Unlocking the Power of the Circular Economy in the Australian AEC Industry

A Journey through Attitudes, Barriers and Enablers

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AUSTRALIAN CIRCULAR ECONOMY HUB PLANETARK

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Executive summary

The architecture, engineering and construction (AEC) industry can be a major driving force towards achieving a circular economy (CE) in Australia. It contributes up to 9% to the country's gross domestic product (GDP) and has an anticipated annual growth rate of 2.4%.

However, the industry also has a reputation for a relatively low resource efficiency. Various avenues are being explored to address the issue, with one option being a shift toward the CE. Policy makers, researchers and practitioners agree on the benefits of adopting CE practices within the AEC industry context and widely recognise its potential for shifting the industry towards sustainable practices. However, for its widespread adoption, relevant stakeholders' perceptions of the concept must first be identified. Hence, this report aims to present stakeholders' perceptions about a transition to CE adoption and to identify the main barriers and enablers affecting its adoption in the Australian AEC industry context. To this end, the report provides an account of a research study that relies on a mixed-methods approach. The data were collected through semi-structured interviews and a questionnaire survey administered among key stakeholders associated with CE in the Australian AEC industry. The survey resulted in 132 duly completed responses with 10 interviews providing additional insights that complemented the survey results.

The report can inform policy development activities and provides the foundation for a roadmap to enhance CE adoption in the Australian AEC industry with a discussion on the following key findings:

1. Most Australian stakeholders have a basic understanding of the meaning of the CE concept and the requirements for a transition to its adoption. However, few possess adequate knowledge to move to the stage of CE adoption and application in their businesses and organisations. A lack of practical guidelines, use cases and workable solutions is highlighted within the Australian context.

2. Most Australian stakeholders realise that adopting a CE is an indication of their commitment to business ethics and a vehicle to improve management, benefits and the reputation of their organisations.

3. The top three barriers are reported as: 'a lack of incentives', 'a lack of specific regulations' and 'a lack of knowledge'.

4. The top three enablers are reported as: 'research and development (R&D) of enabling technologies', 'education of project stakeholders' and 'provide evidence of CE's added value'.

5. Awareness of CE among study participants has a significant impact on adoption, as demonstrated by a statistically significant association with key CE adoption indicators, comprising willingness to apply a CE, actual adoption, agreement on a CE as a component of business ethics and perceived CE benefits. Therefore, raising awareness of CE among stakeholders may serve as an effective strategy for promoting its adoption within organisational contexts.

The report presents a series of recommendations and calls to action for key stakeholders in the domain, emphasising the need for a cohesive and collaborative approach to effectively address barriers and enhance the impacts of enablers.

This report is structured into six sections as follows:

1. Introduction provides the background, a brief overview of the problem, the aim and objectives, and the significance of this study.

2. Contextual background provides an overview of the Australian AEC industry in terms of its economic significance and environmental impact and introduces the CE as an alternative approach to production. This section concludes with a summary of the key barriers to and enablers of the CE in other sectors of the economy and other countries, as identified in past research. The section underlines a need for a comprehensive updated picture of the landscape of CE adoption in the Australian AEC industry.

3. Research methods describes the details of the mixed-methods approach employed to explore various dimensions of CE adoption within the Australian AEC industry.

4. In Findings, the survey results are discussed, including participants' profiles, awareness and intention to adopt a CE, business considerations in CE adoption, ranking of barriers and enablers, key players and the generalisability of results.

5. Discussion critically analyses findings in the context of the Australian and international literature and provides workable recommendations to inform practitioners, policy makers and researchers to facilitate a transition towards the CE in the Australian AEC industry.

6. In Concluding remarks, a summary of the study's findings is provided within the broader context, its contributions are highlighted, its potential limitations are acknowledged and future research areas are identified.

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List of acronyms

10R framework	refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover and remine
ACE	Australian Circular Economy (Hub)
AEC (industry)	architecture, engineering and construction
BIM	Building Information Modelling
C&D	construction and demolition
C2C	cradle to cradle (model)
CE	circular economy
CEMAG	Circular Economy Ministerial Advisory Group
EMF	Ellen MacArthur Foundation
EPD	Environmental Product Declaration
EPR	extended producer responsibility
GBCA	Green Building Council of Australia
GDP	gross domestic product
GHG	greenhouse gas
GS	Green star certification
IT	information technology
KPI	key performance indicator
NSW	New South Wales
NWR	National Waste Report
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
RII	Relative Importance Index
SA	South Australia
SPSS	IBM SPSS Statistics (software)
UK	United Kingdom
US/USA	United States/United States of America
Vic	Victoria

Glossary

Barriers:
Barriers stop interested parties from taking on practices or actions that assist the transition to a CE, in the form of unfavourable behavioural controls or contextual factors [1].

Enablers:
Enablers refer to all positive reinforcements that are essential to promote, motivate and enhance the success of CE adoption in a particular context [2].

Industry project management teams:
The industry project management teams are the group of project management professionals within a business organisation who are responsible for planning, executing and controlling projects related to the industry or sector in which the business operates.

Industry associations:
Industry associations represent a group of businesses or industries with similar interests, objectives or needs. For example, the Green Building Council of Australia (GBCA) is an industry association that promotes sustainable building practices and supports businesses in the building and construction industry.

1

Introduction

The architecture, engineering and construction (AEC) industry plays a pivotal role in driving the Australian economy. With direct employment of approximately 1.2 million Australians, it stands as the largest non-services industry within the economy.

Furthermore, the AEC industry is renowned for its significant secondary job creation effects, as every job within the sector leads to the creation of three additional jobs in the broader economy [3]. Despite these benefits, the Australian AEC industry has been widely criticised for its low resource efficiency [4]. The industry is also infamous for its unsustainable practices that adversely affect the environment, the community and the economy [5, 6]. To address these issues, one option for Australia is to transition towards a CE which has the potential to strengthen the sustainability of the AEC industry [7, 8]. The term 'CE', to date, has been defined in various ways [2, 9]. The definition of a CE has been the subject of debate, with various suggestions proposed. However, the definition provided by the Ellen MacArthur Foundation (EMF) has gained widespread recognition and adoption among researchers, practitioners and government officials. According to the EMF, a CE is characterised by its restorative or regenerative nature, with its aim being to maintain the value of products, materials and resources for as long as possible within the economy [10]. The European Parliament provides a more concise definition of a CE as a production and consumption model that emphasises sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products to extend their life cycle. This approach promotes the circular flow of resources and materials, as well as reducing waste, pollution and carbon emissions [11].

In the AEC industry context, the CE refers to an economic system that extends beyond the conventional 'end-of-life' ethos [12]. The current focus of a CE in the AEC industry is on minimising waste and optimising the use of resources through practices such as creative repurposing, recycling and salvaging of materials , design for disassembly and distribution and consumption processes. By retaining materials in the cycle for as long as possible, natural resource exploitation in projects can be reduced [2, 9, 12].

The importance of sustainable practices has gained momentum in Australia, leading to an increased interest in the adoption of a CE as one tool to help achieve sustainability goals. This interest stems from a growing recognition of the necessity for environmental sustainability [13, 14, 15]. The benefits of adopting a circualr economy approach within the AEC industry context are widely recognised and acknowledged by both practitioners and researchers, due to its potential to shift the AEC industry towards more sustainable practices [14, 16]. In reality, neither widespread CE adoption within the AEC industry nor the envisaged systemic transition have occurred [17, 18, 19]. This has primarily been attributed to the challenging regulatory, political, social and practical context surrounding the adoption process [20, 21]. Indeed, it is essential to identify the barriers and potential enablers in order to facilitate CE adoption. A thorough understanding of the perceptions of relevant stakeholders associated with adopting sustainability solutions, including a CE, is a prerequisite for its integration into AEC industry practices [22, 23, 24]. In the context of implementing a CE, it is crucial to understand how the relevant stakeholders perceive this innovative idea. Only by doing so, as argued by Shooshtarian et al. [25], can interventions be designed that facilitate CE adoption within a specific context.

Prior research has focused on the 'why' question of the transition towards a CE, while only a limited number of studies have addressed the 'what' and 'how' questions of CE transition in the AEC industry context. Accessible scholarly literature is also lacking on this topic in the Australian context. Therefore, this report aims to fill this gap by providing an overview of the current state of CE adoption in the AEC industry in Australia, highlighting barriers and enablers, and assessing stakeholder perceptions. The aim of this report is to provide a contemporary overview of CE adoption among relevant stakeholders in the Australian AEC industry. Specifically, this report seeks to achieve the following objectives:

- Identify the primary barriers hindering CE adoption in the Australian AEC industry.
- Explore the key enablers that can facilitate CE adoption in the Australian AEC industry.
- Evaluate the understanding and perceptions of relevant stakeholders on the various aspects of the CE in the AEC industry in Australia.

2

Contextual background

2.1 The Australian AEC industry

The architecture, engineering and construction (AEC) industry is one of the largest sectors of the global economy [26]. This industry is a significant contributor to the global economy, with construction-related expenditure accounting for 13% of gross domestic product (GDP) worldwide.

The industry generates approximately US$10 trillion in total annual revenue and is projected to reach US$14 trillion by 2025 [26, pp. 1-2]. The Australian AEC industry plays a significant role in the national economy, contributing up to 9% of the country's GDP in 2021, with this expected to grow at an annual rate of 2.4%. With such a substantial impact, it is essential that the industry considers sustainable practices [27]. The AEC industry also accounts for almost 9% of the Australian workforce, with a notable secondary job-creation impact, as every job in the industry leads to the creation of three more jobs in the broader economy [28, 29].

From this perspective, a crucial question arises: considering the significant role of the Australian construction industry in contributing to the economy and society, how can its performance be improved on a national scale? [30, 31]. The question is particularly relevant given the AEC industry's notorious reputation for unsustainable practices that cause significant environmental impact.

2.1.1 Materials consumption

One impact of AEC industry activities is related to the intensity of their consumption of materials. Approximately one-third of all raw materials consumed are attributed to the construction of built assets [32]. This includes one-third of all timber, one-sixth of all water and 40% of everything else [33]. This is also true for the Australian AEC industry. Australia has one of the highest per capita materials footprints in the world [34]. In 2019, the total materials footprint of Australia was just over 1,000 million tonnes, around 40.6 tonnes per capita [35].

