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Transformation towards a circular economy in the Australian construction and demolition waste management system

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ABSTRACT

Australia's increasing rate of construction and demolition (C&D) waste generation indicates low resource efficiency in the architecture, engineering and construction (AEC) industry. This study aims to identify C&D waste disposal reduction (WDR) opportunities and barriers in various stages of the construction materials lifecycle using a systematic literature review approach. The review is guided by the Less of Waste, More of Resources (LoWMoR) model. Overall, 58 barriers and 73 opportunities are identified from 62 Australian literature sources published over the last two decades. The results show that the most opportunities are presented at the design stage, followed by the transport and landfilling elements. Furthermore, the review identifies 20 stakeholders who play a significant role in realising these opportunities including key stakeholders such as project managers, government organisations, industry associations and waste operators. The study recommends improvements in fostering broader research collaboration, harmonising waste management systems, and analysing key stakeholders involved in C&D waste management. The research findings are valuable to various stakeholders in the AEC industry and waste management and resource recovery (WMRR) sector, to drive a circular economy and improve resource efficiency. Further research is recommended in the following areas: the benefits of University-Industry Engagement (UI-E) in the AEC and WMRR industries; the impact of technologies in achieving waste minimisation objectives in Australia; waste minimisation opportunities during construction material transportation; and the direct impact of sustainability rating tools in C&D waste minimisation.

1. Introduction

The architecture, engineering and construction (AEC) industry is generally low in resource efficiency worldwide. As documented in the literature, this poor performance has resulted in serious negative environmental impacts caused by high construction and demolition (C&D) waste generation, greenhouse gas (GHG) emissions, air and water pollution, and forest degradation. Globally, the construction industry is estimated to be responsible for approximately 40% of energy consumption, 30% of CO_2 emissions and 40% of total solid production waste (Herczeg et al., 2014).

In Australia, the AEC industry is a significant contributor to the nation's economy; it is estimated (Australian Industry and Skills Committee, 2020) that it generates over $360 billion in revenue and shares 9% of the total gross domestic product (GDP). Australia's average national construction value growth rate shows that construction activities have increased (ABS, 2020) to accommodate the growing needs of urban populations. The population growth in the capital cities of Australia is influenced by overseas migrations (out-migration) and migration (in-migration) from rural to urban areas (Forbes et al., 2020). Inevitably, extensive construction activities are causing C&D waste generation at an unprecedented rate. According to the latest National Waste Report, the Australian construction industry generated 27 mt of C&D waste in 2019-20 (NWR, 2020), a 61% increase on the figures recorded in 2006–2007. Currently, this waste stream, with more than 44% and 47% generated and recycled, respectively, is the largest source of waste in Australia.

Abbreviations: AEC, Architecture, Engineering and Construction; BIM, Building Information Modelling; C&D, Construction and Demolition Waste; C&I, Commercial and Industrial Waste; CE, Circular Economy; DfD, Design for Disassembly; DoW, Design Out Waste; EfW, Energy from Waste; EPR, Extended Producer Responsibility; GHG, Greenhouse Gas; LoWMoR, Less of Waste, More of Resources; PPP, Polluter Pays Principle; RWP, Recycled Waste Product; UI-E, University-Industry Engagement; WMRR, Waste Management and Resource Recovery; WDR, Waste Disposal Reduction; RL, Reverse Logistics; NSW, New South Wales; NT, Norther Territory; WA, Western Australia; SA, South Australia; QLD, Queensland; Vic, Victoria; Tas, Tasmania; ACT, Australian Capital Territory; LCA, Life-Cycle Assessment; EIA, Environmental Impact Assessment.

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A circular economy (CE) in this space offers a way to minimise waste's environmental and economic costs, such as landfill maintenance, extracting virgin materials, landfill levies, transportation costs and illegal dumping. The CE model, as a comprehensive strategy for sustainable development, has already spread throughout the world. This model has been conceptualised as a system that is restorative by design with a core strategic focus on reframing and reorganising materials, information and energy flow to achieve greater resource efficiency through the reuse, remanufacture and recycling of materials. Its key premise is that waste minimisation can act as a new source of value for a business (Martin, 2019). Fundamentally, the concept of the CE model encapsulates the tension between limits and growth, advocating for a shift from linear to circular patterns of resource use and management. Long-established sustainability principles, such as cradle to cradle (C2C), are reconfigured through this lens (Braungart et al., 2012).

Due to the size of the industry and its adverse and unwanted impacts on Australia's environment, society and economy, an assessment of resource efficiency is necessary. In response to the emerging socio-environmental issues caused by the improper management of C&D waste materials, Australian federal and state governments have started to prioritise these resources in their environmental planning (Australian Government, 2018). Much of the planning to date focuses on specific universally tried and tested mitigating strategies. Research and education are critical factors highlighted in all waste strategy and guideline documents (Shooshtarian et al., 2020e, Desha and Caldera, 2019). Despite the abundance of research on C&D waste in the Australian context, limited studies have provided an overview of these individual attempts. Some of the previous review studies focus on C&D waste energy recovery (Shooshtarian et al., 2019b), market development (Shooshtarian et al., 2020a, Tennakoon et al., 2021), policy analysis (Shooshtarian et al., 2020e), reusing recycled materials (Park and Tucker, 2017), and waste data and reporting systems (Ratnasabapathy et al., 2019a).

This study aims to identify opportunities for waste disposal minimisation in various stages of the construction materials lifecycle, by examining at the literature investigating C&D waste management in Australia. Within this context of waste reduction opportunities (i.e. minimising waste generation) will be considered within design, manufacturing, procurement, transportation and construction stages. In addition, waste disposal reduction opportunities (i.e. minimising waste ending up in landfills) will be discussed considering strategies to increase recovery (reuse, recycle, upcycle) and prevent illegal dumping and stockpiling. The following objectives are set to define the scope of the review and to achieve the primary study aim:

- To explore the specific Australian C&D waste management situation
- To understand the main barriers and enablers of C&D waste minimisation practices
- To assess stakeholder perceptions and behaviour regarding C&D waste management in Australia

2. Method

This section describes the method adopted to review relevant C&D waste literature in the context of Australia.

2.1. Data collection and processing

The review study employs a structured literature review to collect data on key waste disposal minimisation opportunities in the context of Australia. This approach was informed by the 'Preferred Items for Systematic Review Recommendations' (PRISMA) method described by Moher et al. (2009) and the five key phases mapped out by Denyer and Tranfield (2009). The goal is to understand how, in various stages of construction materials' lifecycle, C&D waste can be diverted from landfill. The primary eight search keywords were 'Australia', 'construction waste', 'construction and demolition waste', 'landfilling', 'recycling', 'waste minimisation', 'technology' and 'policy'. A combination of three search engines (Google Scholar, Web of Science and Scopus) were used to identify the relevant research outputs. The following selection criteria were adopted to select studies with the most relevance to the objectives:

- Studies published in the last two decades to reflect the current conditions of the industry and market
- Studies with a focus on the Australia C&D waste climate
- Studies investigating the managerial aspect of C&D waste and rather than technical characteristics such as material engineering

A meta-search was conducted on literature from 2000 to 2021 using the eight primary keywords; this resulted in 135 research outputs, which then increased to 168 through the identification of other sources referenced in the initial research outputs. Duplicates were removed, and the most relevant research for recycled C&D waste was considered. Finally, after removing duplicates, applying the inclusion and exclusion criteria, and additional quality assurance checks, 62 pieces of literature were selected for the review. The selection process is presented in the PRISMA flow chart in Fig. 1. The critical literature analysis was undertaken in two stages: descriptive analysis and thematic analysis. The full review protocol was inspired by the systematic literature review approach defined by Denyer and Tranfield (2009).

2.2. Theoretical framework

This review study builds on the CE objectives focusing on waste minimisation in the C&D waste resource cycle. Australia's previous studies draw on certain frameworks to classify and investigate issues and solutions centred around the C&D waste stream. For instance, some studies use construction phases (e.g. procurement, design and planning, demolition and construction) to identify waste minimisation solutions (Kabirifar et al., 2021b, Zhao et al., 2021, Doust et al., 2021, Udawatta et al., 2020). Others employ a waste hierarchy framework (Ratnasabapathy et al., 2019c); the direction of financial flow across entities (Tennakoon et al., 2021); characteristics of the project (Li and Yang, 2014); three layers of waste management solutions (i.e. organisation, process and people) (Davis et al., 2019a, Newaz et al., 2020); or roles and responsibilities of stakeholders involved in waste management planning and practices (Park and Tucker, 2017).

This study, however, adopts a multi-dimensional approach to develop a framework that addresses waste management issues in more detail. This framework is informed by the CE concept, various stages of the construction materials lifecycle, the waste management hierarchy and stakeholder perspectives. This framework (Fig. 2), called Less of Waste, More of Resources (LoWMoR) assumes that waste is not a waste but a resource. The LoWMoR framework aims to identify opportunities for diverting waste from landfills within various resource lifecycle stages. The framework proposes eleven components in which waste disposal can be minimised. This study employs LoWMoR to investigate C&D waste research in Australia.

