in construction that should be prioritized to reduce the environmental impacts of new constructions and demolitions. Considering maintenance and repair as alternatives to replacement is recommended to extend the lifespan of products and buildings, thereby reducing waste and the consumption of new materials. It is also advised to prioritize a major shift toward fully assessing the feasibility of retrofitting and rehabilitating built assets as the first step, and approving new construction only if these options are not viable.

Lastly, implementing material traceability through material passports and aligning procurement models with circular economy (CE) principles were mentioned as essential steps. Interviewees pointed out that material passports can provide detailed information about the materials used in products, thereby facilitating easier recycling and reuse. Simultaneously, promoting new procurement models like product-as-a-service (PSS) that align with CE principles was deemed to have the potential to unleash a new wave of operational efficiencies by increasing throughput in production processes.

6.2 | Political systems and structures

Government-led initiatives have the potential to play a pivotal role in facilitating collaboration and synergy across different sectors. Nevertheless, interviewees raised concerns about intellectual property issues, which could hinder knowledge sharing and collaboration due to commercial and confidentiality considerations. To address these potential lock-ins, the concept of establishing an independent third-party body was proposed as a viable solution. Such an entity could serve as a repository for existing knowledge, making it accessible to all businesses, thereby mitigating intellectual property concerns and fostering collaboration more effectively.

Furthermore, the interviews underscored the potential for governments to play a proactive role in catalyzing markets for manufacturers utilizing secondary materials, thereby addressing prevalent lock-ins and driving demand for circular products. For example, interviewee #4 proposed the concept of governments providing incentives, such as rebates to concrete manufacturers based on the volume of recycled materials they incorporate into their products. Additionally, interviewee #6 highlighted that governments could foster an innovation-friendly environment, conducive to experimental design and the prototyping of novel ideas. This could be achieved by mitigating legal lock-ins, such as establishing insurance mechanisms to support innovative ventures. It was emphasized in the interviews that enhancing the value chain is a critical strategy in the transition to a CE. This can be achieved by establishing an institutional buyer committed to purchasing recycled goods, thereby creating a sustainable market for circular products. Interviewees also stressed the importance of regulations and codes requiring transparency in the CE supply chain and highlighted the need for establishing product stewardship and ownership practices in the market that include take-back/buy-back commitments. Additionally, interviewees highlighted the importance of building a sustainable financial infrastructure, facilitated through collaborations with major investment firms. Such collaborations would ensure the availability of financing for businesses undertaking the transition to circular business models.

Moreover, the interviews underscored the significance of creating a certification framework that offers clear guidelines and promotes consistent practices for the successful implementation of a CE principles. Interviewees recommended requiring companies to acquire certifications similar to those issued by the World Green Building Council (WGBC, 2024), or local equivalents, to demonstrate their alignment with a CE in project delivery. Nevertheless, it was recognized that in certain situations, decision-making should be decentralized, and customized, context-specific solutions should be employed to tackle lock-ins effectively. In particular, most interviewees expressed the importance of incorporating the certification framework as a mandatory requirement in projects. However, interviewee #7 pointed out that immediate mandatory measures might not be feasible or effective within the existing system.

> "Regulation would be jumping a step to too far in that. It wouldn't achieve a solution. It's a very difficult thing to impose. Because it impacts the economic viability of the industry… adopting a circular approach to the built environment is complex and potentially not readily available now."

The interviewees placed significant emphasis on the importance of localizing the necessary infrastructure and highlighted the significance of processing materials onshore within Australia. This approach is aimed at improving affordability, ensuring that the benefits of CE practices are widely accessible within local communities. Similarly, past research has recommended a focus on local and operational interests, including consultation with local authorities during infrastructure planning and an emphasis on natural resources and ecosystems for local development.

6.3 | Personal beliefs, emotions, and employment

Based on the insights garnered from the interviews, several strategic recommendations can be advanced to facilitate the adoption of CE practices and the associated socio-cultural and behavioral changes, as discussed next.

