CIRCULAR ECONOMY ADOPTION PRACTICES WITHIN THE SOUTH AUSTRALIAN CONSTRUCTION INDUSTRY: AWARENESS, CHALLENGES AND FUTURE OPPORTUNITIES

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Circular economy (CE) adoption benefits are well reported in literature. However, its uptake in the Australian construction industry (CI) is limited. Therefore, this paper aims to: (1) examine the current awareness of CE practices; (2) identify CE adoption challenges; and (3) recommend future opportunities relating to the CE practices adoption within the South Australian CI. This study adopts mixed-methods sequential exploratory design, qualitative followed by quantitative. Content analysis and descriptive statistics found the CI as becoming more conscious of CE practices, particularly those that prioritise the use of sustainable materials, reducing the amount of waste, and efficient utilisation of available resources. The challenges were limited awareness and understanding, cost implications, resistance to change, lack of suitable technology, regulatory obstacles, economic implications, and a lack of general industry expertise. Opportunities identified include enhanced sustainability, reduced environmental impact, improved resource efficiency, cost savings and competitive advantage. The findings of this study can help inform the construction practitioners on the adoption of CE practices by addressing exclusive area challenges and focusing on opportunities.

Keywords: circular economy; construction industry; practices; mixed-methods; South Australia

INTRODUCTION

Globally, the construction industry (CI) is responsible for over 30% of the extraction of natural resources, as well as 25% of solid waste generated. Equally, the CI is also a major consumer of materials, and a major producer of great waste stream (especially construction and demolition (C&D) (Eurostat, 2020). For instance, Australia generated 75.8 million tonnes of solid waste in 2018-19, which was a 10% increase over the last two years (since 2016-17). Additionally, according to the National Waste Report (2022), in 2020-21, Australia's resource recovery rate (including waste reuse, recycling, and energy recovery) was 63% and the recycling rate was 60%. In the U.K, the current available data shows that in 2018, 137.8 million tonnes of CD&E

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waste were produced with 119.4 million tonnes in England alone. In Europe alone, studies such as Eurostat (2020) have shown that the construction industry generated about 924 million tons of wasted materials which accounted for about 30-40% of all total solid waste generated. In South Australia, the local government through its South Australian Government Climate Change Action Plan 2021-2025 has a target of 50% emissions reduction by 2030 and identified the following 3 sectors of the Built Environment civil infrastructure, commercial construction and residential construction as consuming the most materials. Further, the waste generation is attributed to construction industry's reliance on the linear economy of 'make, use and dispose'. Additionally, the destination of the generated and unrecovered waste is normally landfills leading to serious environmental and health issues due to leaching of toxins to soil, groundwater, and vegetation. Circular economy has emerged as one such solution for moving away from the 'dispose' of the economic model of linear economy and increase recovery rates. However, as the construction industry is at an early stage of the move towards CE, it is not well understood around the South Australian construction industry readiness and in general, and CE uptake in the Australian construction industry (CI) is also limited and according to Ho et al. (2023), fragmented. Therefore, to bridge the knowledge gap, this paper aims to: (1) examine the current awareness of CE practices; (2) identify CE adoption challenges; and (3) recommend future opportunities relating to the CE practices adoption within the South Australian CI.

LITERATURE REVIEW

There is a plethora of studies examining the role and impact of CE awareness of its adoption (Adam et al., 2017; Chang and Hsieh, 2019; Salvioni and Almici; 2020; Osei-Tutu et al., 2022). For instance, Adams et al., (2017) investigated the awareness, challengers, and enablers from the U.K perspective. Using the context of Taiwan, Chang and Hsieh (2019) explored the state of practice (i.e., challenges and enablers), stakeholders' awareness, and future potentials of CE in the built environment, a higher level of CE awareness was found among the government policy makers, whereas the industry practitioner, and particularly the manufacturer's had low levels of awareness. Salvioni and Almici (2020) identified improved relations with relevant stakeholders as critical for circular economy transition and recommended the creation of strong awareness with them on issues such as ecosystem protection, health-related safeguards, and the careful use of resources; and Tutu et al., (2022) identified lack of awareness among the CE uptake barriers. In Australia, Shooshtarian et al., (2024) have acknowledged the importance of increased awareness in the construction industry as a precursor or driving force the adoption of CE models. Ho et al., (2023) explored the understanding of CE amongst major stakeholders within the state of Victoria in Australia and established that its influence (awareness) in the implementation of CE within the Victorian context remains limited. In South Australia, the CE awareness was found to be shaped by stakeholders' beliefs, knowledge, background of experience and education, and thus the perceptions around it varied among the stakeholders (Crocker et al., 2021).