3. Results

The selection process yielded 62 publications, including 45 journal articles, 15 conference papers and two book chapters. The

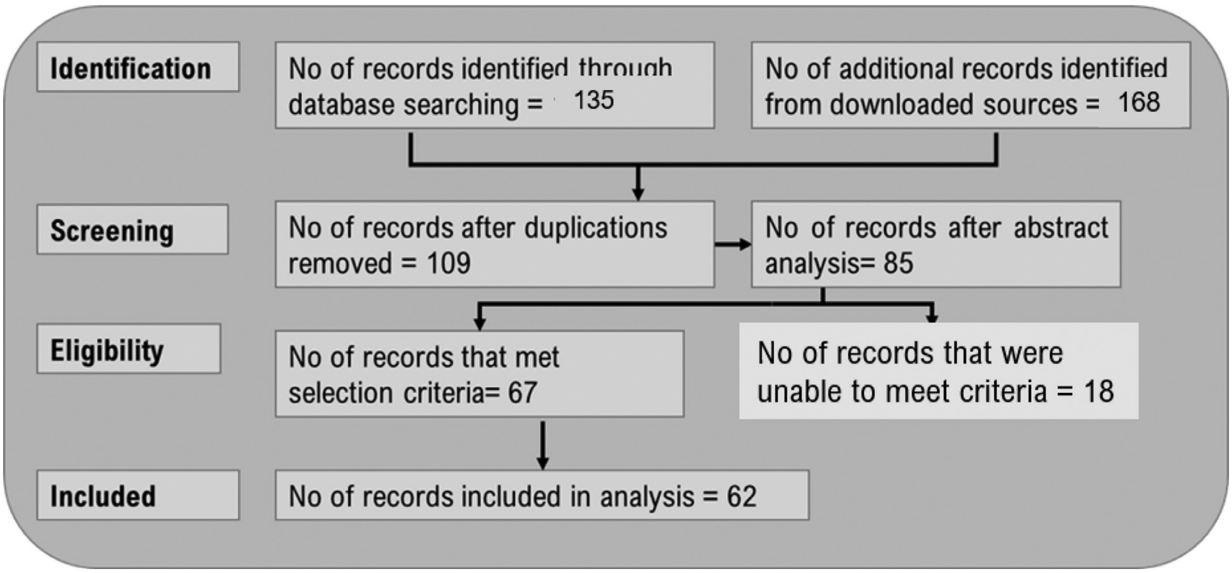

Fig. 1. PRISMA flow diagram (adapted from Moher et al., 2009)

Fig. 2. An investigation framework for C&D waste minimisations. Source: Authors

findings are structured based on the components of the LoWMoR framework.

3.1. Reducing waste during design

Design contributes to the amount of waste generated in the AEC industry through decisions that are made within the planning and design stages (Crawford et al., 2017, Newaz et al., 2020), even more so than onsite construction practices (Udawatta et al., 2015b, Lingard et al., 2000). Therefore, proper waste management should begin early in the design process as it dictates the type of construction materials, potential waste avoidance possibilities and utilisation of more waste efficient processes (Tam et al., 2018). In recent years, more researchers have focused on the design as-

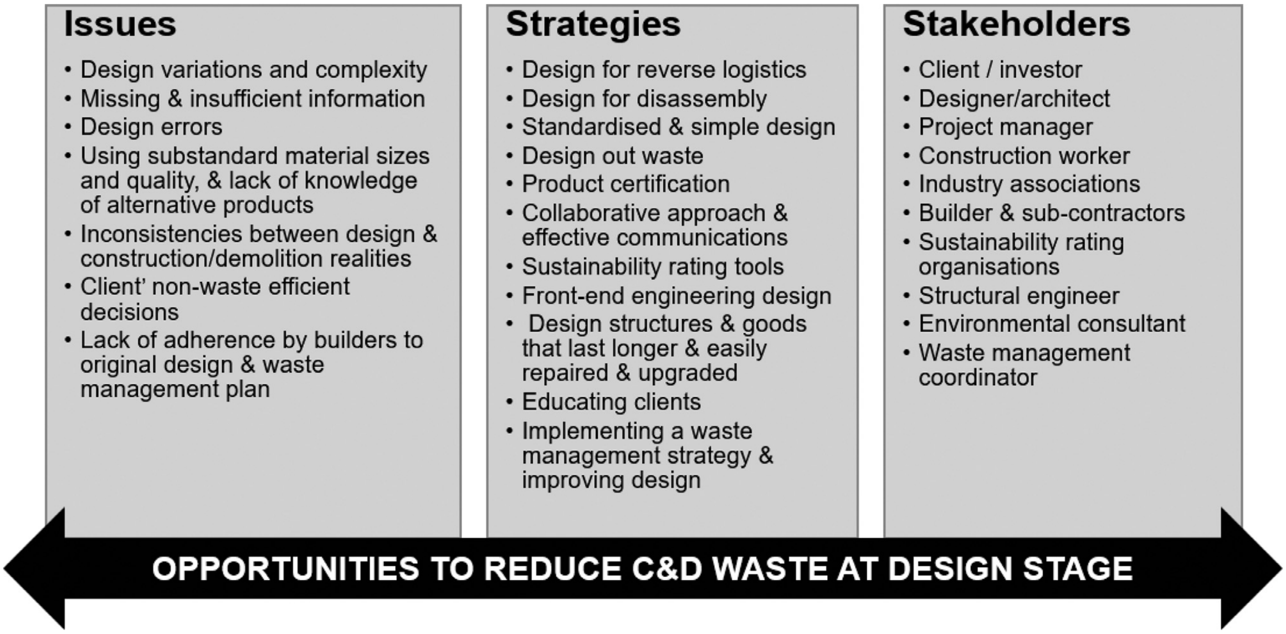

Fig. 3. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at the design stage

pects of C&D waste management (Fig. 3), aiming to create a positive impact on C&D waste management in the industry (Newaz et al., 2020, Udawatta et al., 2018, Chileshe et al., 2016, Fini and Forsythe, 2020). As a simple definition, waste minimisation at the design stage pertains to the design of structures and goods that last longer, are easily repaired, upgraded or used differently in future cycles, complemented by avoiding errors and instructing construction activities with waste minimisation in mind (Shooshtarian et al., 2020b).

There are many issues regarding C&D waste management emerging from the design and planning phase, and their priority and occurrence vary from one project to another. For instance, an analysis of a case study in regional areas of the NT shows that design-related factors can affect the level of waste (Crawford et al., 2017). According to the authors, these factors include design changes, design complexity, design errors, missing information, designs not using standard material sizes, and inconsistencies between design objectives and construction/demolition realities. Another study on retrofitting projects suggests that high project complexity, incompleteness, errors or uncertainty in design information and project variation are design-related waste management challenges (Li and Yang, 2014). Similarly, Shooshtarian et al. (2020b) list variations and changes, the complexity of detailing, selection of low-quality materials, lack of familiarity with alternative products, and errors in contract clauses or incomplete contract documents as the major design issues. Doust et al. (2021) report that design changes (design and detailing errors) ranked first as Australia's most significant source of waste generation. Other design-related issues include the lack of adherence by builders to the waste management plan embedded in tender documentation after securing the project (Doust et al., 2021, Davis et al., 2019b) and the influence of client non-waste efficient decisions on design team behaviours (Udawatta et al., 2018).

The analysed literature provides opportunities for waste minimisation at the design stage. These include a commitment to reduce waste through input into the design process (Lingard et al., 2000, Gollagher et al., 2017); paying extra attention to the selection of durable, creating a sufficient critical mass that justifies recycling through reusable and recyclable construction materials with relatively homogeneity (Udawatta et al., 2015b, Fini and Forsythe, 2020); emphasizing the significant role of designers for reusing recycled materials that reduce recycling activities costs (Forghani et al., 2018); educating clients, implementing a waste management strategy and improving design (Park and Tucker, 2017); considering a collaborative approach (Gollagher et al., 2017); creating simple, modular and standard designs (Doust et al., 2021); devising a method of storage for waste storage and separation onsite (Shooshtarian et al., 2019c, Gollagher et al., 2017); participating in construction sustainability rating schemes (Shooshtarian et al., 2019c, Caldera et al., 2020b); and holding post-tender meetings with subcontractors to review and operationalise waste management targets (Udawatta et al., 2020).

Several studies highlight the importance of the design team's involvement in waste management planning (Udawatta et al., 2015b, Zhao and Tang, 2021). The design team focusing on waste issues ideally consists of designers, architects, structural engineers, environmental consultants and waste management coordinators. Generally, the literature shows that, for the most part, client and design team interaction determines how waste is to be managed, including type and quantity of waste generation (Crawford et al., 2017). Park and Tucker (2017) state that the design team should communicate the waste minimisation framework and associated strategies to clients at the design stage. This will result in the team making sustainable decisions that minimise waste disposal. In the authors' opinion, this is operationalised through improved awareness and change of attitudes. This task might not be delivered by contractors, according to Udawatta et al. (2018), as most construction project arrangements are price-driven. Therefore, designers can illustrate comparative cost performance at the early design stage among various waste management-related strategies (Tam et al., 2018).

A detailed analysis of the literature yields several design-related strategies and concepts that together can address C&D waste issues in the AEC industry. These include design out waste, design for reverse logistics, design for disassembly, front-end engineering design, standardised design, collaboration approaches, design variations, sustainability measurement schemes and product certification. Some of these concepts overlap with waste minimisation opportunities in the construction materials manufacturing stage.