It was emphasized that there is a need to cultivate mindsets that value long-term sustainability over immediate gratification. Educational campaigns and public discourse should emphasize the long-term environmental, economic, and social benefits of CE practices. By

shifting the focus from short-term gains to long-term benefits, individuals and organizations may become more inclined to adopt CE-related behaviors. To encourage participation in a CE, it is essential to highlight the positive emotional outcomes associated with sustainable practices. Publicity campaigns should focus on the joy, pride, and satisfaction derived from contributing to a sustainable future. Promoting these emotional rewards can motivate individual and collective actions toward CE. Policymakers need to craft and disseminate targeted messages that highlight the emotional and practical benefits of participating in a CE. These messages should be designed to resonate with diverse audiences and should be disseminated through various media platforms to ensure broad reach and engagement. The success of CE practices depends significantly on their ability to attract and retain participants. Strategies should include creating community-based programs that demonstrate the benefits of CE, thereby recruiting new adherents and sustaining existing practices through social proof and community endorsement.

Additionally, interviewees referred to the labor-intensive nature of CE practices. Training programs, therefore, can play a dual role. They equip individuals with the necessary skills to participate in CE and also serve as a medium to propagate CE values and principles. Continuous learning and development programs can help maintain high levels of qualification and adaptability among employees, fostering a workforce that is competent and supportive of circular practices. The implementation of CE practices creates new job opportunities, which can be leveraged to influence community behaviors and attitudes toward sustainability. By linking employment opportunities directly to circular practices, communities can see tangible benefits of engagement, which in turn can motivate further participation and support for CE initiatives.

In conclusion, as articulated by interviewee #7, every individual agent within the system can play a role thus effectively contributing to a CE and closing the loop.

> "having the ability to look upstream and downstream at a few gates on either side,"

7 | DISCUSSION OF FINDINGS

The objectives of this study were formulated, as follows: (1) identify the factors that impede the adoption and diffusion of technological innovations conducive to facilitating a transition to CE; (2) investigate how these constraints interact and contribute to the formation of system-level lock-ins within the socio-technical system of the AEC sector; (3) provide viable remedies aimed at addressing the system-level lock-ins. To this end, O'Brien's three spheres were taken as the theoretical lens by which to establish a clear and accessible framework for understanding the key areas of focus when addressing linear lock-ins in situations where a transition from current practices to sustainable ones is necessary. This framework is generally in alignment with various other theories and approaches, such as those found in the literature on the multilevel perspective, social-ecological transformations, social innovation, and social practice theory (Geels, 2011).

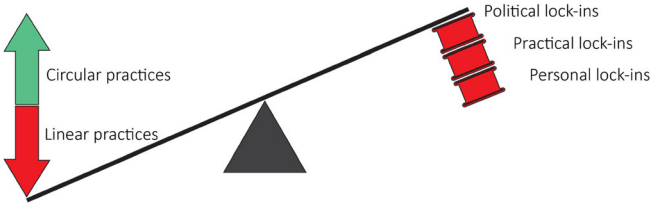

FIGURE 3 The stepwise approach to tackle lock-ins within the Australian AEC context.

In the realm of sustainable transitions, there has been a prevailing assumption that the political sphere holds the greatest leverage (O'Brien, 2018). This assumption is based on the belief that policies can significantly impact feedback loops, information dissemination, and, most crucially, the rules governing a system, particularly when those in positions of power possess the authority to modify these rules (Magnan & Michelon, 2024). Consequently, it is contended that the ability to influence these rules is of paramount importance, making political agency a central driver for addressing lock-ins and propelling transformative changes (O'Brien, 2015). The significant influence of political lock-ins has been consistently underscored in research examining the obstacles to transitioning to a CE within the Australian AEC context; in these studies a transition has often relied on regulatory interventions as a means to facilitate change (Chileshe et al., 2018; Shooshtarian et al., 2023). This acknowledgment is evidenced by the findings of the current study within the Australian AEC context (see Figure 3).

Nevertheless, past research argues that the most influential leverage points are associated with the system's objectives and the mindset or paradigm from which the system, including its objectives, structure, rules, delays, and parameters, emerges (He et al., 2024; Ødemark et al., 2024). This aspect primarily resides within the personal sphere, encompassing individual and collective notions of justice, desirability, and sustainability. These notions are shaped, modified, contested, or advocated for within the political sphere and translated into action within the practical sphere (O'Brien, 2015, 2018).

Findings of this study, specific to the Australian AEC context challenge this assumption. In this context, it becomes evident that addressing practical and political lock-ins is paramount. Relying solely on the influence of the personal sphere or considering it as the means to address the lock-ins in the practical and political spheres, does not yield the desired results. This perspective even contrasts with the prevailing discourse within the Australian context, which predominantly emphasizes the mitigation of personal lock-ins as a means of addressing lock-ins in other spheres (BWA, 2023; Li et al., 2018).