Construction accounts for approximately one-quarter of these materials [36]. It is no surprise that the AEC industry is now experiencing a scarcity of resources. In addition to the depletion of natural resources, the extraction and processing of raw materials for building construction is highly intensive in terms of energy, water and land, leading to a detrimental impact on both the climate system and biodiversity [37].

2.1.2 Waste production

One consequence of the activities of the AEC industry is the generation of waste flows. Building construction and demolition (C&D) activities create nearly half the world's waste [38]. According to Blue Environment's "Australian National Waste Report (NWR) 2020" [39], Australia creates 27 megatonnes (mt) of C&D waste per year, a 61% rise from the amount tallied in 2006–2007, comprising Australia's most sizable waste source. With China's limitations on waste imports, prohibition of certain foreign waste materials and imposition of stricter restrictions, pressure on Australian landfill sites has increased. Although official statistics report that 76% of C&D waste in Australia is recycled, the recycling rates are far from optimum, with a massive increase essential to counter the negative effects of landfill, such as habitat destruction, the use and degradation of land, and contamination of soil and groundwater [40]. Moreover, the quality and value of recycled materials are not adequately preserved. For example, many reusable building materials, such as plasterboard, are rarely recovered owing to the use of non-removable finishes or toxic substances.

As a result, the bulk of C&D waste ends up in mixed debris which is usually broken down into granulates for primary use as a filler in roads and building foundation works.

2.1.3 Greenhouse gas (GHG) emissions

A third impact of AEC industry activities comprises energy-related greenhouse gas (GHG) emissions associated with not only buildings' operation but also their construction. Buildings consume half of all energy used worldwide to support occupants' requirements, such as heating, lighting, etc., while a further 10% of energy is used to produce building products [41]. In the Australian context, buildings contribute significantly to annual carbon emissions, accounting for approximately 25% of total emissions. This highlights the urgent need for the Australian AEC industry to adopt sustainable practices to reduce its environmental impact [42]. Additionally, the AEC industry's GHG emissions have been reported to be higher in comparison to similar countries [43].

To counter these different types of detrimental impact, the AEC industry must be radically transformed from its traditional take, make and 'dispose of' attitude. Governments at both federal and state levels in Australia have acknowledged the potential advantages of adopting the CE model and are committed to facilitating its implementation. This is evident in the 2018 report titled "Never Waste a Crisis: The Waste and Recycling Industry in Australia", in which the Senate's Standing Committees on Environment and Communications recommended the "establishment of a CE in which materials are used, collected, recovered, and re-used, including within Australia" as a priority for the Australian government [44, p. 5]. They recommended that these initiatives extend beyond conventional waste management practices, instead focusing on promoting sustainable design strategies to foster a CE [45]. Despite widespread recognition of the advantages of the CE approach, anecdotal evidence suggests that its adoption has not occurred on a large scale, nor has the intended systemic change taken place in the sector [4].

2.2 Circular economy (CE) as an alternative approach

2.2.1 The circular economy (CE) concept

The current CE model has its roots in concepts from the 1970s. It is heavily influenced by the Club of Rome's limits to growth theory [46]; biomimicry [47]; industrial ecology [48]; industrial symbiosis; McDonough et al.'s cradle to cradle model [49]; and Lyle's regenerative design model [50]. The CE concept has gained prominence in recent years through the work of the Ellen MacArthur Foundation (EMF), a global thinktank dedicated to advancing CE transition [51]. The EMF's "butterfly" diagram, distinguishing between biological and technical cycles, is widely used to communicate how the CE system functions.

The CE concept pertains to a circular system of resource flows, where waste is managed as a valuable commodity that circulates continuously within an economy [52]. It aims to transfer the linear economic model of taking resources, making products and then throwing away waste into one where waste and pollution are eliminated, materials are circulated and nature is regenerated [53]. Kirchherr et al. [9, p. 224] upon reviewing 114 definitions, defined the CE as an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes '…' with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.

Circular strategies are central to the CE concept and are usually grouped within R frameworks [54]. The 10R framework is shown in Table 1. It consists of the 10R strategies: "refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, and remine" [54]. These strategies can be used in parallel or in combination to narrow, slow or close resource loops [55].

Table 1: The 10R framework (adapted from [9, 54])

Narrowing Resource Loop	R0: Refuse	Make production redundant
	R1: Reduce	Increase production efficiency
	R2: Reuse	Use products again (directly)
Slowing Resource Loop	R3: Repair	Repair products to bring them back to working order
	R4: Refurbish	Revive products to bring them up to state of the art
	R5: Remanufacture	Make new products from second-hand products
	R6: Repurpose	Reuse products for another function
Closing Resource Loop	R7: Recycle	Process materials for the best possible value
	R8: Recover	Incinerate materials with energy recovery
	R9: Remine	Retrieve materials in landfill

Increasing circularity

The hierarchy in the priority of these strategies is based on the extent to which they retain the value of the resource. For example, it is more resource efficient to reuse a serviceable brick than to break it down for recycling.

Despite varying perspectives on the CE concept, the general consensus is that it presents an effective method of resource management. The CE model has been applied in various sectors, including the supply of electrical and electronic equipment, automotive manufacturing and the AEC industry [56].

2.2.2 The circular approach to construction

In recent years, momentum has been growing towards wider CE adoption in the AEC industry, as promoted by numerous national and international organisations worldwide [2, 10]. The unprecedented global attention on CE adoption has contributed to a similar level of interest within the Australian AEC industry context [4]. A CE approach in the AEC industry adheres to a built environment that is designed to retain value over time, is tailor-made for specific service lives and is responsive to potential disruptions [57]. It operates on multiple implementation scales, from micro scale (products, components) to meso scale (buildings, eco-industrial parks) and macro scale (cities, built environment) [58], as illustrated in Figure 1. Consequently, CE implementation in the AEC industry requires a systemic perspective that extends beyond the boundaries of scale and touches on a myriad of practices across the life cycle of the industry's assets (see Figure 2 for examples). Therefore, CE implementation in the AEC industry could be hindered by various obstacles; however, it is important to note that as barriers appear, enablers are also found.

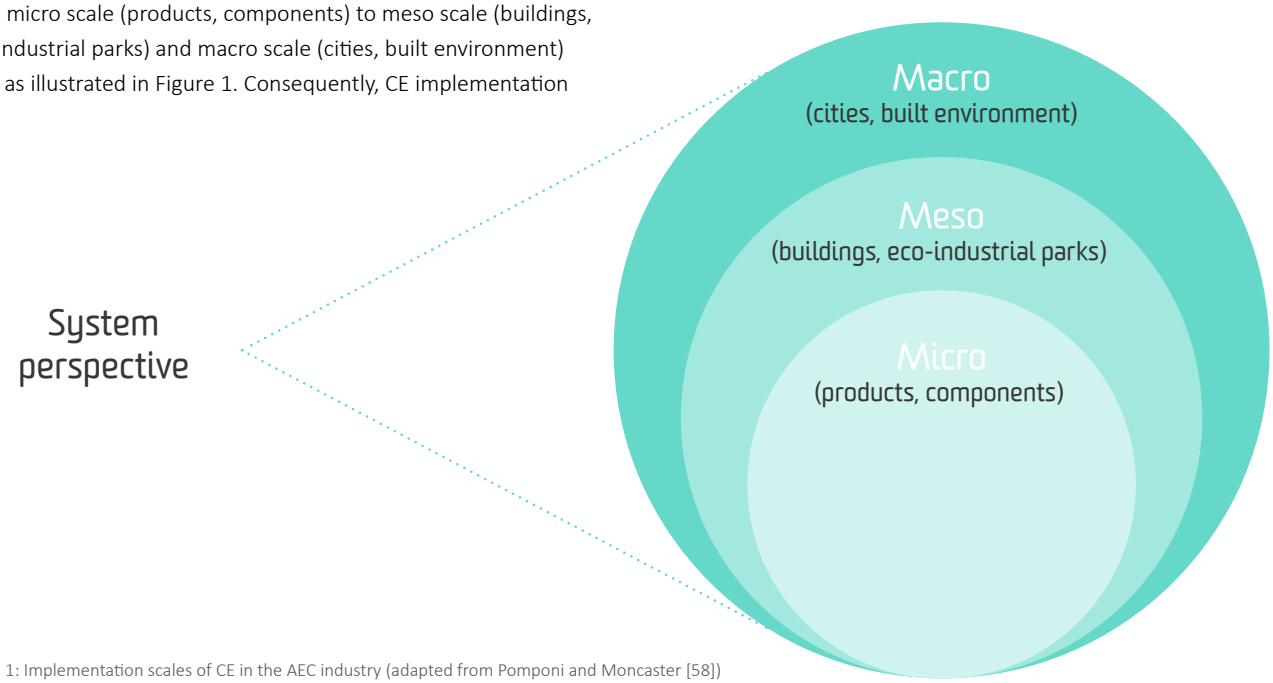


Figure 1: Implementation scales of CE in the AEC industry (adapted from Pomponi and Moncaster [58])

Circular Economy Practices

Project Design

- Design and use of modular buildings
- Design for disassembly of building structures
- Design for adaptability of existing buildings
- Use of a simulation in a BIM model to analyse the reuse potential of the materials of different types of designs early in the project
- Use of life cycle analysis to find the benefits of reusing different types of materials in the design stage
- Use of materials stock data to help reuse of materials of a new building
- Anticipate changes in requirements

Manufacture

- Change of use of materials by giving its ownership to the manufacturers to reuse the materials after the end of life of the first building
- Reuse of secondary materials in the production of building materials
- Development of material passports

Construction

- Reuse of building materials in a new construction
- Waste reduction
- Off-site construction
- Prescribe in procurement contracts that waste should be seperated on site to facilitate recycling
- Favour construction systems that incorporate CE thinking
- Conserve, update and share information so that it can remain valid and relevant during the whole life cycle of the building

Operation

- Use of a tool to evalutate the state of materials during the lifespan and end of life of a building
- Use of water management practices
- Minimise recuperative maintenance with preventive maintenance

End of life

- Analyse the potential for reuse or recycling of existing materials and it's feasibility compared to using new materials
- Management of demolition waste
- Use of a circularity tool to evaluate existing buildings and give the best possible solutions to refurbishment
- Deconstruction of building structures and parts
- Ask for detailed information from providers and designers or products, materials and the design of buildings

Figure 2 illustrates CE priority practices during the five stages of a construction project's life, namely, project design, manufacture, construction, operation and end of life.