From the literature, it can be understood that designers and architects are unaware that waste management should be an integral part of the AEC industry. Research findings from two studies show that designers do not tend to take responsibility for waste or see its management as part of their role (Crawford et al., 2017, Udawatta et al., 2015a). This tendency can create a disconnection between design objectives and construction practices. Recently, it has been argued that education will make a cultural shift geared towards sustainable construction that involves innovative and modern design promoting recycled or second-hand construction materials (Shooshtarian et al., 2020b). Park and Tucker (2017) point out that the shortage of educated designers with sustainability concerns who are willing to apply reused elements increases the cost of reusing material.

Given the complex nature of construction projects, diversity of stakeholders and uncertain environment, a collaborative approach within the project team will result in better waste management. Studies recommend an early and extended involvement of contractors in retrofitting projects (Li and Yang, 2014), new buildings (Gollagher et al., 2017) and infrastructure projects (Doust et al., 2021). Udawatta et al. (2015a) suggest that stakeholders should pay attention to waste generation's environmental consequences and avoid them as early as possible. In the Gollagher et al. (2017) case study in WA, it was observed that the design team alone could not develop designs and that the involvement of contractors resulted in the redesign of the project site layout for better waste management.

It is often argued that design information and documentation are central to the AEC industry's waste management (Li and Yang, 2014). Sharing design information results in reduced design errors and variations. For instance, Rameezdeen et al. (2016) empirical research on reverse logistics (RL) in SA shows that a lack of information sharing is strongly associated with recognition for RL. To ensure a collaborative approach is maintained throughout the project lifecycle, effective communication is required. In Davis et al. (2019b), research participants ranked collaboration and communication improvements between stakeholders second among design-related factors. Technologies such as Building Information Modelling (BIM) can facilitate this communication. The Davis et al. (2021) case study indicates that BIM-enabled collaborative planning at the design stage informed by the waste management consultant, builder and BIM operator would result in a more accurate prediction of C&D waste in real time.

Drawing on the different design concepts indicated in Fig. 3, design guidelines and standards should be developed to encourage reusable and adaptable materials leading to resource efficiency. In the literature, various design concepts are used for C&D waste minimisation opportunities at the design phase. These include design out waste (Shooshtarian et al., 2020d); design for disassembly (DfD) (Ratnasabapathy et al., 2020); design for RL (Chileshe et al., 2016); and product certification policies (Park and Tucker, 2017). Design out Waste (DoW) is a design guideline that encourages the use of available materials as efficiently as possible to minimise the quantity of resources used for construction. However, Fini and Forsythe (2020) indicate that DoW guidelines are not adequately detailed to implement the best waste management plan (WMP). Design for disassembly facilitates future changes and dismantlement (in part or whole) to recover systems, components and materials. RL involves planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging and finished goods, from the manufacturing, distribution or use point to the point of recovery or proper disposal. Product certifications provide confidence in the quality and performance of recycled materials. Park and Tucker (2017) and Zhao et al. (2021) suggest that these policies should be included in the Building Codes of Australia and the National Construction Code to improve the overall industry sustainability. Such guidelines provide clarity on the potential sustainable practices undertaken during C&D activities. They can go a long way in separating and collecting products at the end of their useful lifetime. The literature indicates that implementing these policies is the responsibility of the design team (Chileshe et al., 2016, Udawatta et al., 2018).

Therefore, one way to encourage the design team is to mandate or incentivise compliance requirements set by construction sustainability rating schemes such as Green Star (Green Building Council of Australia) and ISCA (Infrastructure Sustainability Council of Australia) (Shooshtarian et al., 2019c). Udawatta et al. (2020) reveal that using these schemes is often driven by marketing benefits and utilising a sustainable design benchmark can change designer behaviours. In their study, such a change leads to setting waste management targets and careful selection of construction materials. On this note, utilisation of tools measuring the environmental impacts of design decisions helps the design team contribute to project sustainability and better compliance with sustainable rating systems requirements. For instance, Le et al. (2018) develop a computer-assisted model to estimate lifecycle GHG emissions.

3.2. Reducing waste during manufacturing

Waste minimisation opportunities during manufacturing are twofold: reducing waste during manufacturing and using waste materials in the production line to create new materials. A report by the Australian government suggests that between 70 and 80% of the environmental impact of a product is locked in at the manufacturing phase (Senate Environment and Communications References Committee, 2018). The National Waste Policy (Australian Government, 2018) proposes that providing continuous support to consumers and manufacturers is necessary to make more informed decisions (Ratnasabapathy et al., 2019a).

Shooshtarian et al. (2020b) note that there are initiatives among manufacturers in Australia to reduce waste during production. For instance, a clay brick manufacturer in WA returns all clay brick production waste into the product mix. A manufacturing plant in Victoria has managed to markedly reduce the instance of malformed or off-specification green (unfired) bricks; it is reported that any such units are automatically recycled into the clay mix rather than going to landfill (Brickworks Building Products, 2012).

Studies suggest that construction material producers should pay special attention to DfD (Fig. 4) as this will maximise the chance of resource circularity in the construction and demolition phase (Forsythe and Fini, 2018, Shooshtarian et al., 2020d, Udawatta et al., 2020, Ratnasabapathy et al., 2020). A review by Zhao et al. (2021) indicates that DfD is effective in Australia. Implementing these strategies, however, requires encouragement, primarily through market-driven strategies. Market development (Ratnasabapathy et al., 2021, Caldera et al., 2020b) and product certification (Park and Tucker, 2017) are two strategies that encourage manufacturers to use waste materials in their production lines. The former provides sustainable supply, and the latter builds confidence in the existence of demand for products with recycled content. King et al. (2020) confirmed that an online marketplace can connect a recycler with a manufacturer to ensure material flow.

Furthermore, off-site manufacturing is proven to be a waste-efficient methodology in the AEC industry. Udawatta et al. (2015b) findings show that 25% of interviewees agree that off-site manufacturing helps reduce waste generation. In Davis et al. (2019a), participants rated the utilisation of off-site manufacturing as a priority strategy for waste reduction. Other waste minimisation strategies in this phase include raising manufacturer aware-

Fig. 4. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at manufacturing stage

ness of environmental consequences of their activities (Treloar et al., 2003) and the use of other waste materials from different streams in production lines, which reduces the need for using raw materials (Shooshtarian et al., 2020b).

However, there are issues affecting waste minimisation in the manufacturing phase. Transportation of waste materials to manufacturing plants, as well as the lack of local plants, is challenging in regional areas (Corder et al., 2014). For instance, Crawford et al. (2017) state that policies such as Extended Producer Responsibility (EPR) are not feasible to be implemented in remote areas due to long distances. Other identified issues in the review include the unwillingness of the manufacturing industry in participating in waste trading exchange systems (Corder et al., 2014); low manufacturer interest in using waste materials in their production processing (King et al., 2020); and a high rate of packaging and pallet waste (Doust et al., 2021).

In addition to market-driven strategies, regulatory support can promote a CE at the manufacturing phase. One relevant policy approach to encouraging the utilisation of waste materials in the manufacturing of new construction material is EPR, otherwise known as take-back or the polluter pays principle. This policy suggests that the material manufacturer or supplier is financially and/or physically responsible for the waste generated from their supplies for the entire lifecycle (Tam and Lu, 2016). No mandatory EPR policy is currently legislated for construction material manufacturing, though New South Wales (NSW) and Wester Australia (WA) have voluntary EPR policies (Shooshtarian et al., 2020d). Ratnasabapathy et al. (2021), Park and Tucker (2017) identify the lack of mandatory EPR policy as a barrier to reusing waste materials and developing C&D waste trading networks in Australia, respectively. Shooshtarian et al. (2020d) study the application of EPR in Australia and indicate that there is widespread support among different stakeholders to develop EPR. The researchers report barriers such as cost and time implications; complexity of policy establishment and enforcement; diversity of stakeholders involved; construction product lifecycle; responsibility of manufacturers; and health and safety issues. The recommendations include creating an effective supply chain system; promoting DfD; waste responsibility assignment; product documentation; and improved health and safety risk management.

3.3. Reducing waste during procurement

The literature suggests that ineffective construction and procurement is a significant source of C&D waste generation. A research participant in a study by Udawatta et al. (2015b) states that construction practitioners do not allocate enough time for the planning stage when it is busy, which creates procurement and design problems. Therefore, adequate planning for procurement with waste management prioritisation is necessary before the construction phase (Fig. 5). In this phase, a correct estimation of materials is required (Shooshtarian et al., 2020b), as is adopting waste efficient technologies (Davis et al., 2021); time management for material delivery (Shooshtarian et al., 2020b); and use of contract power to procure waste efficient materials and services (Davis et al., 2019a). Sustainable procurement (Park and Tucker, 2017) is the main strategy that review studies recommend to reduce waste during procurement.

Sustainable procurement, by definition, is a process whereby organisations meet their needs for goods, services, works and utilities in a way that achieves value for money over their whole life. Sustainable procurement provides an incentive for further waste recovery. This policy is suggested in different Australian waste-related guidelines and strategy documents (Shooshtarian et al., 2020e), including the 2018 National Waste Policy (Australian Government, 2018). One study reports that research participants indicate that sustainable procurement is a crucial solution for organisational waste management as long as it is a viable option or the client consents to pay extra (Davis et al., 2019b).