As depicted in Figure 3, it is essential to recognize that the resolution of personal lock-ins should follow the successful mitigation of political and practical lock-ins. In practice, when professionals are

actively engaged in addressing practical and political lock-ins, the focus should remain primarily on these aspects, while personal lock-ins should not be the immediate priority for intervention. This sequential approach aligns with the understanding that political and practical lock-ins often exert a more substantial influence on the prevailing system dynamics, including regulations, norms, and practices within the AEC industry (Brandão et al., 2022).

Recommendations of the study also have support from past research. Notably Osobajo et al. (2022) underscore the critical impact of manufacturer-led initiatives that have been previously undervalued but are essential for industry-wide transitions. Complementing this, Ali et al. (2023) recommend modular construction and material contingency planning as effective means to diminish waste and boost resource efficiency. Adding to this, Camilleri (2019) advocacy for prioritizing maintenance and repair over replacements offers a pathway to significantly reduce material waste and extend the functional life of buildings. Furthermore, Camilleri (2019) champions product-as-a-service (PSS) procurement models, which are in harmony with circular economy principles and promise to usher in enhanced operational efficiencies. Collectively, these research-backed recommendations form a robust framework for advancing sustainability in the AEC industry.

As for political lock-ins sphere the strategic importance of localizing infrastructure within Australia was recommended, to streamline onshore material processing. This localization not only fosters self-sufficiency but also addresses regional development imbalances. The dialogs with experts also pinpoint the necessity of strengthening inter-locality networks, thereby enhancing the socio-economic fabric across various Australian communities. Similarly, Battaglia et al. (2020) have advocated for this local-centric approach, along with the continuous exploration of innovative practices that serve to minimize adverse effects on local populations and the environment. Within the sphere of personal lock-ins, community engagement was deemed integral. Hao et al. (2020) have supported this insight and have emphasized the effectiveness of community-based programs that exemplify the merits of CE, advocating that such initiatives can garner support through social validation and local advocacy. These programs attract new followers and reinforce existing CE practices within the community. Additionally, establishing a direct correlation between CE-driven employment opportunities and community welfare was recommend as a pivotal strategy. Galarza-María et al. (2024) acknowledge this by witnessing that communities are likely to increase their participation and support where CE principles foster job creation, which in turn strengthens community backing for CE, thereby promoting a CE.

8 | PRACTICAL IMPLICATIONS

The findings offer a strategic, sequential roadmap to reduce or eliminate lock-ins impeding the transition to a CE within the Australian AEC sector. Once the political and practical barriers are effectively mitigated, the focus can shift toward personal lock-ins. This phased approach ensures that the structural and regulatory conditions are suitable for transformative changes and lays a solid foundation for integrating individual and collective shifts in mindset. Thus, by strategically realigning the focus from personal to practical and political barriers first, the AEC industry can establish a more robust platform for comprehensive and sustainable change. Consequently, by following this strategic, phased approach, the AEC sector can dismantle the most significant obstacles first, thereby enabling a more effective and sustainable adoption of CE principles. This methodical dismantling of lock-ins ensures that changes are deemed robust enough to endure, leading to a profound and lasting impact on the sector's goals for a transition to a CE.

9 | CONCLUSION

While the concept of a CE remains relatively novel in numerous contexts, there has been a sustained discourse exploring its various dimensions, particularly over the past decade in developed economies, such as Australia. Consequently, the existing body of literature in these countries has almost reached a point of saturation in its identification of the barriers and drivers that influence the transition toward a CE. This paper advocates for a departure from the current discourse—which predominantly centers on identifying barriers and challenges. Instead, it calls for a fresh perspective, one that views the process of transitioning toward a CE through the lens of linear lock-ins that sustain the prevalence of linear practices within the Australian AEC industry. By doing so, this article offers several noteworthy theoretical contributions to the field.

This study introduces the concept of linear lock-ins to the ongoing discourse concerning a transition to a CE within the AEC context. It is novel in advocating for a departure from the mere identification of barriers and challenges toward an approach that is informed by the concept of lock-ins and emphasizes strategies for their resolution. Furthermore, this study adapts and contextualizes the "three transformational spheres" framework, originally developed in a different context, to suit the specific needs of the Australian AEC sector. The components of each sphere within this customized framework are identified and presented to provide a tailored perspective for the Australian context. All these contributions offer a steppingstone for further research in the domain that rely on the concept of lock-ins rather than offering list of barriers.