2.3 Barriers to and enablers of the transition to a circular economy (CE)

In recent years, the number of studies focusing on the CE concept has significantly increased, garnering unprecedented interest and support from various national and international organisations worldwide. The AEC industry has not been exempt from this trend, as interest is growing in exploring CE implementation within this sector. Table 2 summarises the key barriers to and enablers of CE in the AEC industry, as identified in other countries.

Table 2: Key barriers to and enablers of the CE in the AEC industry

Barriers	Enablers	Context	Reference
Organisational; Information technology (IT); Infrastructure and logistics; Economic and market; and Regulatory.	-	global	Oluleye et al. [59]
Additional costs; Lack of market mechanisms; Societal trends; Lack of awareness and demand; and Culture and attitude.	-	United Kingdom (UK)	Charef et al. [23]
Lack of an incentive to design for end-of-life issues; Lack of market mechanisms to aid greater recovery; Unclear financial case; and Fragmented supply chain.	Clear business case, Assurance arrangements for reused materials; and Best practice examples.	UK	Adams et al. [17]
Budget and upfront costs; Schedule and project timeline; Lack of awareness and change resistance; Current construction business model; and Lack of regulations and implementation guidelines.	Education and cultural change; Data availability; Policies and market-based incentives; and Popularisation of new voluntary stewardship programs.	United States (US)	Guerra and Leite [2]
Lack of incentives for supply chain actors to make a change towards circularity; Lack of mutual interests between supply chain actors; High uncertainties and risks; and Clashes of perceptions on all levels in supply chains.	Incentives from the government; and New technologies.	Netherlands	Schraven et al. [60]
Low understanding of the CE among stakeholders; and Required information, storage and disclosure.	Engagement and networking among key players; and Establishment of financial incentives and platforms for materials circularity.	Taiwan	Chang and Hsieh [61]
Lack of supportive regulations; Lack of qualified professionals; Lack of circularity knowledge, interest and vision; Lack of innovation and proper technical resources; and Uncertainty and unclear financial case.	-	Oman	Al Hosni et al. [62]
Lack of environmental regulations and laws; Lack of customer/public awareness; Lack of support/ backing from public institutions; and Inadequate financial resources.	Focus on strategies that can help overcome these barriers.	Developing countries	Bilal et al. [20]
Lack of awareness and low-level self-consciousness; Outdated standards; Lack of qualified personnel; and Economic barriers.	-	Kazakhstan	Torgautov et al. [63]

Numerous studies in Australia have outlined the prerequisites for transitioning to a CE, highlighting the necessity of resource efficiency and waste recovery to achieve sustainable development [13, 15, 21]. In their review study, Ogunmakinde et al. [64] argued that 14 concepts should be recognised as CE pillars in construction. Halog et al. [15] provided an overview of CE adoption in Australia, highlighting that different states and territories have taken various approaches with varying levels of similarity and difference. They emphasised that some states and territories are more advanced than others in terms of their stages of development and implementation. Through their systematic literature review, Shooshtarian et al. [65] identified opportunities for and barriers to reducing C&D waste disposal across various life cycle stages of construction materials for the Australian AEC industry. As an industry group, the Australian Circular Economy (ACE) Hub [21] highlighted the challenges impeding the transition to a CE in the Australian context, with these identified as lack of awareness and insufficient regulations and incentives. Recently, a survey identified inadequate knowledge, lack of capital and uncertainty about returns on investment as the top three barriers to implementing CE practices in organisations [13]. Likewise, Wijewickrama et al. [8] underlined the challenges associated with a lack of information across the supply chain as a major obstacle that hinders efforts towards wider CE adoption.

Another research stream in Australia has focused on identifying the fundamental dimensions of transitioning towards a CE and has outlined related challenges and opportunities. These fundamental dimensions comprise: extended producer responsibility (EPR); building energy efficiency [66]; industrial symbiosis [67]; C&D waste cross-jurisdictional materials trading [68]; China's waste policy [69]; waste interstate mobility [70] and waste diversion rate [71]; application of a cloud–BIM platform for C&D waste reuse [72]; multidisciplinary research opportunities [4]; and collaboration and knowledge sharing with other countries [73]. However, to enhance the understanding of CE implementation in the Australian AEC industry, a comprehensive and updated depiction is required.

3

Research Methods

Overall, the current study's chosen methods relied on data collected via a survey and complementary semi-structured interviews to allow for the triangulation of both qualitative and quantitative data.

Known as a mixed-methods approach, and also titled the "third methodological movement" [74, p. 22], this approach is regarded as one of the most effectual methods for conducting research in the fields of management and organisational arenas through combining qualitative and quantitative methods [75, 76]. The key advantage of mixed-methods research is its methodological pluralism, frequently resulting in superior research compared to research using mono-method designs [77] and yielding stronger inferences [76]. In other words, drawing on one method for collecting data might not be adequate, as worthwhile findings can be achieved when results are based on diverse converging methods [78]. According to Teddlie and Tashakkori [79], the mixed-methods approach provides better opportunities to answer research questions and assists researchers to evaluate the 'goodness' of their findings. By combining qualitative and quantitative methods, researchers are able to capitalise on the strengths of the two approaches, compensating for each approach's weaknesses and drawbacks [80, 81].

When designing a mixed-methods approach, a myriad of designs, sequences and orientations are suggested by investigators [79]. However, the most effective design for a mixed-methods study is the one that best suits the nature of the research questions to be asked and the purposes defined as the study's driving forces. According to the literature, various mixed methods can be employed in this approach. Both quantitative and qualitative methods are applied with equal priority or one method may be favoured over the other. Additionally, they can be conducted in parallel or one after the other. Sequential research methods involve conducting a qualitative phase, then a separate quantitative phase, or the other way round. In this way, it is easier to explain and interpret the findings of the former technique with the help of the latter. For example, a researcher can use the QUAN→QUAL sequence, in which the study starts with the collection of quantitative data, followed by qualitative data collection, with qualitative findings used to explain quantitative results, to complement them and to triangulate with them [75]. Past research has shown that moving from quantitative data to qualitative data is the dominant sequence when using the mixed-methods approach. This approach, termed 'explanatory design', is used in the current research study with the researchers first collecting and analysing quantitative data, then building on their findings through a qualitative follow-up. The qualitative part – mostly interviews with experts – is used to complement and provide a better understanding of the quantitative results. The qualitative follow-up is conducted to triangulate the study findings – typically from the survey data – and to generate further understanding of the underlying phenomenon [75, 82].

A research framework informed the current research journey (Figure 3). This framework consists of four stages that outline how the research objectives were met.

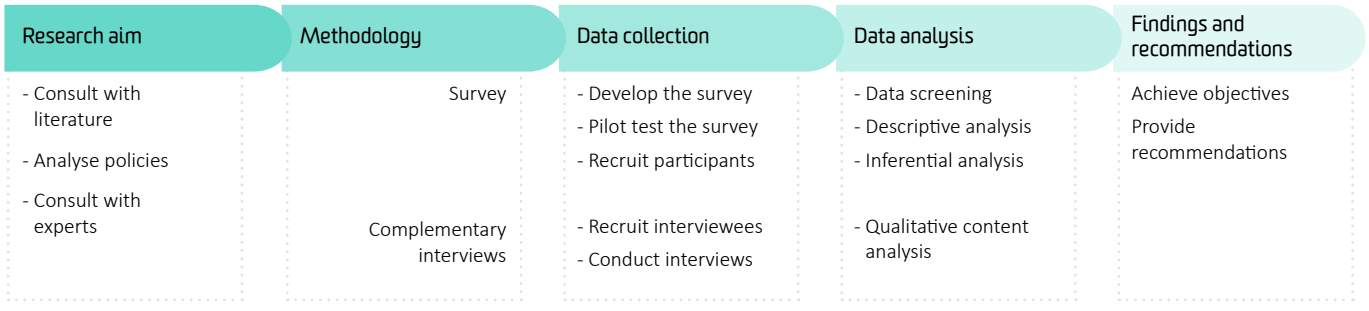


Figure 3: Research process and design

3.1 Data collection

3.1.1 Survey

A survey is a robust, ubiquitous method used in the research field for the collection of perceptions from a population of interest about variables and factors that are deemed, in this case, to be similar across the built environment in a certain context [83]. A survey can be conducted in many available forms, with the ubiquity of questionnaire surveys attesting to their proven effectiveness and ease of use [84], especially when the purpose of data collection is to generalise the findings across a specific setting [83, 85].

The current study's survey questionnaire was structured as two parts: the first part gathered demographic information from participants, while the second part focused on factors that may influence CE adoption in the AEC industry. Ethics approval was obtained from the Deakin University Human Research Ethics Committee (study number 426931-A). Prior to conducting the survey, a pre-testing phase was carried out among a group of five experts, with the feedback received incorporated to improve the clarity of questions. The number of questions was reduced, with terms changed to align with commonly used language within the construction industry. The online platform Qualtrics was utilised to conduct the survey. To gather data from companies in the AEC industry, direct contact was made through website addresses and regulatory body lists. Stratified random sampling was employed to increase the likelihood of representing the population (see Robson [86, p. 262]). The sample for the study was drawn using a stratified approach, comprising architects, engineers, design consultants and contractors. The sample pool included 780 architectural companies, 1,508 contractors and 750 engineering design firms. In total, 203 questionnaires were filled in by the end of September 2021, 132 of which met the predetermined threshold of 85% completion rate, thus serving as the basis for subsequent data analyses. Given the novelty of the topic, the response rate was deemed acceptable. However, it is worth noting that response rates as low as 10–12% are not uncommon in construction management research [87].

The internal consistency and reliability of the questionnaire items were assessed using Cronbach's alpha coefficient, a widely used statistical measure. The values obtained for the enablers and barriers groups were 0.99 and 0.98, respectively, both well above the threshold of 0.7 that is considered acceptable for research in the AEC industry context [88].