Sustainable procurement directly relates to market development for recovered C&D waste materials (Caldera et al., 2020b). Shooshtarian et al. (2020a) survey find that sustainable procurement is among the top three factors contributing to C&D waste market development. The literature analysis shows that Australia's relationship between procurement and C&D waste minimisation is not well studied. Hence, multiple research studies highlight the need to investigate the impact of procurement methods on WMPs (Teo and Loosemore, 2001, Udawatta et al., 2015b, Doust et al., 2021).

Correctly estimating the materials needed for a construction activity can save a significant quantity of unwanted materials that

Fig. 5. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at the procurement stage

might otherwise have been landfilled. Inaccurate quantity take-off and/or over-ordering ultimately create extra waste. In Australia, builders typically order 2-3% more than is required to allow for offcuts and waste (Scarvaci and Barrett, 2019 as cited in Shooshtarian et al., 2020b). However, on large jobs, the risk of over-ordering tends to be reduced because deliveries are made progressively throughout the project, and only the last order requires accurate take-off and ordering (Shooshtarian et al., 2020b). Doust et al. (2021) research findings show that procurement ordering and take-off errors are among Australia's five top sources of C&D waste. The researchers also indicate that poor material control and logistics need to be improved for the best results, and an integrated materials supply chain to drive efficient material flows is required. The use of technologies can be helpful for waste management in the procurement stage. For instance, BIM can produce information on the exact quantities to order or prepare, resulting in minimum generation (Davis et al., 2019a).

Just-in-time materials delivery to a construction site should be planned to avoid damage due to insufficient space for proper storage and adverse weather conditions (BRE Group, 2019). Moreover, suppliers can be encouraged to provide more flexible "last pack" sizes (i.e. a "fractional" pallet instead of a full pallet) to minimise the waste because of over-ordering.

Another management strategy relating to the procurement stage is the effective utilisation of contractual agreements that present an opportunity to minimise C&D waste. Through this agreement, stakeholder responsibilities for waste management are identified, and they are required to incorporate waste minimisation activities in their work schedule and discipline poor waste management. There is evidence that even the type of contract could influence how waste is generated. For instance, it is reported that "fix only" subcontracts rarely motivate bricklayers to reuse offcuts (Shooshtarian et al., 2020b). This strategy plays a vital role in public projects where government purchase power, via a sustainable procurement policy, can guide stakeholders' waste management decisions and behaviour (Davis et al., 2019b, Hardie et al., 2007).

3.4. Reducing waste during transportation

In the AEC industry, resource procurement and waste management plans specify the requirements for resource handling and transportation. Transportation is the physical connecter between the main stages of resource circularity as depicted in the study framework (Fig. 2). Hence, waste minimisation practices can be exercised during transportation. In research conducted in NSW (Wilmot et al., 2014), industry experts rated transport distances as one of the top determinants of resource efficiency in C&D waste management.

Generally, there is limited knowledge on how waste minimisation opportunities can be realised. Most studies that cover this stage only focus on waste transportation environmental impacts as opposed to waste minimisation practices during construction materials shipping (Fig. 6). A study exploring opportunities for brick waste minimisation during transport (Forsythe and Máté, 2007) indicates that technical deficiencies such as poor protection of bricks, hand unloading and unpacked supply can result in waste generation.

Under waste transportation, the focus is often placed on analysing the environmental and economic (cost and GHG emissions savings) benefits of waste transport to recycling facilities rather than landfills (Le et al., 2018, Doust et al., 2021). Well-coordinated waste transportation maximises the chance of waste recycling. The decision to transfer source-separated waste to recycling facilities depends on the cost and minimum quantity of homogenous waste required to load a truck. In this case, Fini and Forsythe (2020) suggest that waste collectors need to assess the feasibility of collecting C&D waste from multiple construction sites. Otherwise, additional charges for waste movement and temporary storage may encourage waste disposal. Research by Tam et al. (2009) in Queensland (Qld) reveal that the relatively high cost of transportation is among the top five barriers to using recycled materials. To this end, Yazdani et al. (2021) propose a hybrid simheuristic algorithm tool based on an integrated simulation-optimisation method to optimise vehicle route planning for C&D waste collection. The tool can inform decisions regarding C&D waste management, assist with travel cost reduction and ultimately improve waste resource recovery.

Waste transfer can occur at the local, interstate, national and international levels. The general perception is that waste transfer over long distances is a barrier due to cost implications and socio-environmental impacts (Tennakoon et al., 2021, Wilmot et al., 2014). However, it may also provide opportunities to reduce waste disposal when recycling facilities are not located close to the region where waste was initially generated (King et al., 2020), particularly in remote areas (Crawford et al., 2017). The Wu et al. (2020) investigation of waste transfer in Australia documents waste exchange among states and territories to create a map of C&D waste mobility routes across the country. Furthermore, waste export to other countries is also recorded (Wu et al., 2020), due to new opposing national and international regulations (Doust et al., 2021).

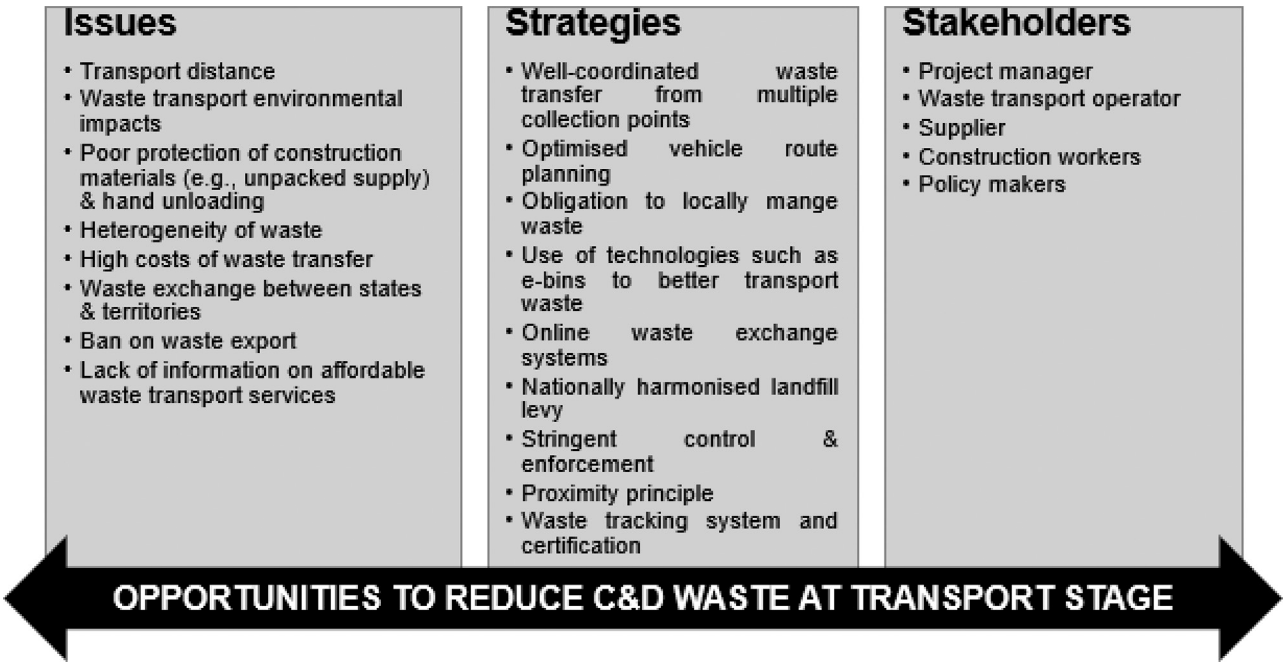

Fig. 6. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at transport stage

Technological advances can improve waste minimisation through effective transportation (Davis et al., 2021, Jayasinghe et al., 2018). Davis et al. (2021) suggest that using eBins equipped with compact cameras, programmable and compatible with BIM applications, can make waste transportation better coordinated, more straightforward and cost-effective. The King et al. (2020) case study highlights that online matchmaking platforms to accumulate waste collected at different sites would result in better resource recovery regardless of distance. However, the authors indicate that the distance could potentially be a significant factor in future.

The literature analysis suggests that Australian states and territories can achieve waste disposal reduction (WDR) related to transportation through multiple strategies. These include stringent control and enforcement, plus a nationally harmonised landfill levy preventing interstate waste transfer to cheaper landfills, stockpiling or illegal dumping (Wu et al., 2020, Shooshtarian et al., 2020c); utilisation of simulation tools predicting the most cost-effective method to deliver waste materials to recycling facilities (Yazdani et al., 2021); deploying waste tracking systems and waste tracking certificate (Jayasinghe et al., 2018); applying the proximity principle that supports resource efficiency (Shooshtarian et al., 2020c); sharing information on available waste transportation services with affordable fees (Chileshe et al., 2019); the possibility of waste collection from multiple sites justifying waste recycling over disposal (Fini and Forsythe, 2020, Caldera et al., 2020b); and using data sharing technologies and matchmaking algorithms to enable such possibilities (Corder et al., 2014, King et al., 2020).