Moreover, using the "three transformational spheres" framework, this study challenges a prevailing assumption within the sustainability transformation literature—which has been extended recently to the domain of CE. This assumption asserts the paramount importance of the personal sphere and advocates for prioritizing it as the primary driver of sustainable practices during a transition. In contrast, the findings of this study suggest a different approach, asserting that addressing practical and political lock-ins must precede the tackling of personal ones. The stepwise approach presented in this study is a novel contribution, offering a clear path for addressing lock-ins across the various spheres. This will likely stimulate lively discussions in the

field, helping to clarify the sequence for addressing linear lock-ins and paving the way for further research. Furthermore, future research endeavors could contribute to the maturation of this insight, to formulate a comprehensive roadmap for resolving linear lock-ins.

In practical terms, the findings of this study offer a reliable point of reference for practitioners and policymakers to identify and tackle the factors that hinder widespread transitions to a CE. The array of recommendations presented here adds further value, serving as a starting point for practical implementation.

Despite its contributions, some limitations of this study must be acknowledged. The sample size of interviewees, at just 15, is relatively small, suggesting the need for further studies with larger samples and diverse methods of data collection. Future research could include broad surveys employing statistical methods, such as structural equation modeling (SEM) to test the model proposed in this study. Additionally, while the collected data represent a broad and experienced diversity of experts, the range of views could be enriched by including representatives from additional industry sectors to provide further insight and nuance. Nevertheless, the expertise documented here serves as a significant foundation for designing and launching further research aimed at interrogating and validating the findings presented. Another limitation is that applying these findings to contexts beyond the Australian AEC sector should be approached with caution. Consequently, this research could be extended to other developed or developing countries that face similar lock-ins impeding the transition to a CE. This extension would test the applicability of the findings across various contexts. Furthermore, experts could be engaged to evaluate the likely efficacy of CE transition proposals developed through the O'Brien framework introduced in this study.

ACKNOWLEDGMENT

Open access publishing facilitated by The University of Melbourne, as part of the Wiley - The University of Melbourne agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ORCID

M. Reza Hosseini https://orcid.org/0000-0001-8675-736X

REFERENCES

ACE Hub. (2020). Strategic action plan 2020–23: Facilitating the transition to a circular economy. Retrieved from https://acehub.org.au/documents/strategic-action-plan-2020-23

Aida, H., Jenni, Y.-M., & Eva, P. (2021). Current status of circular economy research in Finland. *Resources*, *10*(5), 40. https://doi.org/10.3390/resources10050040

Ali, A. H., Kineber, A. F., Elyamany, A., Ibrahim, A. H., & Daoud, A. O. (2023). Identifying and assessing modular construction implementation barriers in developing nations for sustainable building development. *Sustainable Development*, *31*(5), 3346–3364. https://doi.org/10.1002/sd.2589

Aminoff, A., & Sundqvist-Andberg, H. (2021). Constraints leading to system-level lock-ins—The case of electronic waste management in the circular economy. *Journal of Cleaner Production*, *322*, 129029. https://doi.org/10.1016/j.jclepro.2021.129029

Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, *99*(394), 116–131. https://doi.org/10.2307/2234208

Atapattu, A. M. D. S., Hadiwattage, C., Perera, B. A. K. S., & Rajaratnam, D. (2024). Employing criteria scoring matrix in appraising the economic return of transcending to a circular built environment. *Smart and Sustainable Built Environment*, *13*(2), 267–290. https://doi.org/10.1108/SASBE-04-2023-0077

Battaglia, M., Annesi, N., Calabrese, M., & Frey, M. (2020). Do agenda 2030 and Sustainable Development Goals act at local and operational levels? Evidence from a case study in a large energy company in Italy. *Business Strategy & Development*, *3*(4), 603–614. https://doi.org/10.1002/bsd2.125

Bazeley, P. (2013). *Qualitative data analysis: Practical strategies*. Sage.

Bilal, M., Khan, K. I. A., Thaheem, M. J., & Nasir, A. R. (2020). Current state and barriers to the circular economy in the building sector: Towards a mitigation framework. *Journal of Cleaner Production*, *276*, 123250.