3.1.2 Interviews

As asserted by du Toit and Mouton [89], one of the most effective methods for elucidating experts' experiences and practices in their natural context is conducting interviews as a qualitative data collection technique. In fact, interviews are the most widely used method of data collection for qualitative research studies [90], particularly for the qualitative part of mixed-methods studies [74]. To select interviewees, a purposive sampling strategy was used, with this referred to as "... sampling in a deliberate way, with some purposes or focus in mind" [80, p. 187]. Through researching the social media platform LinkedIn, company websites and members of the ACE Hub platform, a list of CE experts was created. Those who expressed keen interest in being interviewed were then selected from that list to be the final interviewees. By following this strategy, high-quality data were acquired due to the enthusiasm of interviewees to take part in the research. Purposive sampling should be used to gather qualitative data from highly knowledgeable individuals who have an extensive understanding of the topic and are passionate to contribute to the research. Through this approach, the individuals who are most willing to engage in the topic and have an openness to that topic can be identified [91].

As shown in Table 3, this process resulted in 10 practitioners as interviewees, all of whom had experience in adopting a CE within the AEC industry context. As these interviews were part of a qualitative complementary study to enrich the quantitative phase, having a sample of 10 interviewees, recruited through purposive sampling criteria, was deemed adequate. As argued by Perera et al. [92], the number of people interviewed in a complementary qualitative study is not important: what matters is the ultimate quality of the data initially gathered from both the literature and quantitative sources and then improved with interview data.

Table 3: Interviewees' profile

Interviewee	Position	Experience (yrs)	Organisation
1	Director	>21	Consultant (infrastructure and services)
2	Senior Associate	>21	Consultant
3	Senior Strategic Planner	>21	Government administration
4	Associate, Sustainability and Energy Services Consultant	11–20	Consultant (Engineering)
5	Sustainability Advisor	6–10	Real estate
6	Sustainability Manager	<5	Consultant (Accounting)
7	Director	11–20	Architect
8	Senior Sustainability and Resilience Consultant	6–10	Consultant (Civil Engineering)
9	Sustainable Design Engineer	11–20	Consultant
10	Energy and Sustainability Consultant	<5	Consultant (Engineering)

3.2 Data analysis

During analysis of the survey data, the Relative Importance Index (RII) was employed to ascertain the primary enablers of and barriers to CE adoption in the Australian AEC industry. In the field of construction management research, the RII is a commonly used technique to evaluate human responses on Likert scales [93], as illustrated in Equation 1:

$$RII = \frac{\Sigma wi}{AN'} \ (0 \leq RII \leq 1)$$

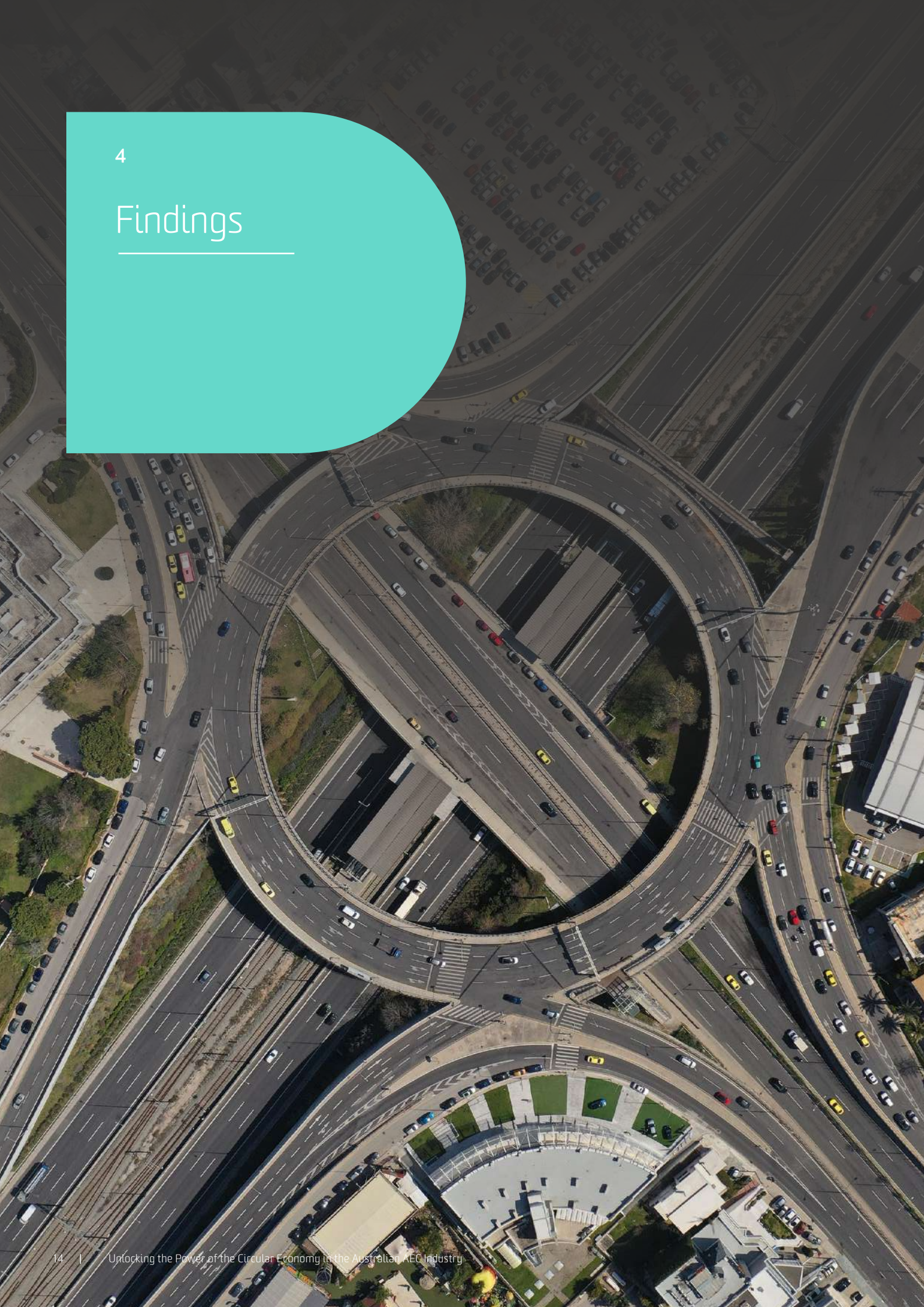
Here, 'w' represents the sum of individual scores given to each factor by participants; 'A' denotes the highest score for each factor (which is 5 in this case); and 'N' represents the total number of responses concerning the factor.

To assess the association between categorical variables, a chi-square test was performed using IBM SPSS Statistics (SPSS) v.26. The variables in question were determined to be categorical in nature, following the advice of Higgins and Koch [94]. The statistical significance of each relationship was determined using its asymptotic significance (p-value).

A qualitative content analysis approach was used to analyse interviewees' responses against the factors identified through the survey.

4

Findings



4.1 Survey findings

4.1.1 Participants' profile

The profile of the surveyed stakeholders (i.e., participants) and their respective organisations is presented in Table 4. Most participants (80.5%) belonged to small organisations (1–4 employees) and to medium organisations (5–19 employees) at the time of the survey. The current study found it surprising that most participants (71.3%) had over 20 years of employment experience in the AEC industry. More than half the participants' organisations provided architectural and design services (54.9%), followed by consultancy firms (13.4%) and general contracting companies (12.2%). A significant proportion of participants held positions as architects/designers (47%) and managers (26.8%). Half the participants (50%) represented organisations that specialised in residential buildings (refer to Table 4).

Table 4: Summary of participants' profiles and their organisations' characteristics

% of employees	1–4	5–19	20–199	>200				
	54.3	26.2	15.5	4				
Employment history (%)	<5 years	6–10 years	11–20 years	>21 years				
	3	7.3	18.3	71.3				
Organisation expertise (%)	Residential building	Non-residential building	Residential & non-residential	Other heavy & civil engineering	Residential & other heavy & civil engineering			
	50	29.01	19.1	1.2	0.6			
Participant organisation (%)	Architect	Facility manager	Client	Consultant	General contractor	Manufacturer, Supplier	Sub-contractor	Other
	54.9	0.6	1.2	13.4	12.2	5.5	2.4	9.8
Participant position (%)	Architect, Designer	Engineer	Estimator, QS, Contract manager	Executive	Project manager, Project engineer	Skilled worker	Other	
	47	3	1.2	26.8	11.6	0.6	9.8	

Note: Engineer: civil, electrical, mechanical and structural; Executive: CEO, President and Vice-President (VP)

The surveyed participants were highly experienced in the AEC industry, indicating a good level of knowledge regarding the different aspects of the industry. Moreover, these participants were considered representative of the significant businesses that play a critical role in CE adoption throughout the industry.

4.1.2 Awareness and intention to adopt a circular economy (CE)

At the time of administering the survey to participants, an industry-oriented CE definition was provided, with several examples of various materials and products in the AEC industry, to provide a consistent understanding of the term CE as used in the survey. Afterwards, the level of CE awareness of these participating key stakeholders in the AEC industry was examined. Close to 70% (12.9%+18.7%+38.1%=69.7%) of research participants indicated that they understood the meaning of the CE concept; however, only 12.9% had adequate knowledge to adopt and apply a CE in their businesses and organisations (see Figure 4a).

Participants' responses to other questions also revealed that a lack of awareness and knowledge was hindering CE adoption and implementation in the AEC industry. The data indicated that only a small percentage of participants (12.9%) possessed sufficient knowledge to adopt and apply CE principles in their organisations, despite nearly 70% indicating that they understood the CE concept (Figure 4a). Moreover, the survey data suggested that only 40.6% of participants' organisations applied CE principles to a limited extent (i.e., 20% and lower) (Figure 4b). Nonetheless, the vast majority of participants (38.7%+47.1%=85.8%) expressed a willingness to incorporate CE principles into their projects (Figure 4c).