3.5. Reducing waste during construction

The construction stage represents a period in which the materials and products are assembled to create the finished built environment. Generally, construction activities generate C&D waste materials. The sources of waste during construction, as suggested by the literature, can range from poor workmanship to inappropriate materials handling and storage through to building defects and inefficient waste management planning and practices e.g. inadequate waste separation, lack of space, unwillingness to recruit a waste coordinator (Davis et al., 2019a, Newaz et al., 2020); preference for waste disposal (Tennakoon et al., 2021); and resistance to adopt technology-enabled waste efficient strategies (Park and Tucker, 2017). Newaz et al. (2020) review the nature of waste in the construction phase, including wreckage and packaging waste, structure waste and finishing waste.

In a highly profit-driven construction context, time, cost and quality come before environmental concerns. Responses from construction experts to an Australian survey reveal that waste reduction efforts are challenged by time pressure, inadequate waste management facilities and space, plus lack of knowledge (Teo et al., 2000). Hence, a factor that plays an important role in adopting sustainable WMPs is the right attitude. Attitudes represent peoples' evaluations of objects or situations that predispose them to behave in a certain way (Azjen, 1993). According to the theory of reasoned action, behaviour is controlled by intention and intention is influenced by attitudes and subjective norms (Bagozzi, 1992).

In terms of attitudes among construction players, however, the findings in the literature are mixed. While some studies report labourers care more about waste management than management teams (Lingard et al., 2000, Teo et al., 2000), other studies provide opposing evidence (Tam et al., 2018). Lingard et al. (2000) state that labourers consider that waste management is beyond their control, not cost-effective and that senior management is not supportive of WMPs. Udawatta et al. (2015a) found that decisions on WMPs in Australian commercial construction projects follow financial benefits unless project owners are required to comply with requirements set by sustainable building rating systems. The authors report that owners of these projects resist reusing or using recycled products (Udawatta et al., 2015a). In recent years, with more sustainability awareness and requirements, as well as available incentives and perceived financial benefits from waste recycling (Crawford et al., 2017), managers are more conscious about WMPs. Tam et al. (2018) show that unsupportive work routines and operating procedures, the task's difficulty as opposed to the convenience offered by waste collection for landfilling, and the minimal impact of employers on labourers waste handling behaviour are among the top reasons why labours do not exercise WMPs. Crawford et al. (2017) observe that since it is free to discard clean fill at waste transfer stations, managers tend to separate this material from other waste resources.

When it comes to waste efficient behaviours on construction sites, labourers' working practices, attitudes and knowledge of handling construction materials are critical. Teo et al. (2000) argue that due to the labour-intensive nature of construction activities, behavioural impediments can affect levels of waste. A study in Australia shows that poor workmanship could generate up to 75% of total brick waste in a construction project (Forsythe and Máté, 2007), and the estimated cost for ordering materials to cover the wastage during construction is found to be 4% of the total construction cost for a standard house in Australia (Treloar et al., 2003). Park and Tucker (2017) state that poor workmanship is a fundamental issue, and builders attempt to reduce waste by hiring experienced labourers. Forsythe and Máté (2007) identify the nature of brick wastage by exploring improper brick layering practices. Empirical research by Davis et al. (2019a) suggests that avoiding confusion among supervisors and labourers about WMP is a key solution under the roles and responsibilities category. Newaz et al. (2020) also report that the biggest challenge for contractors is to motivate workers to put waste resources into the appropriate bin. Therefore, training construction workers play an essential role in developing resource-efficient working practices. Lingard et al. (2000) suggest the involvement of labourers in identifying waste management solutions and the practical aspects of WMP minimises on-site waste. Zhao et al. (2021) note that meeting the government compliance requirements warrants training to shift construction employees' attitudes and awareness, resulting in an enhancement of their sustainable WMP knowledge.

In addition to monetary profit, construction managers are motivated to carefully design and implement sustainable WMPs by being accredited by a sustainability rating scheme. It is argued that accreditation can improve a construction companies' image and promote their products (Le et al., 2018). In Australia, two major organisations offer such accreditation in the AEC industry: the Green Building Council of Australia (GBCA), targeting green buildings. and the Infrastructure Sustainability Council of Australia (ISCA), which evaluates sustainability in infrastructure projects. Shooshtarian et al. (2019c) review how rating systems provided by these two organisations encourage WDR during the construction stage. Research by Gollagher et al. (2017) and Udawatta et al. (2020) indicates that the industry embraces these tools to adopt sustainable WMPs effectively. However, one study on the barriers to implementation of GC in Australia shows that the initial enthusiasm for separating the C&D waste materials dissipated as the projects progressed (Wilson and Tagaza, 2006). Some studies suggest improvements and more elaboration on the requirements of these rating tools is required (Udawatta et al., 2020, Park and Tucker, 2017).

In Australia, most construction companies use bins as vessels to collect C&D waste (Davis et al., 2021), and gates fees are charged based on the composition of the waste going into bins (Newaz et al., 2020). In the literature, many studies highlight onsite waste separation as an effective waste management solution. It reduces gate fees at recycling facilities due to recyclers' preference for receiving homogenous resources (Fini and Forsythe, 2020); however, this process requires physical labour and the allocation of an additional budget (Newaz et al., 2020). New technologies can facilitate onsite waste separation and promote sustainable WMPs *a fortiori*. Advanced technologies facilitate waste documentation monitoring and minimisation. Davis et al. (2021) demonstrate that applying a deep convolutional neural network based on digital images can separate single and mixed waste at a 94% accuracy rate and control the resources deposited manually by the labourer on site.

As such, investing in technologies that will offer less waste disposal is deemed a top priority by several waste management strategies in Australia (Shooshtarian et al., 2020e). Notably, in the National Waste Policy 2018 (Australian Government, 2018), investment in new processes and technologies is recognised as a means to enable significant changes in the generation, management and disposal of waste. The literature recognises technological barriers as a significant hindrance towards effective waste management and emphasises the necessity of their wide application in C&D waste management (Kabirifar et al., 2021a, Park and Tucker, 2017, Ratnasabapathy et al., 2021). Udawatta et al. (2015b) find that adopting construction technologies to minimise waste is the most critical solution for C&D waste management and that the government should financially support technological development.

However, there are issues regarding the application of tools and technologies. Insufficient education in the private sector about investing in waste management technologies is a significant limitation in adopting C&D waste-related technologies in the Australian industry compared to its Japanese counterpart (Tam, 2009). Park and Tucker (2017) point out that the industry's conservative approach to adopting new technologies prevents their wide application in the Australian waste management and resource recovery ecosystem. Chileshe et al. (2016) argue that the lack and discriminative support for technology enhancement prohibit their broad application. However, in recent years, both national and state governments have provided significant funding for a technological overhaul in resource recovery centres. Shooshtarian et al. (2019b) maintain that while the technology for energy recovery has been around for decades and thoroughly road-tested in certain parts of the world (e.g. Europe and Asia), it is still at an early stage of development in Australia as very few facilities with advanced technologies for waste recovery exist. A recent review by Zhao et al. (2021) suggests that limited studies have explored the emerging technologies for the C&D waste stream in Australia. Davis et al. (2021) maintain that C&D waste management logistics in the AEC industry have not changed considerably, which arises from neglecting the use of new technologies in other sectors.

A recent review article on the application of smart technologies to the C&D waste stream, infers that these technologies are still at the prototype stage (Ratnasabapathy et al., 2019b). The authors categorise these technologies as spatial, identification, data communication and acquisition, and data management and transaction packages.

The C&D waste-related technologies include the following:

Waste efficient construction methodologies such as prefabrication and 3D printing (Li and Du, 2015, Davis et al., 2019a);

- Building Information Modelling (BIM) that enables a reduction in waste emerging from poor communication and design errors (Udawatta et al., 2015b);
- Remote sensing and drones that facilitate monitoring of waste disposal and illegal dumping sites and bins' content (Glanville and Chang, 2015, Davis et al., 2021);
- Lean construction that eliminates non-value-adding activities (Zhao et al., 2021); Industry 4.0 and Digital Twining (Shooshtarian et al., 2020d, Ratnasabapathy et al., 2019b);
- Low waste operational robotics (Shooshtarian et al., 2020b);
- Mobile crushers,
- Sensors to know when the bin is full, magnets to separate metals from other waste (Davis et al., 2019a); and
- deep CNN (Davis et al., 2021).