Brandão, R., Hosseini, M. R., Macêdo, A. N., Melo, A. C., & Martek, I. (2022). Public administration strategies that stimulate reverse logistics within the construction industry: A conceptual typology. *Engineering, Construction and Architectural Management*, *29*(8), 2924–2949. https://doi.org/10.1108/ECAM-07-2020-0547

Brenda Mutanu, M., & Nicholas, C. (2018). Towards sustainable infrastructure development: Drivers, barriers, strategies, and coping mechanisms. *Sustainability*, *10*(12), 4341. https://doi.org/10.3390/su10124341

BWA. (2023). Behavioural roadmap to circular consumption. Retrieved from https://www.behaviourworksaustralia.org/major-project/responsible-consumption-behavioural-roadmap-to-circular-consumption

Camilleri, M. A. (2019). The circular economy's closed loop and product service systems for sustainable development: A review and appraisal. *Sustainable Development*, *27*(3), 530–536. https://doi.org/10.1002/sd.1909

Cecere, G., Corrocher, N., Gossart, C., & Ozman, M. (2014). Lock-in and path dependence: An evolutionary approach to eco-innovations. *Journal of Evolutionary Economics*, *24*(5), 1037–1065. https://doi.org/10.1007/s00191-014-0381-5

Chileshe, N., Rameezdeen, R., Hosseini, M. R., & Lehmann, S. (2015). Barriers to implementing reverse logistics in south Australian construction organisations. *Supply Chain Management: An International Journal*, *20*(2), 179–204. https://doi.org/10.1108/SCM-10-2014-0325

Chileshe, N., Rameezdeen, R., Hosseini, M. R., Martek, I., Li, H. X., & Panjehbashi-Aghdam, P. (2018). Factors driving the implementation of reverse logistics: A quantified model for the construction industry. *Waste Management*, *79*, 48–57. https://doi.org/10.1016/j.wasman.2018.07.013

Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Łuniewska, M., Ruggieri, A., & Ioppolo, G. (2021). Enabling the circular economy transition: A sustainable lean manufacturing recipe for industry 4.0. *Business Strategy and the Environment*, *30*(7), 3255–3272. https://doi.org/10.1002/bse.2801

Commonwealth of Australia. (2018). Never waste a crisis: The waste and recycling industry in Australia/The senate, environment and communications references committee. Retrieved from https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/WasteandRecycling/Report

Corvellec, H., Zapata Campos, M. J., & Zapata, P. (2013). Infrastructures, lock-in, and sustainable urban development: The case of waste incineration in the Göteborg metropolitan area. *Journal of Cleaner Production*, *50*, 32–39. https://doi.org/10.1016/j.jclepro.2012.12.009

Crawford, R. H., Mathur, D., & Gerritsen, R. (2017). Barriers to improving the environmental performance of construction waste management in remote communities. *Procedia Engineering*, *196*, 830–837. https://doi.org/10.1016/j.proeng.2017.08.014

du Toit, J. L., & Mouton, J. (2012). A typology of designs for social research in the built environment. *International Journal of Social Research Methodology*, *16*(2), 125–139. https://doi.org/10.1080/13645579.2012.657013

European Parliament. (2022). Circular economy: definition, importance and benefits. Retrieved from https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits

Galarza-María, J., Díaz de Junguitu, A., & Labaien, I. (2024). Social dimension of the circular economy: Impact categories through fuzzy Delphi method. *Sustainable Development*, *32*(5), 4726–4737. https://doi.org/10.1002/sd.2933

GBCA. (2021). A circular economy discussion paper. Retrieved from https://new.gbca.org.au/news/thought-leadership/circular-economy-discussion-paper/

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Ghisellini, P., & Ulgiati, S. (2020a). Circular economy transition in Italy. Achievements, perspectives and constraints. *Journal of Cleaner Production*, *243*, 118360.

Ghisellini, P., & Ulgiati, S. (2020b). Managing the transition to the circular economy. In *Handbook of the circular economy* (pp. 491–504). Edward Elgar Publishing.

Goldstein, J. E., Neimark, B., Garvey, B., & Phelps, J. (2023). Unlocking "lock-in" and path dependency: A review across disciplines and socio-environmental contexts. *World Development*, *161*, 106116. https://doi.org/10.1016/j.worlddev.2022.106116

Greer, R., von Wirth, T., & Loorbach, D. (2021). The waste-resource paradox: Practical dilemmas and societal implications in the transition to a circular economy. *Journal of Cleaner Production*, *303*, 126831. https://doi.org/10.1016/j.jclepro.2021.126831

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105–117). Sage.