Several studies have explored the challenges and barriers to CE adoption across different sectors and industries (Sharma et al., 2023; Govindan and Hasanagic, 2018; Adams et al., 2017; Tura et al., 2019; Osei-Tutu et al., 2022). For instance, Sharma et al., (2023) examined the challenges faced by the food industry while applying digital technology to attain sustainable production and consumption and identified "strategic barriers" and "organisational barriers" are the two biggest obstacles making it difficult

for organisations to adjust to change; these are the biggest obstacles to environmental management. Within the Australian context, a study by Ho et al., (2023) aimed at understanding the CE development through the investigation of CE awareness, drivers, challenges, enablers, and barriers across stakeholders established the following top 4 challenges to CE adoption: 1) Lack of CE awareness; 2) financial viability; 3) organisational structure; and 4) CE measurement matrix. The lack of technologies, knowledge and information also hinder the adoption of CE business models (Tura et al., 2019).

Whilst the focus of this study is on the challenges to CE adoption, it is prudent to review some of the challenges affecting enablers to CE adoption as technology and digitalisation. According to Antikainen et al., (2018), digitalisation not only has the potential of reducing waste, but can help closing the material loops by providing accurate information on the availability, location, and condition of products. The Antikainen et al., (2018) study identified the challenges related to the CE and digitalisation as those related to business models, data ownership, data sharing, data integration, collaboration, and competence requirements. Considering digitalisation as an enabler to CE, Ritzén and Sandström (2017) identified the barriers to actualising the benefits of digitalisation and classified these into financial barriers (measuring financial benefits, financial profitability); structural barriers (missing exchange of information, unclear responsibility distribution); operational barriers (infrastructure, supply chain management), and attitudinal barriers (perception of sustainability, risk aversion). The technological barriers related to the product design and integration of digital technologies into production processes were also identified. Osei-Tutu et al., (2022) used a scientometric analysis and identified 79 barriers which were categorised into the following 6 categories: Economic/financial; Technical; Social; Cultural; Technological; and Environmental barriers.

The current study seeks to investigate on the most significant opportunities for the construction industry in combining circular economy principles and digital technologies. Some studies such as Antikainen et al., (2018) identified using digitalisation, interacting with stakeholders, and virtualising products and processes among the most important opportunities for putting CE-based business models into practice. However, the opportunities provided should be treated with caution as the application of digital tools whilst pivotal in design and construction phases, their application to existing structures is less straightforward, with challenges including the absence of digital twins for demolished structures (Banihashemi et al., 2024). Driven by the need to fill this gap, this study aims to investigate the status quo of CE adoption practices through examination of the current awareness, identification challenges; and leading to recommendations for future opportunities.

METHOD

This study's research employed a mixed-methods approach, which integrated qualitative and quantitative techniques due to its ability to overcome the limitations of a single method's narrow focus. It can also address low response rates commonly seen with single methods, and finally, it can enhance the validity and reliability of findings through multiple data sources. (Creswell et al., 2007). This combination is essential for conducting in-depth analyses of difficult research and grand challenges. Circular economy involves numerous actors in collaborative supply chains. According to Ferraro et al., (2015), the analytic facets of grand challenges are ‘evaluative’, ‘uncertain’, and ‘complex’ whose problems are characterised by many interactions

and associations, and nonlinear. CE is closely aligned the Sustainable Development Goals 12 of 'responsible consumption and production', aimed at reducing their negative environmental impacts. This is also regarded as a grand challenge. According to Molina-Azorin and Fetters (2019), a mixed-methods approach is well suited in addressing such grand challenges and has the ability of facilitating the involvement and participation of different stakeholders through combination of qualitative and quantitative approaches.

The study employed an exploratory sequential mixed methods approach with interviews as the starting point. The interviews followed a semi-structured approach as this enabled the participants to share their experiences, points of view, and primary reasons for participating. Purposive sampling method, using the snowball sampling technique was used for the selection of the interviewees. Further, the snowball sampling technique was adopted as it increases the degree to which the sample is representative of populations that are not easily approachable. The data collection comprised an interview protocol as developed with 14 open-ended questions related to three domains of knowledge (i.e., current construction practices, circular strategies implementation barriers, and circular economy enablers).