Ratnasabapathy et al. (2019b) also provide a list of smart technologies with applicability in the C&D waste stream, including

- Imaging and image processing,
- Wireless network,
- Radio Frequency Identification (RFID),
- Artificial Intelligence (AI),

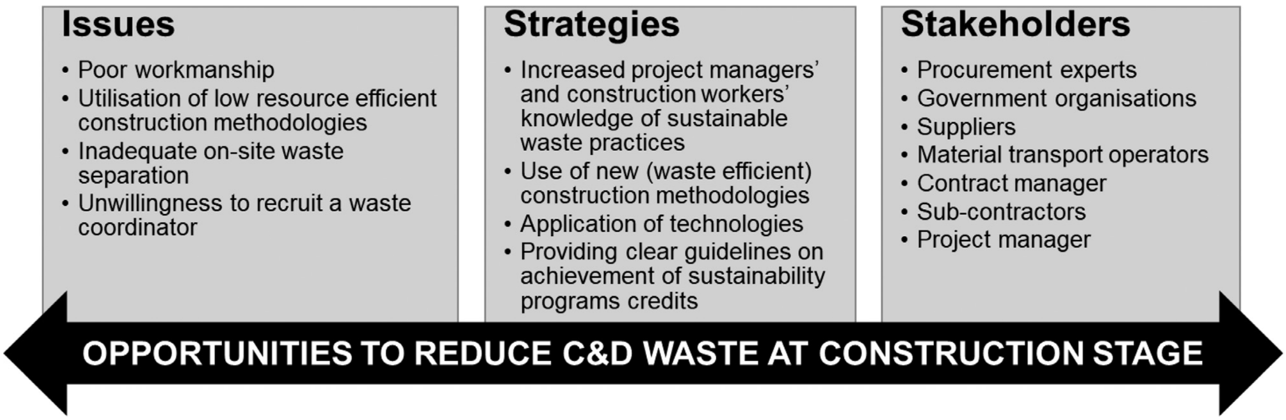

Fig. 7. Issues, solutions and key stakeholders playing a role in C&D waste reduction at construction stage

- Resource passport,
- Blockchain,
- Internet of Things (IoT) and
- Big data.

Lastly, successful implementation of waste management policy approaches such as EPR, design out waste, minimum recycled content through sustainable procurement scheme and other relevant policies heavily dependent on the knowledge, experience and cooperation of those directly involved in construction activities. These include (Fig. 7) construction managers, site supervisors, subcontractors, labourers, and civil and structural engineers (Park and Tucker, 2017). Newaz et al. (2020) presents findings from interviews with 19 practitioners in NSW, which indicates that knowledge, experience and training of site operatives are essential factors influencing C&D WMPs.

3.6. Reducing waste during demolition

Generally, the demolition sector is a primary source of C&D waste in the AEC industry (Fig. 8). The technique used in demolition activities (mechanical demolition, deconstruction and selective deconstruction) plays a decisive role (Tennakoon et al., 2021). Mechanical demolition is generally more difficult to control and provides little space to separate materials (Newaz et al., 2020). Observations from a case study in NSW show that most of the mixed waste emerging from fast-tracked demolition is sent to landfill (Forsythe and Fini, 2018). In this space, the deconstruction technique is more environmentally sustainable, which results in less waste disposal. In selective deconstruction, some materials are targeted for reusing and recycling. Project planning involves the scheduling for dismantling components, defining work tasks, choosing the technology and estimating the required resources. A study in NSW revealed that deconstruction is cheaper than demolition, by anywhere between 55% (Asbestos fibro, bricks and concrete removal) and 294% (full brick) (NSW Office of Environment and Heritage, 2010). This is because waste disposal fees are significantly reduced. However, regular demolition requires less time than deconstruction, including the workforce (total man-hour) and active plant costs (Shooshtarian et al., 2020b).

The decisions of specific stakeholders determine demolition activities. As outlined above, it is often suggested that deconstruction, design for disassembly and design for reuse need to be incorporated in the design stage (Udawatta et al., 2015b, Forghani et al., 2018), hence designers and architects have a pivotal role to play. According to Fini and Forsythe (2020), waste-conscious design practices can facilitate deconstruction in office building fitouts projects. Waste recyclers play an essential role in providing information to demolition operators regarding waste resources to be dismantled, as well as setting requirements for accepting them in their recycling facilities (Tennakoon et al., 2021).

Demolition operators also have a crucial role in deciding what happens to the waste. Several studies observe that waste operators apply cost-benefit analysis to decide the waste fate between recycling and landfilling options accordingly (Fini and Forsythe, 2020, Rameezdeen et al., 2016). Such an analysis covers separation cost, transport fees, the number of waste materials and recycling benefits. Tennakoon et al. (2021) state that due to a lack of standardised practices for demolition waste recovery and financial motivations, demolition operators tend to use demolition, resulting in the generation of mixed waste ending up in landfill. Survey data from Forghani et al. (2018) reveals that while having a positive attitude towards sustainable demolition, 38% of demolition operators in NSW did not have any guideline to reuse building components. This study also indicates that operators are motivated by both environmental and economic benefits.

A word query analysis on the existing literature shows that deconstruction is not well investigated in the Australian context. Chileshe et al. (2016) investigate RL practices on three levels: project, organisational and industry. The findings demonstrate that understanding the benefits and challenges of deconstruction at the organisational level is an essential factor, as senior management support is required for making big decisions. The researchers suggest that the industry should provide deconstruction services with capable facilities. Rameezdeen et al. (2016) identify the significant barriers to RL implementation, which could also be appliable to deconstruction. These included an unsupportive regulatory framework, extra costs involved, lack of recognition in the AEC supply chain and additional effort required. Tennakoon et al. (2021) highlight that the demolition operators' limited knowledge of opportunities for deconstruction is rooted in weak information sharing between them and recyclers, which results in unguided and inefficient deconstruction practices.

The analysis of the literature identified opportunities for waste reduction in the demolition stage. These are as follows:

- The capability of the Green Star initiative can be enhanced through more focus on disassembly at the design stage and planning for adaptive reuse and deconstruction in the end-of-life stage (Udawatta et al., 2020);
- Establishing an interactive communication platform to enable the cooperation of demolition operators with other parties involved (Forghani et al., 2018);
- Developing appropriate methodologies before demolition including analysis of each project's specific requirements (Newaz et al., 2020);

Fig. 8. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at demolition stage

- Communicating information on highly valuable materials, regulatory requirements, quality and composition of waste resources, and demand in market to demolition operators through an as built, construction drawings and demolition contract (Tennakoon et al., 2021);
- Applying sustainable design practices such as using relatively homogenous materials to justify recycling, ensuring fast knock-down from volumetric to flat and stackable packages, and using screw or bolted joints (Fini and Forsythe, 2020);
- Providing incentives to limit mechanical demolition (Ratnasabapathy et al., 2020);
- Improving the availability of intermediate waste sorting and storage facilities (Tennakoon et al., 2021);
- Development of a second-hand market (Caldera et al., 2020b); and
- Pushing EPR schemes (Shooshtarian et al., 2020d).

3.7. Reducing waste disposal through recovery: reusing, recycling and upcycling

Minimisation of C&D waste disposal is best practised through waste recovery. Waste recovery can be described as any operation in which the principal result is waste serving a useful resource by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy (Hall, 2010). According to the waste hierarchy concept, waste recovery (in the forms of reusing, recycling, upcycling and energy recovery) is the most preferred waste management method after waste minimisation. The following sections present key literature related to the abovementioned recovery methods, and other influential factors such as technology, marketplace and policies enabling waste recovery in the AEC industry.

Reusing construction materials in the AEC industry does not currently receive support due to a wide range of inhibiting factors specified in the literature (Canberra Business Chamber, 2014, Fini and Forsythe, 2020). But recycling has received much attention due to its ability to use the recycled waste products (RWP) in the same industry as it was generated, while upcycling occurs between two industries, otherwise known as industrial symbiosis (Caldera et al., 2020b).

In comparison with recycling, upcycling has not been well adopted by the AEC industry, waste recycling sector and government sector. EfW is a new waste management notion in Australia; its development has been hindered by a lack of regulatory support and environmental concerns (Shooshtarian et al., 2019b).

Although not recognised as the preferred waste recovery method, energy recovery, or energy from waste (EfW), is more viable than landfilling.

The significant aspects of waste minimisation during waste recovery include technology, infrastructure, policy, stakeholders' knowledge and attitude towards waste minimisation, engagement and end-market development. The following sections review the above aspects to deepen our understanding of the waste recovery climate in Australia.

In the literature, technological advances and fitting infrastructures are repeatedly cited as significant enablers in waste minimisation activities during waste recovery (Ratnasabapathy et al., 2019b). Ratnasabapathy et al. (2019c) research findings indicate that while C&D recovery is well-established in most Australian states, landfilling is the most practical option, notably mixed waste loads. This finding also implies a limitation in technologically advanced recovery facilities across Australia. Newaz et al. (2020) conclude that technologies related to C&D waste processing are improving rapidly in Australia, and Shooshtarian et al. (2020c) state that the success of many WMPs and strategies is subject to the availability of technologically advanced infrastructure. The main technologies used to perform energy recovery are either based on thermal treatment or biological processing of biodegrade waste and include: [1] combustion producing heat; [2] gasification that generates a combustible syngas; [3] pyrolysis that produces syngas, oil or char; [4] anaerobic digestion/fermentation that produces biogas; and [5] mechanical sorting and processing that produces combustible refuse derived fuel (RDF).

The main stakeholders influencing WMPs include recycling facilities operators, the government, the public and buyers of RWPs in this stage. A review study shows that clients' lack of interest and demand, attitudes towards reuse practices, and inadequate training act as disincentives to proactive and sustainable waste recovery. In their research to identify significant barriers to using RWP, Ratnasabapathy et al. (2021) find that the lack of knowledge about implementing advanced technology to recycle waste material is an essential factor. As for Australian perceptions of EfW activities, the limited literature investigating this issue shows that incineration is not tolerated among the public due to environmental concerns. This perception is expected to gradually change over the coming years (Shooshtarian et al., 2019b).