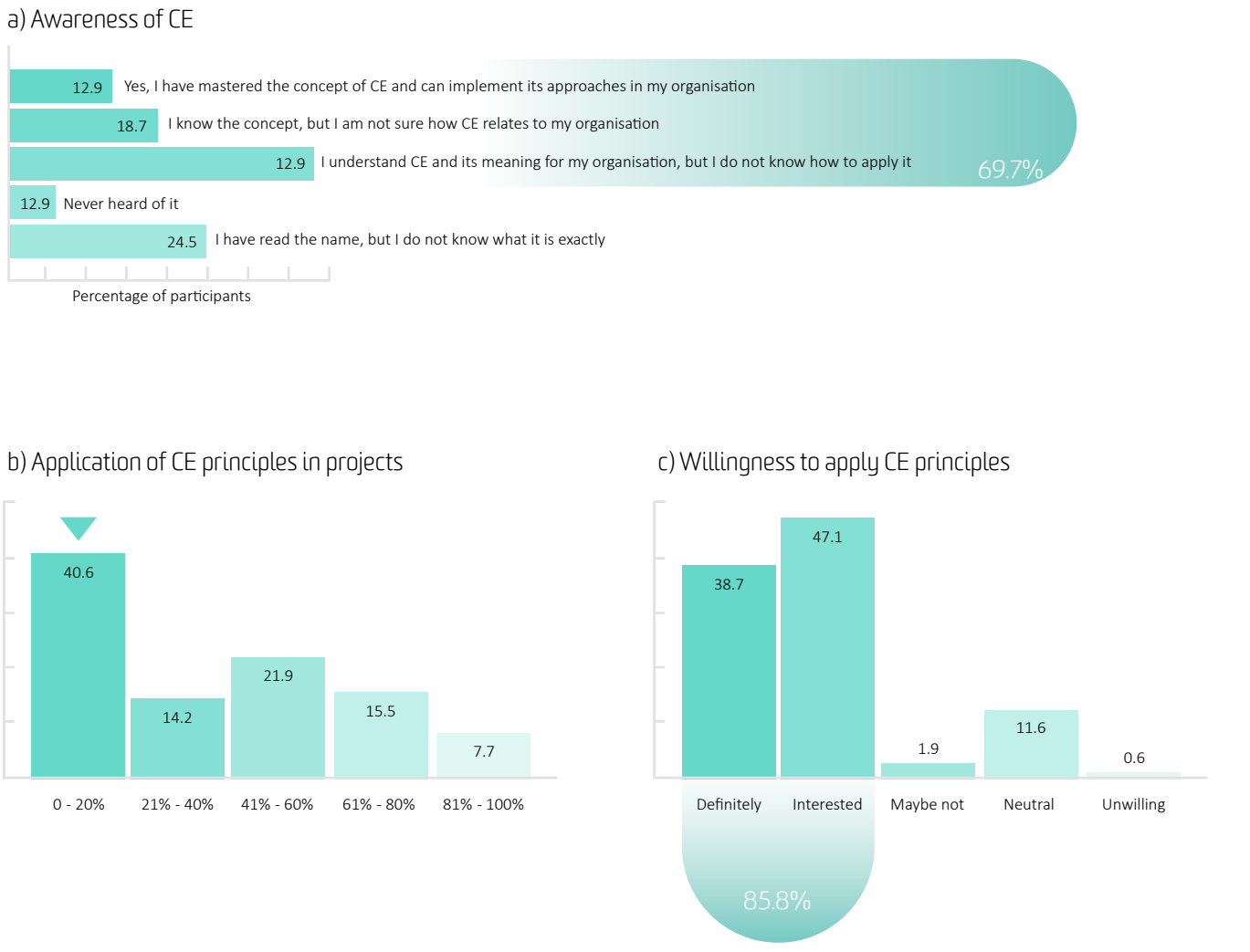


Figure 4: Frequency distribution of responses (%) on (a) participants' awareness of CE principles; (b) the actual adoption of CE principles; (c) and willingness to apply CE principles

4.1.3 Business considerations in circular economy (CE) adoption

The second part of the survey questionnaire aimed to understand participants' perceptions of CE benefits for their businesses and organisations. Two key aspects were explored: (1) whether CE adoption was aligned with their business ethics and (2) whether CE adoption was advantageous for their organisational management, profitability and reputation.

Participants were asked to express their level of agreement/disagreement with these statements.

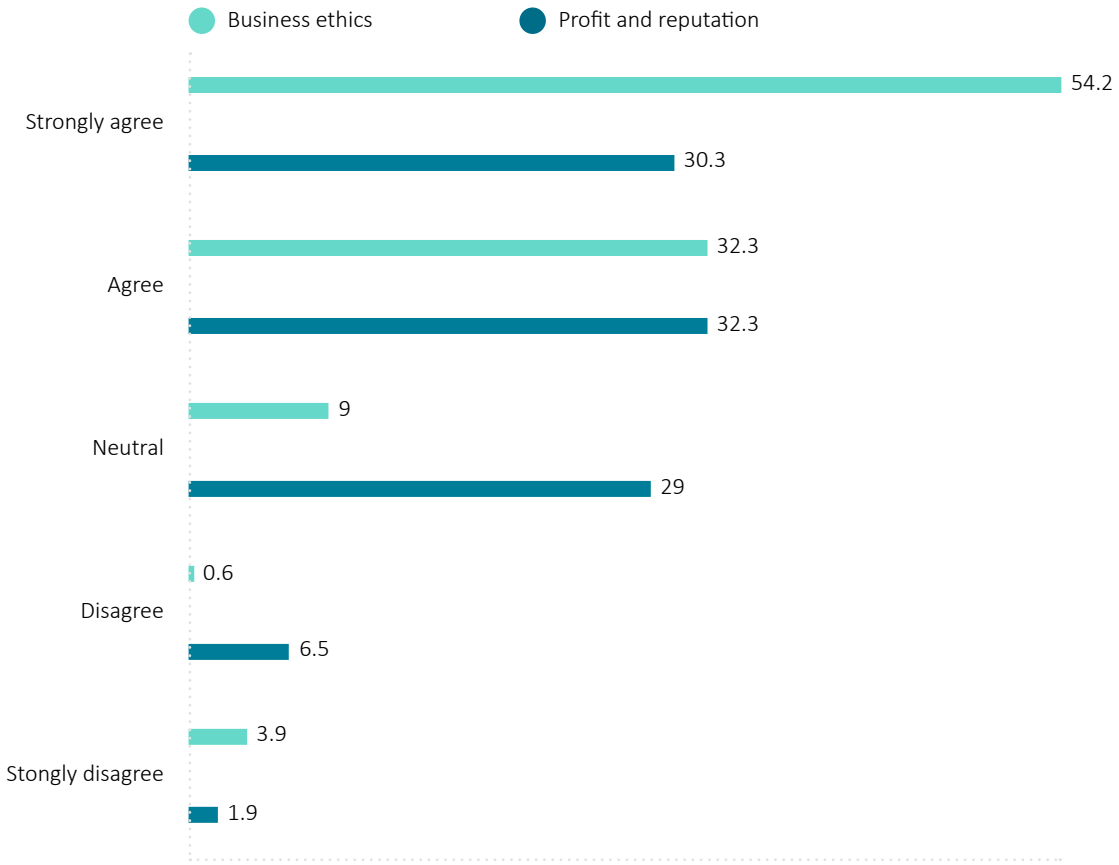


Figure 5: Participants' perceptions of the circular economy (CE)

As can be seen in Figure 5, a high percentage of participants (54.2%+32.3%=86.5%) agreed that CE adoption was in line with their business ethics, indicating a strong commitment to ethical practices. Furthermore, 62.3% of participants (30.3%+32.3%) believed that the adoption of CE principles would enhance the management, benefits and reputation of their organisations.

These findings suggest that CE adoption is closely aligned with the major strategic aspects of running a business within the Australian AEC industry, with most participants agreeing on the strategic benefits to their businesses of CE adoption to enhance various dimensions of their operations.

4.1.4 Barriers

In total, 132 responses were analysed to identify the main barriers hindering CE adoption within the Australian AEC industry. To determine the importance of each variable as perceived by participants, the Relative Importance Index (RII) score was computed using Equation 1. The results, including the list of barriers and each barrier's corresponding ranking, are presented in Table 5.

Table 5: Ranking of the main barriers to CE adoption in the AEC industry

Barriers	Mean	Relative Importance Index (RII)	Rank
Lack of incentives	4.2662	0.8532	1
Lack of specific regulations	4.1367	0.8273	2
Lack of knowledge	4.1295	0.8259	3
Lack of collaboration	4.0576	0.8115	4
Lack of awareness	3.9784	0.7957	5
Tight schedule for projects	3.8993	0.7799	6
Lack of consideration in project phases	3.8705	0.7741	7
Technical difficulties	3.8345	0.7669	8
High upfront cost	3.7698	0.7540	9
High operational cost	3.6403	0.7281	10
Lack of demonstration cases	3.6115	0.7223	11

Table 5 presents the summary of the analysis results from the 132 responses, with participants asked to identify the primary barriers to CE adoption within the Australian AEC industry. The importance of each barrier was determined using the RII, as outlined in Equation 1. According to the findings, the top three barriers to CE adoption were identified as 'lack of incentives' (rank=1, mean=4.2662, RII=0.8532); 'lack of specific regulations' (rank=2, mean=4.1367, RII=0.8273); and 'lack of knowledge' (rank=3, mean=4.1295, RII=0.8259). Conversely, the barriers with the lowest impact, in ascending order, were 'lack of demonstration cases' (rank=11, mean=3.6115, RII=0.7223); 'high potential cost' (rank=10, mean=3.6403, RII=0.7281); and 'high upfront cost' (rank=9, mean=3.7698, RII=0.7540). Barriers related to the CE operational aspects were ranked in the middle, with 'lack of collaboration' ranked as the fourth most influential barrier and 'technical difficulties' ranked eighth.

4.1.5 Enablers

The key enablers of adopting CE principles in the Australian AEC industry were also identified (Table 6). The results of the survey (n=132) showed that the top three enablers were 'R&D of enabling technologies' – supporting CE adoption – (rank=1, mean=4.3636, RII=0.8727); 'educate project stakeholders' (rank=2, mean=4.3409, RII=0.8682); and 'provide evidence of the CE's added value' (rank=3, mean=4.3258, RII=0.8652).

Table 6: Ranking of the main enablers of the CE in the AEC industry

Enablers	Mean	Relative Importance Index (RII)	Rank
R&D of enabling technologies	4.3636	0.8727	1
Educate project stakeholders	4.3409	0.8682	2
Provide evidence of the CE added value	4.3258	0.8652	3
Provide guidelines	4.3182	0.8636	4
Provide viable take-back schemes	4.3106	0.8621	5
Offer financial incentives	4.2576	0.8515	6
Foster collaboration	4.2576	0.8515	7
Establish partnerships	4.1667	0.8333	8
Client's commitment	4.1515	0.8303	9
Adopt CE principles in pilot projects	4.0833	0.8167	10
Enforce legislation	4.0076	0.8015	11
Include CE among the GS criteria	3.9167	0.7833	12

Based on the findings presented in Table 6, it is worth noting that the enablers identified as having the lowest impact on CE adoption in the Australian AEC industry are 'include CE among the GS [certification schemes of sustainable projects like Green Star] rating' (rank=12, mean=3.9167, RII=0.7233); 'enforce legislation' (rank=11, mean=4.0076, RII=0.8015); and 'adopt CE principles in pilot projects' (rank=10, mean=4.0833, RII=0.8167). These results suggest that these specific enablers are not considered by the surveyed participants to be highly significant factors in facilitating the adoption of CE practices.