Qualitative data analysis -Thematic analysis was employed to analyse qualitative data obtained from in-depth interviews. According to Braun and Clarke (2012), this type of method is accomplished by searching across the data collected in the interview transcripts to identify and collate repeated trends. Therefore, transcripts and textual data were systematically coded and organised into themes related to awareness, challenges and opportunities associated with CE adoption practices. Content analysis was used for textual data gathered from documents and reports. Content analysis involved systematically categorising and coding textual data to identify key information and insights relevant to the research objectives. The total number of interviewees was 8, and Table 1 summarise the interviewees details.

Table 1: Details of interviewees

Experience range (years)	Number of responses	Percentage (%)	Cumulative (%)
2-4	3	37	37
4-6	1	13	50
6-10	3	37	87
20 +	1	13	100

Quantitative data collection

The questionnaire survey comprising 18 questions was structured around the following three parts: 1) Digital technologies and circular economy in construction; 2) Challenges, opportunities, and future perspectives; and 3) Additional comments. The last section was open-ended and sought to gather any further opinions from participants. The findings reported in this paper are from the second part only as it is beyond the scope of this paper to report on the digital technologies and circular economy in construction. Purposive sampling or authoritative sampling was selected as, this non-probability sampling technique is based on researcher's knowledge and judgement (Rowley, 2014). Therefore, questionnaire surveys were distributed in both formats, using 'survey monkey' link and a soft copy (word document) depending on the convenience of each participant. The ideal minimum target respondents were initially at 30 (minimum criteria). However, due to unavailability of some participants, only 24 respondents completed the survey. The respondents were from the commercial, modular, residential, and interior refurbishment sectors of the

building industry. Relative to the respondent's position, the interviewees comprised 2 Estimator and contracts administrator; and 1 each from the following - General manager, building surveyor, Sales consultant, Project administrator, Construction manager and Managing director.

Quantitative data analysis: The measures of central tendencies and frequency analysis were utilised to analyse the quantitative data collected through the survey. This was through ranking of the significant challenges to CE adoption. Mixed survey approaches have been used previously in investigating challenges and opportunities in the Australian construction sector (Shooshtarian et al., 2022; Ho et al., 2023).

RESULTS AND DISCUSSION

According to Ho et al., (2023), understanding CE plays a crucial role in transitioning towards circularity and developing circular value chains, which can utilise either biological or technical cycles. Therefore, the respondents were asked whether they were familiar with the concept of circular economy in the context of construction industry. Informed by the Innovation Diffusion Theory lenses advocated by Rodgers (2004), this innovation occurs over the following 4 phases: 1. Knowledge, 2. persuasion, 3. decision, 4. implementation and 5. confirmation. Therefore, as shown in the Rocca et al., (2022), the knowledge phase or awareness is the first stage for the adoption of innovation (i.e., Circular Economy) and thus a precursor to the Australian construction practitioner's decision to adopt (or reject) the system. Moreso, according to Rocca et al., (2022), at this stage, the individual or organisation approaching the innovation wants to understand what it is, how it works and why it is useful. The results showed that the majority (75%, f =18) were somewhat aware. This finding is very encouraging as the implementation of CE in Australia is in a very nascent stage, and the limited quantitative testing of these transformational frameworks to assess their potential in assisting CE implementation for businesses, with many studies being conceptual in nature and lacking empirical insights (Parida et al., 2019). Some recent studies such as Gonella et al., (2024) found that a low level of awareness about CE and other sustainable approaches may reduce the precaution in undertaking CE-oriented efforts. Therefore, preparation of stakeholders can be a key step in promoting and increasing circular economy awareness.

The results of the challenges to CE adoption as obtained from the questionnaire survey are summarised in Table 2. Drawing on the conceptualisation put forth by Ho et al., (2023), understanding challenges from the past to better enables the overcoming of the barriers in the future, and develops future enablers based on past challenges.

Examination of Table 2 shows "Limited awareness and understanding" as the most significant challenges in implementing circular economy practices in construction as selected by the majority (33%) of the respondents. This was further reinforced by one of the interviewees who noted that:

> "Lack of government driven initiatives and incentives. For a big change to occur, it must make economic sense for it to be implemented by construction businesses in the private sector. It must be profitable or cost comparable with existing alternative options and must have the same or better lead time and construction time as existing methods".

Another interviewee observed that increased awareness and improved industry standards with incentivised practices will drive circular economy as noted form one interviewee.

Table 2: Ranking of challenges to CE adoption.