The relevant policies that are directly influential in this space include the proximity principle; the ban of waste import by China and other countries; and landfill levy exemptions. In 2018, China's new policy, called China's National Sword Policy, banned recyclable waste imports and made recyclable commodity prices collapse. This event exposed inadequate Australian recycling facilities and indicates an urgent need to innovate and upgrade waste management strategies (Doust et al., 2021).

The lack of a market for waste-derived products is found to be a significant barrier towards sustainable C&D waste management and can impede shaping a CE in the AEC industry (Udawatta et al., 2018, Shooshtarian et al., 2019d). The literature indicates that Australia's C&D waste market development has not progressed as expected (Park and Tucker, 2017, Udawatta et al., 2018). Several studies have focused on market development for construction recyclables drawing on stakeholders' perceptions (Shooshtarian et al., 2020a, Ratnasabapathy et al., 2021, King et al., 2020).

Udawatta et al. (2018) find that 31% of surveyed participants reported that the unavailability of the market for recyclers hinders sustainable C&D WMPs. This research shows that experts rated the market development for the recycled products as among the top solutions for C&D in the AEC industry. The findings of a survey administrated by Shooshtarian et al. (2020a) suggest that 92.5% of participants agree to the increased implementation of market incentives; the surveyed experts also rated the five top enablers of market development as an investment in technology and infrastructure (16.7%), sustainable procurement (14.6%), landfill levy (13.2%), adequate supply chain system (11.1%) and a national approach (7.6%). Another study (Ratnasabapathy et al., 2021) reports that NSW experts rated the technical barriers as the most important barrier category. The results of the survey and focus group discussions from this study also reveal the most significant barriers to developing a market for the C&D waste stream are factors such as the high cost of onsite waste sorting; lack of consistent waste data reporting system; the unsustainable demand and supply; inadequate communications and incentives across the supply chain; and complicated web-based exchange systems.

With the widespread utilisation of the internet, the waste market business model has shifted towards online marketplaces. The web-based waste marketplaces, otherwise known as waste exchange systems, are technically live databases to connect organisations seeking to dispose of materials with organisations looking to reuse or recycle the same materials (Corder et al., 2014). Some studies explore the performance of these systems (Corder et al., 2014, Caldera et al., 2020a, King et al., 2020), demonstrating a failure to achieve their pre-defined objectives. Hence, recent publications pay particular attention to marketplace development, maintenance and performance issues. For instance, Caldera et al. (2020b) develop a framework that helps researchers investigate the main barriers and enablers to developing these systems, drawing on three major categories: governance, operational and market. Corder et al. (2014) list the main barriers as the lack of awareness and promotion; companies' unwillingness to share their waste data; user unfriendliness; little activity in the current systems; local manufacturers' avoidance of using RWP; perceived and actual inconsistencies in jurisdictional waste regulations; conservative business attitudes to waste management; volumes of waste materials; and the typical need for temporary one-off agreements. The authors suggest that these marketplaces should build interest by incorporating current news stories and updates; setting expiry dates on listings and sending notifications for new listings; increasing awareness and building networks through various channels such as relevant industry associations; applying modern administration and maintenance; and creating an effective and consistent business model across the supply chain that is managed by an independent entity. Using the Advisory System for Processing, Innovation and Resource Exchange (ASPIRE) as a case study, King et al. (2020) investigate online waste marketplaces in Australia. The survey findings in this study suggest that facilitator contact with companies, pre-existing personal relationships and companies interested in the future use of recycled materials primarily drive online waste marketplace development. Another study finds that the lack of active user-friendly web-based marketplaces dramatically hinders the effectiveness of waste exchange in the C&D waste stream (Ratnasabapathy et al., 2021).

A pressing issue concerning waste market development is whether the level of operation should be national, or state based. Interestingly, opinions about this issue are divided. While some researchers argue that the national waste marketplace provides sustainable supply and demand (Shooshtarian et al., 2020a, Ratnasabapathy et al., 2021), others view this as an existential risk to the development of such entities (Hardie et al., 2007, Laviano et al., 2017, Wu et al., 2020) due to issues such as motivation for waste disposal, higher cost of operation across states, jurisdictional waste regulation inconsistencies and higher waste transfer costs. Wu et al. (2020) investigate cross-regional mobility of C&D waste in Australia. Mapping out the C&D waste fate and flow among Australian states and territories, the researchers indicate that availability of waste processing facilities, avoiding and reducing the landfill levy fees, and the existence of a market in states other than the original location drive cross-regional waste mobility. The results of site surveys, expert interviews and seminars and desktop research in this study reveal that this phenomenon has negative environmental, economic and social impacts.

3.8. Reducing waste disposal via landfilling

As indicated earlier, in 2018-19, around 6.3% Mt of C&D waste was materials destined for landfill, which was 3.6% down from the previous 13 years (NWR, 2020). This quantity of waste, accounting for 30% of total core waste, has become a source of concern for the government and the public (Newaz et al., 2020). While landfill sites are diminishing in its capacity(Crawford et al., 2017), Gollagher et al. (2017) highlights the significant costs associated with landfilling as $1.4 billion annually. Waste landfilling is the least preferred waste management method, and the worldwide literature has emphasised its adverse effect on the economy, environment and society (Yazdani et al., 2021); however, it is still an integral part of waste management in Australia. In this section, the analytical findings from the literature with relevance to issues related to landfill are presented.

Fig. 9

Currently, landfilling is the preferred construction industry method for managing C&D waste due to its convenience and lower cost (low landfill levy) over other waste management options (Fig. 10), plus its extended operation hours (Chileshe et al., 2019, Fini and Forsythe, 2020). Udawatta et al. (2015a) state that subcontractors are not interested in waste minimisation due to poor

Fig. 9. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction through waste recovery

Fig. 10. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction related to landfilling

financial returns and lack of incentives. This is also highlighted by Newaz et al. (2020), who maintain that the heterogeneous nature of construction does not allow for the prioritisation of waste management when developing designs for construction projects. Analysis of multiple fit-outs case studies in NSW shows that 78% of waste generated onsite is landfilled (Fini and Forsythe, 2020). Tam et al. (2009) indicate that charges for sending waste materials to recycling facilities are relatively higher than landfill sites. A recent study by Ratnasabapathy et al. (2019c) shows that a slight reduction in the Australian C&D waste disposal represents the need for more efforts to reduce landfilled waste. However, the authors anticipate that maintaining the current trend would bring the landfill diversion rate to 78% in 2025.

Most of the relevant studies reviewed highlight the necessity of having a landfill levy. For instance, research finds that high landfill levy fees encourage waste recovery. Shooshtarian et al. (2020c) report that 90% of survey participants endorsed the effectiveness of the landfill levy in general. In Australia, state and territory governments determine the landfill levy rate (Davis et al., 2019a). Depending on the factors involved in the formulation, the rate differs from one state to another (Shooshtarian et al., 2019a). The Shooshtarian et al. (2020e) study of current state-wide waste strategy documents reveals that the second-ranked strategy in these documents is to revise existing levy arrangements to ensure they discourage waste disposal. Notably, Australian Capital Territory (ACT), South Australia (SA), Queensland (QLD), Tasmania (Tas) and Western Australia (WA) are the jurisdictions that proposed this revision (Shooshtarian et al., 2020e).

Several research studies investigated the suitability and quality of current landfill levies across Australia (Newaz et al., 2020, Jayasinghe et al., 2018). Stakeholder considerations include properly designing this scheme to reflect real-world conditions better and maximise its impact (Zhao et al., 2021). Shooshtarian et al. (2020c) argue that while a landfill levy is the best economic driver in some circumstances, it can act as a disincentive in other circumstances, such as increased illegal dumping and waste transfer and reduced waste recycling. Rameezdeen et al. (2016) study on RL in the SA construction industry demonstrates that a higher landfill levy could cause illegal dumping. This conclusion is also confirmed in a state (WA) government report (as cited in Zhao et al., 2021).

One study in Qld shows impacts of state government decisions related to introducing and revoking landfill levies on recycling rates of C&D waste (Forghani et al., 2017). Wu et al. (2020) reveal that the availability of recycling and landfilling sites and inconsistencies in levies are among the top reasons for waste transfer between states. The researchers document C&D waste transfer between NSW and ACT, NSW and Qld, SA and Victoria, a problem that can be alleviated by policies such as the proximity principle (Jayasinghe et al., 2018), whereby waste transfer over long distances is restrained. The research by Newaz et al. (2020) finds that experts believe that the current waste levy is inefficient to discourage waste landfilling in NSW. The main reasons are the lack of tangible outcomes from levies and that the state allows for waste transfer to Qld, where landfill levies are comparatively lower. Shooshtarian et al. (2020c) report that the study participants indicate that the current landfill levy schemes implemented in Australia are not as efficient as they should be and need improvements.

Typically, landfill levies are determined by the location of landfills, levy exceptions for certain materials, composition of waste, and levy zones; as such, they increase periodically (Zhao et al., 2021, Chileshe et al., 2019). Jayasinghe et al. (2018) suggest that levies should be determined based on waste classification, demographics, levy rebates for waste recovery and financial impact analysis. The revenue from the imposition of a landfill levy is partially used to improve enforcement and compliance, development of sound policies, and to fund actions and strategies that contribute to waste minimisation. There is no nationally prescribed method for distributing levies for such purposes in Australia, and each state government does so according to its priorities and objectives (Shooshtarian et al., 2020c).