Gyimah, S., Owusu-Manu, D.-G., Edwards, D. J., Buertey, J. I. T., & Danso, A. K. (2024). Exploring the contributions of circular business models towards the transition of green economy in the Ghanaian construction industry. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-09-2023-0265

Halog, A., Balanay, R., Anieke, S., & Yu, T. Y. (2021). Circular economy across Australia: Taking stock of progress and lessons. *Circular Economy and Sustainability*, *1*, 283–301.

Hao, Y., Wang, Y., Wu, Q., Sun, S., Wang, W., & Cui, M. (2020). What affects residents' participation in the circular economy for sustainable development? Evidence from China. *Sustainable Development*, *28*(5), 1251–1268. https://doi.org/10.1002/sd.2074

He, J., Lin, Y., Hooimeijer, P., & Monstadt, J. (2024). Measuring social network influence on power relations in collaborative planning. *Cities*, *148*, 104866.

Herrfahrdt-Pähle, E., Schlüter, M., Olsson, P., Folke, C., Gelcich, S., & Pahl-Wostl, C. (2020). Sustainability transformations: Socio-political shocks as opportunities for governance transitions. *Global Environmental Change*, *63*, 102097. https://doi.org/10.1016/j.gloenvcha.2020.102097

Horne, R., Dorignon, L., Lawson, J., Easthope, H., Duhr, S., Moore, T., Baker, E., Dalton, T., Pawson, H., & Fairbrother, P. (2023). Informing a strategy for circular economy housing in Australia. Retrieved from https://www.ahuri.edu.au/research/final-reports/403

Hossain, M. U., Ng, S. T., Antwi-Afari, P., & Amor, B. (2020). Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. *Renewable and Sustainable Energy Reviews*, *130*, 109948. https://doi.org/10.1016/j.rser.2020.109948

Kabirifar, K., Mojtahedi, M., Changxin Wang, C., & Tam, V. W. Y. (2021). Effective construction and demolition waste management assessment through waste management hierarchy: A case of Australian large construction companies. *Journal of Cleaner Production*, *312*, 127790. https://doi.org/10.1016/j.jclepro.2021.127790

Kabirifar, K., Mojtahedi, M., & Wang, C. C. (2021). A systematic review of construction and demolition waste Management in Australia: Current practices and challenges. *Recycling*, *6*(2), 34.

Kevin van Langen, S., Vassillo, C., Ghisellini, P., Restaino, D., Passaro, R., & Ulgiati, S. (2021). Promoting circular economy transition: A study about perceptions and awareness by different stakeholders groups. *Journal of Cleaner Production*, *316*, 128166. https://doi.org/10.1016/j.jclepro.2021.128166

Langston, C., & Zhang, W. (2021). DfMA: Towards an integrated strategy for a more productive and sustainable construction industry in Australia. *Sustainability*, *13*(16), 9219.

Levitzke, P. S. M. V. (2020). The development of a circular economy in Australia. In S. K. Ghosh (Ed.), *Circular economy: Global perspective* (pp. 25–42). Springer.

Li, J., Zuo, J., Cai, H., & Zillante, G. (2018). Construction waste reduction behavior of contractor employees: An extended theory of planned behavior model approach. *Journal of Cleaner Production*, *172*, 1399–1408. https://doi.org/10.1016/j.jclepro.2017.10.138

Loosemore, M., Keast, R., & Alkilani, S. (2023). The drivers of social procurement policy adoption in the construction industry: An Australian perspective. *Building Research & Information*, *51*(5), 555–567. https://doi.org/10.1080/09613218.2023.2180344

Magnan, M., & Michelon, G. (2024). Corporate governance and corporate social responsibility: A reconciliation with tension. In M. Magnan & G. Michelon (Eds.), *Handbook on corporate governance and corporate social responsibility* (pp. 2–11). Edward Elgar Publishing.

Marino, A., & Pariso, P. (2020). Comparing European countries' performances in the transition towards the circular economy. *Science of the Total Environment*, *729*, 138142.

Martek, I., Hosseini, M. R., Shrestha, A., Edwards, D. J., & Durdyev, S. (2019). Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions. *Journal of Cleaner Production*, *211*, 281–292. https://doi.org/10.1016/j.jclepro.2018.11.166

McCarthy, A., Dellink, R., & Bibas, R. (2018). The macroeconomics of the circular economy transition. Retrieved from https://www.oecd-ilibrary.org/content/paper/af983f9a-en

Melles, G. (2021). Figuring the transition from circular economy to circular society in Australia. *Sustainability*, *13*(19), 10601.