Challenges to CE adoption	Frequency (n)	Percentage (%)	Rank
Limited awareness and understanding	19	33	1
Cost implications	17	28	2
Resistance to change	13	22	3
Lack of suitable technology	5	9	4
Regulatory obstacles	2	3	5
Others	2	3	6

The quantitative and qualitative findings are also consistent with the previous literature on CE adoption (Adams et al., 2017; Chang and Hsieh, 2019; Guerra and Leite, 2021; Khan and Haleem, 2021; Osei-Tutu et al., 2022; Tura et al., 2019; Zhang et al., 2019). For instance, the construction specific study by Guerra and Leite (2021) found 'lack of awareness' among the barriers, and thus causing the gap between CE theories and practices. The awareness shouldn't be limited to understanding of the CE concepts, but equally be extended to consumer awareness and awareness among the supply chain collaborators which are described as significant CE practice (Khan and Haleem, 2021). The study by Osei-Tutu et al., (2022) also identified lack of awareness, knowledge and understanding on environmental impact of polluted waste and pollution of virgin feedstock among the 'Social Barriers' impeding the CE uptake. Relative to the CE understanding, the regulatory environment needs to be developed highlighting full CE understanding (Ho et al., 2023).

"Cost implications" was the second ranked challenge (f=17) affecting the CE adoption. Reluctant to properly implement CE practices due to cost implications is well documented in literature (Kirchherr et al., 2018; Guerra and Leite, 2021; Osei-Tutu et al., 2022; Shooshtarian et al., 2022; Tennakoon et al., 2023). For instance, Guerra and Leite (2021) found higher upfront costs/initial costs for CE initiatives among the primary barrier for businesses, especially small and medium enterprises (SMEs). Osei-Tutu et al., (2022) further categorised these costs as barriers impeding CE under the 'Economic/financial barriers' and included the following: costs are associated with low landfill cost, design cost, budget and upfront cost, duration and labour cost, cost of approach and material. Equally, Kirchherr et al. (2018) found that the upfront costs for CE initiatives could also impact the financial viability of an organisation. The qualitative study was also consistent with literature. For instance, some the interviewees acknowledged that by the means of saving on costs, builders do not really administer much on waste. Thus, bestowing all demolition waste at the hands of demolition and skip-bin providers. The issue of cost as a challenge also appears to affect the clients more whereas construction practitioners focus more on risks associated with the use of products with recycled content (PwRC), (Tennakoon, et al., 2023).

"Resistance to change" was the third ranked challenge affecting the CE adoption (f =13). The finding is also consistent with literature. Resistance to change is also another separate challenge that the industry is finding hard to amend, thus creating another yet more psychological obstacle in promoting circular economy. Behaviour resistance was a main barrier as elderly people were normally resistant to changing their behaviour to use CE products (Ho et al., 2023). For instance, Osei-Tutu et al., (2022) study aimed at identifying the barriers impeding CE uptake in construction attributed the 'Cultural Barriers' and listed 'resistance to CE integration and models', 'Resistance to change of old generation' and 'Ingrained linear mindset' among those

barriers. Construction specific studies such as Tennakoon et al., (2023) also identified personal factors such as attributed the reluctance to change the status quo and limited decision-making capabilities among those limiting the usage of recycled construction materials. Thus, cultural change has been emphasized as the essential precursor to acceptance and community engagement in the circular economy (Crocker et al., 2021). The findings also affirm Guerra and Leite (2021) observations that the industry is renowned for its conservative outlook and high resistance to change.

Examination of Table 2 shows "Lack of suitable technology" as the third ranked challenge (f = 5). This is a mixed finding as previous literature on technology enabling the transitioning to CE has different schools of thought. On one hand, technology was not considered as a core CE barrier (Kirchherr et al., 2018). In contrast, according to Ghisellini et al. (2016), by adopting the CE as a sustainable development policy, it is necessary to use disruptive technologies, whereas in China, Zhang et al. (2019) identified difficulties with existing technologies and their applications as one of the barriers. Likewise, Khan et al., (2022) identified 'difficulties in upgrading technology' among the barriers to CE integration. The qualitative findings are equally supportive with one interviewee noting that: "I believe integrating technologies to assist considered design could provide flexibility in structures to assist with future adaption, and dramatically reduce waste to landfill and save on cost." Similarly, Tan et al., (2022), recommended the sharing of knowledge and technology amongst stakeholders to support transition to CE. Access to technology is also identified as factor affecting low uptake of reprocessed construction materials (Tennakoon et al., 2023)