4.1.6 Impact of participants' knowledge and experience of, and willingness to apply, CE adoption

To further investigate the impact of participants' knowledge, experience and expertise in applying CE principles to projects, a chi-square test was employed. The analysis results indicated that only participants' CE awareness (as shown in Table 7) had a statistically significant effect on various aspects, including the willingness to adopt a CE, its actual adoption, agreement on considering a CE under business ethics and recognition of the CE benefits. Conversely, factors such as participants' position and period of employment did not demonstrate any statistically significant relationship with CE adoption in the industry. This study's findings can thus be applied and generalised to various stakeholders with varying lengths of engagement in the AEC industry and in diverse positions and roles.

Table 7: Summary of statistics on relationship between participants' demographic details and their opinions about CE adoption and its benefits

	Willingness to apply			Adoption			Benefits			Business ethics		
	Pearson chi-square value	Asymp sign.	Phi value	Pearson chi-square value	Asymp sign.	Phi value	Pearson chi-square value	Asymp sign.	Phi value	Pearson chi-square value	Asymp sign.	Phi value
Awareness of CE	73.8	0.0	0.69	68.7	0.0	0.66	34.53	0.00	0.47	33.3	0.00	0.46
Position	22	0.34	0.37	18.73	0.53	0.34	28	0.70	0.39	36.07	0.14	0.48
Employment history	4.92	0.96	0.17	8.54	0.74	0.23	9.81	0.63	0.25	4.56	0.97	0.17

Note: Asymp. sign.=p-value

4.2 Interview findings

4.2.1 State of play of circular economy (CE) adoption

As with the survey, to ensure consistency in their understanding of the CE concept, interviewees were provided with an industry-oriented CE definition. They were then asked about the current state of play of adopting a CE in the Australian AEC industry and if they knew of any practical examples., Almost all participants indicated that the Australian AEC industry was still in the early days of adopting a CE, as stated by Interviewee 5, "we're in the learning and very much [the] pilot stages".

Interviewees also noted that, to date, the industry's efforts have been mostly limited to recycling. These industry players appeared to lack a unified and clear understanding of the concept, with some even mistaking it for recycling. As highlighted by Interviewee 7, "many times when I start talking about it with people, they concentrate on recycling".

Although some interviewees highlighted solutions that had been implemented, such as the use of secondary materials in the production of concrete and steel, they expressed concerns about the siloed industry approach, with minimal systemic or strategic efforts undertaken to implement CE adoption.

As Interviewee 6 highlighted:

'I don't think it's strategic. I don't think it's systemic. I don't think we're in a very good position to say we're adopting circular economy practices in our construction and infrastructure sectors'

4.2.2 Barriers

Interviewees were asked about the main barriers to higher levels of CE adoption in the Australian AEC industry. Their responses were broadly consistent with conclusions drawn from the literature and survey results. One key barrier highlighted was 'lack of knowledge'; as explained by Interviewee 3: "I think the first main barrier is the lack of understanding or education". The interviewee also noted that much still needed to be learned in the industry about what a CE actually entails: "[t]here's still a lot of learning to be done in the industry and I don't think a lot of people really understand what the CE means".

Additionally, 'lack of collaboration' was identified as a significant barrier, with Interviewee 6 claiming that "[t]hey all [supply chain] face a common problem, and the way to solve those problems is through knowledge sharing and strategic collaboration". It was further highlighted that the supply chain was highly fragmented and that what was missing was a systemic approach to CE adoption from a whole-of-project perspective.

Other identified barriers to the adoption of CE practices included 'lack of incentives', 'lack of specific regulations' and 'lack of demonstration cases' as well as 'cost' of implementing these practices. Interviewees also referred to 'technical difficulties', such as the lack of technological development to offer comprehensive recycling or repurposing of particular commodities and the long lifespan of building projects that made it difficult to think beyond their use cycle. While interviewees mentioned other factors, such as 'lack of awareness', 'tight schedule for projects' and 'consideration in project phase', these factors did not emerge as key discussion points.

Interestingly, interviewees revealed two additional themes for barriers that had not been previously considered. One was the resistance to change driven by traditional mindsets, as stated by Interviewee 5: "The biggest barrier is the change in how the industry operates". The other theme was the geographical and market constraints that could limit either the availability of circular products or access to what is on offer. Market forces also favour the lowest cost which does not often prioritise circular solutions, further impeding the adoption of CE practices in the Australian AEC industry. As stated by Interviewee 1, "we're sort of limited by our suppliers … and what we can get hold of".

4.2.3 Key players

Interviewees were asked to identify the key players that might affect CE adoption in the Australian AEC industry.

Most interviewees acknowledged that everyone within the supply chain had a shared responsibility to collaborate in CE adoption. However, the critical role of some players was highlighted.

The government was often mentioned as a key player, although contradictory perspectives were proposed regarding whether the role of government was as a guiding agent or as a regulatory one. For example, Interviewee 6 claimed that:

> 'I think government needs to be really strategic. But in terms of regulation, it's a very difficult thing to impose because it impacts [on] the economic viability of the industry. Particularly, given that these options, you know … adopting a circular approach to the built environment is complex and projects [are] potentially not readily available at the moment. So, I think, the government, what they can do really well [is to] take a systems approach and provide some strategic guidance to industry'.

Industry associations were also recognised as major players in bringing various practitioners together for education, sharing knowledge and guidance in industry practices, so CE practices could become more mainstream and accepted in the industry. Manufacturers and suppliers were also highlighted as key players owing to their critical role in the supply chain.

Other actors, such as developers, designers, builders, clients, users and R&D, were also mentioned. However, the importance of a systemic approach with every player understanding and adequately playing their role was emphasised, as stated by Interviewee 9, "it's the whole chain that comes around".

4.2.4 Drivers

Interviewees were asked about the changes or drivers needed within the current supply chain structure to allow a transition to the CE in the Australian AEC industry. Their responses were found to be in line with the survey results. Most interviewees identified 'offer financial incentives' and 'enforce legislation' as critical drivers for implementing a CE, with these drivers typically associated with the government's role. For example, Interviewee 4 stated that "regulation or incentives" were necessary as "nothing would change if it was left to the private sector". However, some interviewees believed that a top-down approach on its own would not guarantee successful CE implementation. They emphasised that CE practices must also be encouraged from within by connecting and empowering communities to take responsibility for their actions. In this regard, Interviewee 7 explained that "decision making has to be [at a] … role level, so that communities can make their own decisions and … be empowered to do that".

This highlighted two other important drivers identified by interviewees: 'educate' and 'foster collaboration' both across the industry and between the industry and academia. Interviewee 6 emphasised that industry and academia must communicate better, saying that:

> 'universities really need to be able to deliver solutions that suit industry, and then industry needs to be receptive and searching for new practices and leading practices in academia, because that's where the front edge is.
>
> So, I think that cross collaboration is certainly [going to] be a key driver'.

Other identified drivers included 'provide guidelines', 'adopt CE principles in pilot projects' and 'R&D of enabling technologies'. Some interviewees also noted that 'evidence of the CE added value' should be provided to facilitate its widespread adoption. As highlighted by Interviewee 5, circularity cannot be discussed in isolation from the economy: "it's funny because people always talk about circularity, but they don't talk about the second word, which is economy". Interviewees also referred to 'clients' commitment' and clients' role in demanding CE adoption. Another driver noted by Interviewee 1 was 'provide viable take-back schemes'. As Interviewee 1 explained, "So just a part of our business is we recycle as much as possible as we can get back. So, and for us, the line is the cost of breaking down products, So this is not really a circular question, it's a … it's an efficiency question". Interviewees did not directly mention two themes included in the survey, namely, 'establish partnership' and 'include CE among the GS ratings'.

Overall, the interviewees' responses emphasised the importance of a systemic approach, collaboration and education to implement CE principles within the AEC industry, as well as the need for regulation and incentives to push for change.

5

Discussion

5.1 Contextualising findings within the Australian literature

As inferred from the study's findings, participants' awareness of the CE significantly impacts on their willingness to adopt a CE, actual CE adoption, the level of agreement on considering a CE under business ethics and the perceived CE benefits. However, the position of participants and their length of employment did not show any statistically meaningful relationship with CE adoption in the industry. These findings contribute to the broader understanding of the barriers to and enablers of CE adoption in the AEC industry and are generalisable to various stakeholders, regardless of their position or length of engagement in the industry. Therefore, these findings, as discussed next, can inform the development of policies, regulations and training programs to facilitate the adoption of CE principles in the AEC industry.

This study reveals a shift in emphasis towards the importance of 'R&D of enabling technologies' as the top enabler of CE adoption, with this not having been previously identified. For instance, compared to previous studies in the Australian context [14, 15, 21, 95], the survey findings show that the costs associated with CE adoption are no longer a significant barrier for Australian organisations. The current study's results reveal a notable contradiction to the findings of previous research which had highlighted the initial costs of CE adoption and financial considerations as significant hurdles to the adoption of circular project delivery models within the Australian context. As an example, the study's survey findings oppose the assertions in the study by Chileshe et al. [96] which recommended a focus on reducing the costs of salvaged materials as the way forward to advance the agenda of circular models in the Australian AEC industry. The current study's observation challenges the prevalent notion that the AEC industry's inertia towards embracing circular models is due to its lack of resources despite the industry's interest in CE adoption.

With the growing interest in the CE concept in the AEC industry, stakeholders have deepened their understanding of the factors that either foster or hinder its adoption within the Australian context, as evidenced by this study's findings. This trend was further observed in a cross-comparative analysis presented in a report titled "Circularity in Australian Business: Awareness, Knowledge and Perceptions" which illustrated how stakeholders' views on enablers and barriers varied [13].

Significantly and consistent with previous research, the implementation and technological factors of integrating a CE did not pose a significant barrier to its wider adoption. In both the current study and previous studies in the field, these aspects were not prioritised as influential [96]. This suggests that the technical capabilities within the Australian AEC industry context are relatively mature, enabling them to manage the technical and operational requirements of CE adoption.