Merriam, S. B. (2014). Qualitative research: A guide to design and implementation. Retrieved from http://deakin.eblib.com.au/patron/FullRecord.aspx?p=1662771

Nagatani, T., & Helbing, D. (2004). Stability analysis and stabilization strategies for linear supply chains. *Physica A: Statistical Mechanics and its Applications*, *335*(3–4), 644–660.

Nasir, M. H. A., Genovese, A., Acquaye, A. A., Koh, S., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. *International Journal of Production Economics*, *183*, 443–457.

Neuman, W. L. (2006). *Social research methods: Qualitative and quantitative approaches* (6th ed.). Pearson/Allyn and Bacon.

O'Brien, K. (2015). Political agency: The key to tackling climate change. *Science*, *350*(6265), 1170–1171. https://doi.org/10.1126/science.aad0267

O'Brien, K. (2018). Is the 1.5 C target possible? Exploring the three spheres of transformation. *Current Opinion in Environmental Sustainability*, *31*, 153–160.

O'Brien, K., & Sygna, L. (2013). Responding to climate change: The three spheres of transformation. *Proceedings of Transformation in a Changing Climate*, *16*, 23.

Ødemark, J., Resløkken, Å. N., Lillehagen, I., & Engebretsen, E. (2024). *The sociology of translation and the politics of sustainability: Explorations across cultures and natures*. Taylor & Francis.

Osobajo, O. A., Oke, A., Omotayo, T., & Obi, L. I. (2022). A systematic review of circular economy research in the construction industry. *Smart and Sustainable Built Environment*, *11*(1), 39–64. https://doi.org/10.1108/SASBE-04-2020-0034

Pandey, L. M. S., & Shukla, S. K. (2019). An insight into waste management in Australia with a focus on landfill technology and liner leak detection. *Journal of Cleaner Production*, *225*, 1147–1154.

Parry-Husbands, H., Zwart, J., Rice-Jenkins, B., Gilling, R., & Garofano, N. (2021). Circularity in Australian business: awareness, knowledge and perceptions. Retrieved from https://bit.ly/31vAdJJ

Pasqualotto, C., Callegaro-De-Menezes, D., & Schutte, C. S. L. (2023). An overview and categorization of the drivers and barriers to the adoption of the circular economy: A systematic literature review. *Sustainability*, *15*(13), 10532. https://doi.org/10.3390/su151310532

Peralta, M. E., Luna, P., & Soltero, V. M. (2020). Towards standards-based of circular economy: Knowledge available and sufficient for transition? *International Journal of Sustainable Development and World Ecology*, *27*(4), 369–386. https://doi.org/10.1080/13504509.2019.1701581

PwC Australia. (2021). Building a more circular Australia. Retrieved from https://www.pwc.com.au/environment-social-governance/building-a-more-circular-australia.html

Rameezdeen, R., Chileshe, N., Hosseini, M. R., & Lehmann, S. (2016). A qualitative examination of major barriers in implementation of reverse logistics within the south Australian construction sector. *International Journal of Construction Management*, *16*(3), 185–196. https://doi.org/10.1080/15623599.2015.1110275

Rodrigo, N., Omrany, H., Chang, R., & Zuo, J. (2024). Leveraging digital technologies for circular economy in construction industry: A way forward. *Smart and Sustainable Built Environment*, *13*(1), 85–116. https://doi.org/10.1108/SASBE-05-2023-0111

Rowley, J. (2012). Conducting research interviews. *Management Research Review*, *35*(3/4), 260–271. https://doi.org/10.1108/01409171211210154

Rynne, B. (2020). Potential economic pay-off of a circular economy for Australia. Retrieved from https://assets.kpmg.com/content/dam/kpmg/au/pdf/2020/potential-economic-pay-off-circular-economy-australia-2020.pdf

Shooshtarian, S., Hosseini, M. R., Kocaturk, T., Arnel, T., & Garofano, N. T. (2023). Circular economy in the Australian AEC industry: Investigation of barriers and enablers. *Building Research & Information*, *51*(1), 56–68. https://doi.org/10.1080/09613218.2022.2099788

Shooshtarian, S., Hosseini, M. R., Kocaturk, T., Ashraf, M., Arnel, T., & Doerfler, J. (2021). *The circular economy in the Australian built environment: The state of play and a research agenda*. Deakin University.