Governments have the potential to make a maximum positive impact on the circular economy implementation in construction through its policy instruments such as economic and regulatory (Govindan and Hasanagic, 2018; Ho et al., 2023; Zhang et al., 2019; Shooshtarian et al., 2024). However, the actual role is less investigated and understood. Therefore, the low ranking of 'regulatory obstacles' is understandable. However, support for the role of the government in CE adoption is evident in literature. For instance, regulation has been conceptualised in CE adoption literature as being part of the internal drivers of incorporating CE, external enabler, and external barriers (Ho et al., 2023). Likewise, Govindan and Hasanagic (2018) observed that the CE can be promoted through laws, policies, risk reduction (through tax levies) and strict governance whilst Zhang et al., (2019) has pointed to the pressures of a regulatory body among the challenges to CE adoption. Some of the interviewees also believed that without incentivised government intervention, builders would not deem that any investment in such sphere would be adequate or satisfactory to meet break-even point or have a full return on investment (ROI).

The findings around recommendations for future opportunities were varying with one interviewee acknowledging the following: "I believe there is opportunity in approaching developers who build to lease to promote circular economies with the financial reward of adaptable re-purposing of buildings. Buildings are generally built to suit long term tenant desires, with little consideration for future tenants, whereby the new fit out can result in a slow, expensive, and wasteful process. In response to the following survey question : "In your opinion, what are the most significant opportunities for the construction industry in combining circular economy principles and digital technologies?", the following emerged in the order of number of responses (n) and frequencies (f): 1) Enhanced sustainability (n=20, f = 28%); 2) Reduced environmental impact (n=19, f = 26%); Improved resource efficiency (n=13, f =

18%); Cost savings (n = 9, f = 12%); Competitive advantage (n = 9, f = 12%); and other (n = 3, f = 4%). The 'other' category was associated with the following - opportunity for flexibility in re-purposing building in the future, and long-term cost savings. The findings as reported are consistent with literature. For instance, Shooshtarian et al., (2022) identified "environmental benefits" (n =13), "ensuring the competitive advantage and futureproofing" (n = 9) among the benefits for using PwRC.

CONCLUSIONS

This paper has presented the perceptions of the stakeholders representing the construction organisations in South Australia regarding the examination of the awareness of CE practices, identification of CE adoption challenges, and recommendation of future opportunities associated with adoption of CE. Using a mixed-methods sequential exploratory design, the results showed the highest ranked challenges as limited awareness and understanding, cost implications and resistance to change. The least ranked were lack of suitable technology and regulatory obstacles. Other challenges identified were economic implications, and a lack of general industry expertise. Opportunities identified include enhanced sustainability, reduced environmental impact, improved resource efficiency, cost savings and competitive advantage. Awareness and education were identified as critical in integrating circular economy principles and digital technologies for sustainable construction. The development of industry standards and guidelines were established to be incredibly important, as they became points of performance references for building professionals. The following implications emerge for promoting the adoption of CE. 1) For policy makers, to increase awareness and uptake of CE, the provision of mandatory trainings through accredited professionals with appropriate frameworks that incentivise sustainability or CE could be a start. At the State level, to curb the underfunding of sustainability, and the costly nature of transitioning to CE, the South Australian government could take measures to incentivise sustainable solutions. Furthermore, sustainability, which is without a doubt the greatest challenge in the building industry could be addressed through bi-partisan support from all industry members. Additionally, the government could develop more interventionist policies aimed at improving the circular economy practices in construction, as well as driving the integration of digital technologies in CE. Crocker et al., (2021) acknowledge this as a long-term aspiration for South Australia; and 2) Practitioners, and professional bodies could contribute towards raising the awareness of CE adoptions and its associated benefits through involvement in Continuous Professional Development events. The findings have also the potential of contributing towards the Australian Government's aspiration of having Net Zero by 2030, as well as contributing to ARCOM's future research agenda.

Whilst this study makes significant contributions in shedding light on our understanding of the adoption of CE, awareness, challenges, opportunities, it is not without any limitations. The quantitative sample size was small (n = 24) and limited to South Australia. Therefore, future studies could employ larger sample sizes, across the different Australian states with varying regulatory, waste management and resource recovery aspirations. The interviewees were also skewed and largely drawn from a broad range of builders. Future studies could include a broad range of stakeholders such as project consultants, governmental personnel, architects, construction lawyers, demolition contractors and skip bin providers; also, be extended in establishing what type of actor certain challenges or barriers apply to.

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