Moreover, the study findings underscore the importance of collaborative and systemic approaches to facilitate the transition towards a CE. Notably, the results highlight the crucial role of four key stakeholders in spearheading this shift, namely, government, industry project management teams, industry associations and universities. The government is expected to provide incentives and regulations that support CE adoption. On the other hand, industry project management teams, industry associations and universities are vital for facilitating the education of project stakeholders, providing evidence of the CE's added value and training experts in the field.

5.2 Comparison of findings with the international literature

The growing interest in CE research in the built environment has led to a corresponding increase in the exploration of its implementation mechanisms [97]. As the influential factors in the implementation of a CE can vary depending on the specific context of its operation, a comparative analysis was undertaken to assess the degree of similarity between the current study's findings and those of international research.

As in the current study, several other studies conducted in the UK [17, 19, 23], the US [2], the Netherlands [60, 98], Taiwan [61] and some developing countries [20, 62, 63] have identified a lack of awareness and knowledge as a significant barrier to CE implementation. However, as indicated by other studies, these two factors are not consistently ranked as the primary barriers to CE implementation [97, 99, 100]. To be specific, the factors that were emphasised as barriers to CE implementation were short-term goals, complex supply chains and design issues, indicating a divergence in the interpretation of CE principles, adoption and benefits in different contexts across the world.

Moreover, some studies have highlighted the significance of the lack of incentives as a hindrance to full CE adoption, although this factor was mentioned at a lower frequency. The studies documented in [20, 101] focused on the profit-driven nature of the industry, arguing that AEC industry-related businesses were unlikely to engage in CE adoption without sufficient incentives. In contrast to these studies emphasising financial incentives, the current study's findings indicate that, in the the Australian context, the focus is on regulatory requirements, leadership, and research and development (R&D). As a result, attention has shifted away from financial incentives, with these found to have the least impact on CE adoption, towards other types of driving forces such as regulatory incentives.

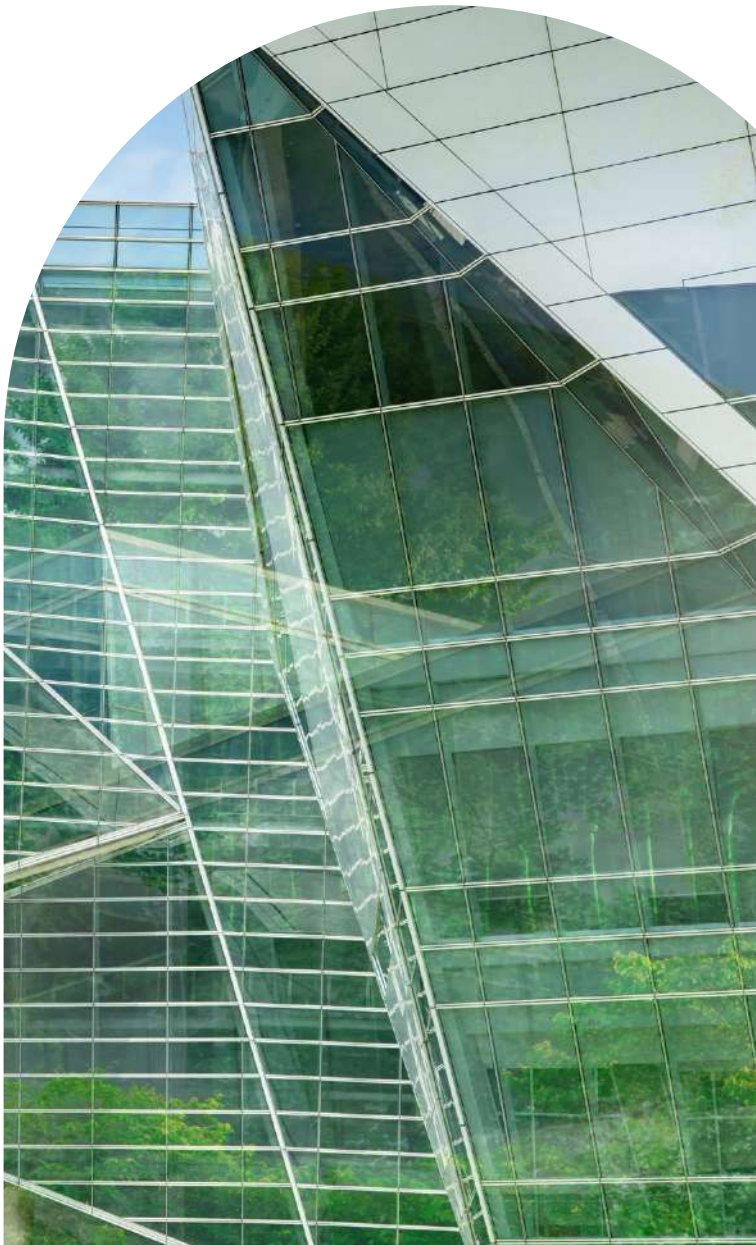
5.3 Recommendations

As discussed, CE adoption remains at a relatively low level in the Australian AEC industry, despite widespread recognition of its potential benefits. Previous research has indicated that a comprehensive and systemic shift towards the CE has not yet occurred [15, 102]. To be specific, the CE is a systemic innovation that requires changes to be made across various disciplines, supply chain boundaries and integrated components of an organisation's business [103]. The adoption of a CE involves practical transformations that necessitate the re-engineering of tasks and processes. The inferential data analysis presented in this report indicates that key enablers related to awareness raising have a significant influence on CE perceptions, intentions and adoption in the AEC industry.

Given that the CE is in its infancy in the Australian AEC industry, efforts to promote transformation towards the CE should focus on awareness. Actions should be targeted at multiple scales, for instance, focusing on systemic changes across the entire value chain (e.g., via policy change) alongside stakeholder group-specific actions (e.g., incentives and tools).

The following recommendations are informed by this study's findings, augmented by findings in related studies in the literature. The intention is to raise awareness of the way forward and to set guidelines that facilitate a transition to a wider adoption of the CE by informing practitioners, policy makers and researchers.

These recommendations should be enacted by all key players in the AEC industry, including government bodies, industry associations, industry project management teams and universities. This approach combines 'top-down' and 'bottom-up' actions to effectively realise a circular approach to widespread and systemic CE adoption in the industry.



Recommendation 1:

Build on existing education pathways to raise awareness across the entire supply chain

The ranking of barriers and enablers highlights the importance of raising awareness and its impact on the willingness to undertake CE adoption in the Australian AEC industry. To raise awareness, stakeholders need to realise the rationale for the transformation to the CE, its economic impact, benefits, risks and alternative options.

Educational collateral needs to be tangible and practical, providing clear examples of the benefits enabled through the adoption of CE methods.

This will initially help stakeholders to understand the benefits themselves, alongside communicating and reporting these benefits to other internal stakeholders. Examples of quantitative and qualitative evidence can create buy-in, as demonstrated in other countries undertaking CE adoption. These include case studies of best practice CE adoption, examples of cost–benefit analyses, life cycle costing calculations and carbon footprint assessments.

Industry bodies and associations are well placed to lead awareness-raising activities, building on existing efforts, for example, by the Green Building Council of Australia (GBCA). However, support from government bodies is required to help improve information dissemination across all actors in the AEC industry.

The future focus should be on reaching those stakeholders that are not yet engaged and that have not been reached by existing networks, for example, small/medium businesses across the value chain of construction and development. This could be supported through, for example, a specialised AEC industry hub for knowledge sharing and training that could, in turn help to create a shared vision for action.

Such a hub could also unify existing fragmented initiatives and facilitate industry-wide collaboration and co-creation towards CE adoption.

Leveraging and building connections between industry and academic groups could achieve expansive knowledge sharing and amplification of existing, yet disconnected, knowledge bases.

Call to action:

Government: Provide support to industry associations by demonstrating leadership and aligning with awareness efforts through policy development, provision of funds for CE education initiatives and implementation of incentive models.

Industry associations: Leverage networks and existing education platforms to disseminate educational collateral. Use these networks to inform and contribute to the development of new content.

Industry project management teams: Proactively seek out and engage with industry bodies and education platforms for the education of organisations' own teams and supply chain partners.

Universities: Leverage expertise and research capabilities to develop educational collateral/material and engage with industry project management teams and industry associations to provide education and training. Collaborate closely with government and industry bodies to secure funding for R&D initiatives.

Recommendation 2:

Build capacity across the value chain to materialise the circular economy (CE)

Education provides the theoretical basis, while capacity building focuses on the practical application of knowledge and skills in real-world contexts.

Awareness of the CE is fundamental but this needs to be reinforced by the knowledge and skills required for its implementation.

Capacity building can shift stakeholders from just having an awareness of the CE (70% of survey participants) to having sufficient knowledge of the CE to adopt it in practice (currently only 12.9% of survey participants).

In conjunction with expanding awareness-based education, this should be elevated to include capacity-building elements.

Capacity building needs to be achieved across the entire value chain, including developers, design consultants, contractors and suppliers, to support systemic change. Each stakeholder group needs to understand its role in CE adoption and how to take action. For example, developers must demand CE design and construction in their projects; consultants must drive the innovation process through building design, specifications and materials selection; contractors must source suitable products and services to realise the design; while suppliers must drive innovation to provide the desired CE products.

Capacity building can be supported through practical programs, and toolkits and workshops that target the needs of specific stakeholders, while suggesting workable solutions.

Prescriptive frameworks and instructions on how and when to integrate CE methods into design and construction processes should be featured in training materials, for example, checklists for assessing CE outcomes and comparative data on materials performance to inform circular materials selection to suit building needs. Stakeholder groups should also be encouraged to share their relevant experiences with others through, for example, communication platforms that reinforce knowledge sharing and support open innovation activities for achieving CE adoption. Funding for, and development of, Environmental Product Declarations (EPDs) for specific materials can help to validate the benefits of selecting circular materials and support conversations that encourage their inclusion in project specifications. Development of EPDs can also lower the barriers to entry by increasing understanding and reporting on the benefits of circular materials, as well as validating product claims.

Call to action:

Government: Drive progress through support and leadership in development of practical training programs, funding initiatives for realted working groups.

Industry associations: Develop training programs and networks to support industry engagement and upskilling across the value chain.