Singh, J., Pandey, K. K., Kumar, A., Naz, F., & Luthra, S. (2022). Drivers, barriers and practices of net zero economy: An exploratory knowledge based supply chain multi-stakeholder perspective framework. *Operations Management Research*, *16*, 1059–1090. https://doi.org/10.1007/s12063-022-00255-x

Sopjani, L., Arekrans, J., Laurenti, R., & Ritzén, S. (2020). Unlocking the linear lock-in: Mapping research on barriers to transition. *Sustainability*, *12*(3), 1034.

Stefan, S., Iva, K., & Helmut, R. (2022). Assessment of sustainable use of material resources in the architecture, engineering and construction industry—A conceptual framework proposal for Austria. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*, 1–21. SDEWES Centre.

Svingstedt, A., & Corvellec, H. (2018). When lock-ins impede value co-creation in service. *International Journal of Quality and Service Sciences*, *10*(1), 2–15. https://doi.org/10.1108/IJQSS-10-2016-0072

Teo, M. M. M., & Loosemore, M. (2001). A theory of waste behaviour in the construction industry. *Construction Management and Economics*, *19*(7), 741–751. https://doi.org/10.1080/01446190110067037

Udawatta, N., Zuo, J., Chiveralls, K., Yuan, H., George, Z., & Elmualim, A. (2018). Major factors impeding the implementation of waste management in Australian construction projects. *Journal of Green Building*, *13*(3), 101–121. https://doi.org/10.3992/1943-4618.13.3.101

Udawatta, N., Zuo, J., Chiveralls, K., & Zillante, G. (2015). Improving waste management in construction projects: An Australian study. *Resources, Conservation and Recycling*, *101*, 73–83. https://doi.org/10.1016/j.resconrec.2015.05.003

Upadhyay, A., Laing, T., Kumar, V., & Dora, M. (2021). Exploring barriers and drivers to the implementation of circular economy practices in the mining industry. *Resources Policy*, *72*, 102037. https://doi.org/10.1016/j.resourpol.2021.102037

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, *168*, 487–498. https://doi.org/10.1016/j.jclepro.2017.09.047

Van Bueren, B. J. A., Iyer-Raniga, U., Argus, K., & Leenders, M. A. A. M. (2022). Closing the loopholes in circular economy definitions and assessments using ontological criteria, with a demonstration for Australia. *Resources, Conservation and Recycling*, *186*, 106554. https://doi.org/10.1016/j.resconrec.2022.106554

Van Bueren, B. J. A., Iyer-Raniga, U., Leenders, M. A. A. M., & Argus, K. (2021). Comprehensiveness of circular economy assessments of regions: A systematic review at the macro-level. *Environmental Research Letters*, *16*(10), 103001. https://doi.org/10.1088/1748-9326/ac209c

WGBC. (2024). Sustainable building certifications. Retrieved from https://worldgbc.org/sustainable-building-certifications/

Wijewickrama, M., Rameezdeen, R., & Chileshe, N. (2021). Information brokerage for circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *313*, 127938.

Wojtynia, N., van Dijk, J., Derks, M., Groot Koerkamp, P. W. G., & Hekkert, M. P. (2023). Spheres of transformation: Exploring personal, political and practical drivers of farmer agency and behaviour change in The Netherlands. *Environmental Innovation and Societal Transitions*, *49*, 100776. https://doi.org/10.1016/j.eist.2023.100776

Wuni, I. Y. (2023). A systematic review of the critical success factors for implementing circular economy in construction projects. *Sustainable Development*, *31*(3), 1195–1213. https://doi.org/10.1002/sd.2449

Ylä-Mella, J., Keiski, R., & Pongrácz, E. (2022). End-of-use vs. end-of-life: When do consumer electronics become waste? *Resources*, *11*(2), 18. https://doi.org/10.3390/resources11020018

How to cite this article: Hosseini, M. R., Memari, S., Martek, I., Kocaturk, T., Bararzadeh, M., & Arashpour, M. (2024). Dismantling linear lock-ins in the Australian AEC industry: A pathway to a circular economy. *Sustainable Development*, *32*(6), 7171–7185. https://doi.org/10.1002/sd.3082