Industry project management teams: Proactively seek out and engage with education platforms and networks to understand their role in the CE and contribute to knowledge sharing across the value chain.

Universities: Promote CE adoption through research, education and partnership with industry associations and government agencies, while contributing in sharing knowledge about CE practices and their benefits to the wider public and industry stakeholders.

Recommendation 3:

Develop indicators for measuring success

Government bodies should lead collaboration with industry associations (e.g., Green Building Council of Australia [GBCA]) and universities to develop key performance indicators (KPIs) for measuring success in the CE transformation process.

This can help to articulate benefits in a transparent and measurable manner, track progress and make necessary adjustments, thereby enhancing trust in CE solutions that could actually provide better production and consumption choices.

This will support conversations across and outside industry to demonstrate progress and system-wide change, as well as supporting internal stakeholder discussions and reporting requirements for businesses.

The development of indicators could be achieved in partnership with, or directly through, current progress by state and territory governments to develop CE measurement frameworks (e.g., New South Wales [NSW], Victoria and South Australia [SA]). For example, this could include indicators specific to the industry in state- and territory-based CE frameworks or implementing a sector-level framework that matches the state- and territory-based CE frameworks.

Call to action:

Government: Lead development of CE measurement frameworks at a state, territory and federal level to guide industry-based frameworks.

Industry associations: Coordinate, lead, monitor and evolve industry efforts in developing a cohesive and uniform approach to measurement, monitoring and reporting.

Industry project management teams: Engage with government and industry associations to understand what information needs to be measured and consider how to implement sufficient reporting mechanisms within their own organisation and project teams.

Universities: Collaborate with government and industry associations in the development and widespread adoption of measurement frameworks, providing ongoing support and training programs as necessary.

Recommendation 4:

Advocate for and develop policies that support/enable CE outcomes

Findings underscore the imperative for the development and implementation of policies that actively facilitate the transition towards a CE. These policies could include a mix of economic instruments (e.g., taxes and subsidies); regulations (e.g., standards, bans and restrictions); voluntary mechanisms (e.g., labelling schemes); and public funding. In addition to CE-focused policy, the National Construction Code and Australian Standards need to be reviewed and amended to support/allow the uptake of proposed circular alternatives to traditional building materials and methods. While efforts have been initiated, the progress towards substantial reform to support a transition to a CE remains limited.

To drive this process, however, systemic change of the Australian AEC industry will need to see policy reform at a higher scale. The implementation of policy needs to be consistent across geographic regions, requiring leadership from state, territory and federal level in lieu of local governments. Local government joint organisations or regional organisations of councils may have sufficient resources to drive and implement legislation at that level, but will require clear and consistent policy from state and territory governments and, in some cases, funding.

The recent establishment of the Circular Economy Ministerial Advisory Group (CEMAG) provides a clear commitment and opportunity to amplify policy efforts in the immediate future.

Universities and industry associations, including AEC industry representatives (e.g., Australian Building Code Board and GBCA) and CE representatives (e.g., Planet Ark's ACE Hub), should collaborate with government and drive the industry voice on these issues. This could take the form of hosting roundtable discussions with industry stakeholders and/or direct consultation with the government bodies leading policy development.

Call to action:

Government: Drive progress through support and leadership in development and revision/introduction of policies that support CE design in construction.

Industry associations: Facilitate industry discussions and lead advocacy for changes to policy and regulatory frameworks.

Industry project management teams: Proactively engage and contribute to industry conversations to support the development of new/updated policies to drive CE implementation in a practical, feasible and beneficial manner.

Universities: Conduct evidence-based research in collaboration with industry to inform CE policy development and engage with policy makers to provide input into the development of policy and regulatory frameworks.

Recommendation 5:

Establish incentives that support policies

In addition to policy-based incentives and drivers, government and industry bodies should **explore incentives to drive CE adoption in a way that benefits existing drivers within the AEC industry.**

Incentives should extend beyond immediate construction costs to indirect benefits, such as shorter review time frames for building plans and permits, more leniency in building approvals and/or reduced utility rates in operations [104].

Incentives should consider each phase of the value chain, with prioritisation of key decision-makers, such as developers, architects and head contractors.

Call to action:

Government: Drive progress through support and leadership in the development, revision and introduction of incentive programs at local, state, territory and federal government levels, including direct incentive levers and funding for industry-led incentives.

Industry associations: Advocate on behalf of industry for government-led incentives, facilitating roundtable discussions and industry collaboration with government to establish best-fit incentives.

Industry project management teams: Demand procurement practices, guided by the principles of a CE. Proactively engage in and contribute to industry conversations to support the development of incentives that respond to barriers to CE implementation and provide secondary benefits to other development elements.

Universities: Support the development and implementation of incentive programs by conducting research on the effectiveness of existing incentive mechanisms or designing new ones that respond to the industry's unique needs and collaborating with government and industry associations to advocate for the adoption of these incentives.

Recommendation 6:

Drive behavioural change among key stakeholders by demonstrating that business-as-usual is no longer an option

In conjunction with tangibly demonstrating the benefits of adopting CE methods, **the apprehension about change shown by many stakeholders needs to be addressed.**

This can be done by leveraging existing agreements and acknowledging that the CE provides benefits to AEC industry activities. Behavioural change regimes should focus on communicating benefits beyond direct environmental benefits, such as operational efficiencies, the positive contribution to business reputation, and financial and social wins.

These campaigns can be amplified by providing examples of quantitative and qualitative evidence that allows key players to effectively communicate in-house to their own stakeholders and key decision-makers.

Raising awareness could include case studies of best practice CE adoption, with examples of cost–benefit analyses as useful evidence to create buy-in, as demonstrated in other countries undertaking CE adoption.

Call to action:

Government: Establish funding for behavioural change campaigns to support awareness, capacity building and adoption of the CE in the AEC industry. Funding should be assigned to initiatives led by government and by industry.

Industry associations: Develop and lead behavioural change campaigns and supporting collateral for dissemination across industry.

Industry project management teams: Engage in industry- and government-led initiatives, encouraging participation by internal teams and supply chain partners.

Universities: Undertake evidence-based research to highlight the benefits of CE practices compared to linear practices. Partner with industry associations to create behavioural change campaigns and incorporate CE principles into university curricula to foster a culture of innovation among students, faculty members and staff.

6

Concluding remarks

6 Concluding remarks

For a CE to be successfully implemented, it is imperative that its implementation becomes a business goal. To this end, it is necessary to assess the level of importance that the CE holds for businesses and practitioners in each sector of the economy. An initial step towards increasing the level of CE uptake in each setting and industry is to evaluate the current level of understanding, the intention to adopt and the perceived benefits of and barriers to adopting CE principles. Despite the considerable attention that a transition to a CE has received in various sectors of the Australian economy, the adoption of CE principles within the Australian AEC industry remains largely unexplored. This report makes several valuable contributions to the field by providing insights into the current landscape of CE adoption within the AEC industry in Australia.

The report provides valuable insights through the first broad survey and complementary interviews on various dimensions of CE adoption within the Australian context. The findings offer a solid foundation for future studies in Australia, by thoroughly mapping the nature of barriers to adoption, enablers of adoption and perceptions of relevant players in the market. Thus, this report establishes a clear picture of the current state of CE adoption within the Australian AEC industry.

The theoretical contribution of the report is significant as it addresses the 'what' question of wider CE adoption within the Australian AEC industry context. By doing so, the report serves as a bridge between the 'why' question of a transition to the CE within the Australian AEC industry (addressed in various reports and publications) and the 'how' question of managing the change and facilitating a successful transition. To date, the latter question has received scant attention.

This report, therefore, contributes to the existing body of knowledge by raising awareness of the current state of CE adoption within the AEC industry in Australia and by proposing practical recommendations to overcome any challenges that may arise during the transition process. Furthermore, the report highlights the need for further research and collaboration among industry stakeholders to facilitate and accelerate the adoption of CE practices and principles.

The study, documented in the report, focuses on the transition from linear supply chain models to circular models in the Australian AEC industry and addresses the associated challenges and opportunities. The study offers valuable insights from the perspectives of AEC industry practitioners regarding potential transformational change procedures and the barriers to adoption of CE principles. The study's findings make a practical contribution by outlining the industrial implications and providing pragmatic recommendations to accelerate the pace of CE adoption by organisations in the Australian AEC industry. As a comprehensive reference to all influential factors associated with CE adoption, this study provides practitioners and policy makers with reliable and collated information on Australia's current position in the adoption of CE principles within the AEC industry, one of the largest sectors of the Australian economy. The study's theoretical contribution lies in addressing the 'how' question of managing the transition to a CE, which has received less attention to date, hence filling the gap in the existing body of knowledge.

As with any research, this study has its limitations. The primary limitation pertains to the composition of participants who were mainly architects from small businesses. This sampling may result in some bias in the research findings, as the sample fails to capture the perceptions of a more diverse range of influential actors involved in CE adoption in the Australian AEC industry. In addition, the number of participants for pre-testing the survey during the instrument development phase was relatively small. Therefore, future studies with a more extensive distribution of participants and adequate sample sizes for the pilot stage are necessary to gain a more in-depth understanding of the perspectives of various professionals in the AEC industry. This should include suppliers, clients and end-users, as well as participants from large companies that deliver large projects.

Moreover, it is important to note that this study is exploratory in nature and, therefore, that it focuses more on the 'what' question, creating a foundation for addressing the 'how' question. Consequently, the study places less emphasis on the 'why' aspects of CE adoption in the AEC industry. Further research may delve deeper into the reasons behind the varying degrees of adoption of CE principles and the motivations of different actors in the industry.

Building on the current study's findings, future research should delve deeper into identifying the root causes of the barriers and drivers influencing CE adoption in the Australian AEC industry. While this study offers recommendations for overcoming the identified barriers and leveraging the enablers, future research should aim to validate and refine these recommendations, providing a more comprehensive and actionable set of guidelines for practitioners and policy makers to facilitate CE transition.

Moreover, it is important to note that this study is limited to the context of Australia and the AEC industry. Therefore, caution should be exercised when applying the findings to other countries or industries, as different sociotechnical environments may pose unique challenges and require tailored approaches. Nevertheless, the insights and lessons learned from this study may serve as a valuable starting point for further research in other contexts. Replication of this study in other countries and industries, followed by comparative analyses based on the same research questions, could offer valuable insights into the similarities and differences in the adoption of CE principles across different regions and sectors.

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