The studies reviewed provide some recommendations to improve waste management related to waste landfilling. For instance, Shooshtarian et al. (2020c) indicate that effective strategies include harmonisation of landfill levies; complementing levy imposition with technology-enabled compliance and enforcement regimes; consideration of transport fees and potential cost implications for construction activities when determining the levy rate; reinvestment of landfill levy revenue in resource recovery activities through, for example, providing low-interest loans or financial incentives; supporting R&D activities; and increasing local infrastructures. Another potential strategy for waste minimisation in landfills is to maximise the use of energy recovered (mainly methane gas) from combustible C&D waste materials destined for landfills (Shooshtarian et al., 2019b). The research by Tam et al. (2009) in Qld suggests that landfill operators should introduce a differential charging of a levy to motivate C&D waste source separation. Further, efficient waste data and reporting systems that capture the exact quantity of landfilled waste would improve planning and regulation for better waste minimisation through landfilling or otherwise (Ratnasabapathy et al., 2019a). Effective waste landfilling is supported by engineered landfills adjacent to transfer stations and reprocessing centres for optimum transportation (Jayasinghe et al., 2018). For best landfilling management, various guidelines are provided in Australian states and territories regarding landfill siting, design, construction, operation, maintenance and closure. However, the Australian government recommends harmonising best-practice landfill standards (as cited in Davis et al., 2019b). Furthermore, a combination of reasonable landfill levies, with the principal proximity policy and long-distance located landfill sites from construction sites, could favour recycling over landfilling. Lastly, the analysis of stakeholders involved in the reviewed studies shows that landfill operators' opinions are barely, less than 2%, captured in extant research studies. This highlights the need for further research to explore opportunities for waste minimisation and resource efficiency at the landfilling stage.

Drawing on global precedents, other strategies such as landfill levies (Duran et al., 2006), storing (landfilling) C&D waste in a separate landfill section (Duan et al., 2015), and material recovery at material recovery facilities located in the area of a landfill site (Gálvez-Martos and Istrate, 2020) have been identified through key literature from China, USA and European countries. For example, a previous study shows that landfilling C&D waste may be done in a separate landfill so the waste can be stored safely for future use in earthwork or road projects. If such a landfill site is not available, the waste may be stored in a special cell at a MSW landfill or used as a cover at MSW landfills (Duan et al., 2015).

3.9. Reducing waste disposal by preventing Illegal dumping and stockpiling

Illegal dumping and long-term stockpiling are severe problems in the Australian C&D waste management ecosystem (Fig. 11). A government report (NWR, 2020) indicates that illegal dumping in C&D waste space is less than 1%. However, anecdotal evidence demonstrates significantly higher rates particularly in WA and NT. Various reasons are specified by researchers for illegal dumping and stockpiling. Shooshtarian et al. (2020a) argue that inconsistent jurisdictional regulations result in illegal dumping and stockpiling. Notably, Rameezdeen et al. (2016) and Shooshtarian et al. (2020c) studies conclude that a higher landfill levy could cause illegal dumping. Shooshtarian et al. (2020b) identify the insufficient return of levy revenue to the C&D waste management sector as a barrier to preventing illegal waste activities.

As reviewed in Shooshtarian et al. (2019a), states and territories penalise these kinds of acts through hefty fines, which are enforced by specialised task forces, and have set an ambitious target to reduce illegal dumping (Zuo and Zhao, 2014). The state governments also outline illegal dumping reduction actions through their waste strategy documents (Shooshtarian et al., 2020e). These actions can be categorised as education (awareness-raising, stakeholder engagement); encouragement (infrastructure development, capacity building and networking); and enforcement (evaluation and monitoring, regulations). Researchers also suggest strategies to reduce illegal dumping and stockpiling. These strategies include more supervision of demolition companies to stop illegal dumping activities (Kabirifar et al., 2021a); using technologies such as remote sensing, GIS and image processing to monitor illegal waste activities (Glanville and Chang, 2015, Ratnasabapathy et al., 2019b); and harmonised regulations including uniform levy fees and funding for educational programs (Laviano et al., 2017, Davis et al., 2019a). As per Jayasinghe et al. (2018), upfront levy liability is an effective strategy to discourage long-term stockpiling. Currently applied in NSW, this policy incurs a fee for waste received at the depot and would fall at the disposal.

Fig. 11. Issues, solutions and key stakeholders playing a role in C&D waste disposal reduction at illegal dumping and stockpiling stage

4. Discussion

Based on these findings the authors present a matrix summarising the issues, strategies and stakeholders across the different stages of LoWMoR.

The Table 1 shows that the majority of issues were related to the operations and laws/ regulations categories. The issues under the operations category include: lack of operational adherence to the WMP; limited quality control; inadequate waste sorting and storage facilities; and lack of consistent reporting on operations. The issues under the laws and regulations category include: unsupportive regulatory framework; restrictions on waste exports; and the complexity of policy establishment. In addition, there were recurrent issues related to lack of market demand, low material quality, lack of quality standards and high costs associated with functions related to each stage.

The most evident strategies used across different stages of LoWMoR include collaboration and laws and regulations. The strategies under collaboration include: reverse logistics, sustainable procurement; stakeholder engagement; collaboration across key experts; well-coordinated waste transfer. The strategies under laws and regulations include: upfront levy liability; creating harmonised levy rates; effective distribution of levy revenues; levy exemptions; and EPR). Furthermore, there were other strategies related to the application of technologies (remote sensing, image processing, Building Information Modelling), waste tracking systems and certification to efficiently management of C&D waste.

As per the analysis of research participants recruited in the Australian studies, the top stakeholders include waste operators, project managers, government (regulators), sub-contractors, and others (designers/architects, site managers and recyclers). It can be concluded that these stakeholders have an essential role in driving WMP and WMR, and therefore, need to be involved in waste management planning, as highlighted by a few studies (Park and Tucker, 2017, Udawatta et al., 2015b). However, as waste management involves varying aspects and requirements in each construction project, stakeholder analysis must be implemented to ensure that all parties play their role in forming waste-efficient construction activities. Such involvement will lead to achieving a circular economy in the AEC industry.

To address the key issues synthesized in the above matrix and to create targeted strategies the authors summarise the following recommendations based on the findings from the key literature examined.

Research collaboration

The identified literature shows that research collaboration on C&D waste management between different institutes and among universities and industries is not well established in Australia. As Scherer (2005) writes, the benefits of research collaboration include 'increased chance of success', 'complex projects', 'grants and funding', 'avoidance of errors' and 'respect'. Therefore, funding agencies and research institutes should revisit their policy to encourage further international research collaborations (Darko et al., 2020). Despite the challenges such as organisational culture and communication highlighted by different researchers (Reddy et al., 2018), research collaboration can aid states and territories in mitigating real-world issues such as skill shortages, inadequate education and research capacities, and lead to technology and knowledge exchange among states. The issues of interstate collaboration could be, however, addressed to maximise the benefits of such collaborations. Notably, research collaboration with industry experts and University-Industry (U-IE) engagement needs to be prioritised to facilitate knowledge transfer between research institutes and the industry. U-IE is found to generate benefits such as learning, access to in-kind resources and access to funding (Henningsson and Geschwind, 2019). Di Maria et al. (2019) find that industry financial performance is positively associated with U-I collaboration centred around knowledge transfer for environmental innovation and that the higher the U-I contracts activated, the better the economic performance.

4.1. Harmonisation of waste management systems

In Australia, waste is regulated by state and territory governments. The literature reveals that inconsistent waste management climates across Australia impede sustainable C&D waste management. For instance, Park and Tucker (2017) report that inconsistent legislation around sustainable buildings hinders the use of RWP. Hence, harmonisation of waste management regulatory systems and practices can benefit all parties involved in C&D waste management. Some studies highlight the benefits of harmonising regulations pertaining to C&D waste management, such as preventing construction companies from sending their waste away (Davis et al., 2019b) and reducing complications for companies operating in various states (Shooshtarian et al., 2020c). A national approach, led by the federal government, however, needs to be devised in consultation with state and territory authorities to ensure their po-

Sustainable Production and Consumption 30 (2022) 89–106

Table 1
A matrix summarising the issues, strategies and stakeholders across the different stages of LoWMoR (categories shown in alphabetical order)

Stage	Types of issue							Types of strategies						Types of key stakeholders						
	Financial	Laws and regulations	Logistics	Market	Material	Operations	Standards (design, quality etc)	Certification / Standards	Collaboration	Education & Communication	Laws and regulations	Planning and/or Design	Technology	Government	Industry associations	Operators	Others	Project manager	Policy makers	Supplier
Reducing waste during design				•	•		•	•	•	•	•	•			•	•	•	•		
Reducing waste during manufacturing	•	•	•	•	•	•	•	•	•	•	•	•				•	•		•	
Reducing waste during procurement			•		•	•			•		•	•	•	•		•	•	•		•
Reducing waste during transportation	•	•	•		•		•		•		•	•	•			•		•	•	
Reducing waste during construction						•				•						•		•	•	•
Reducing waste during demolition	•	•	•			•	•	•	•		•	•		•	•	•		•	•	
Reducing waste disposal through recovery: reusing, recycling and upcycling	•	•	•	•	•	•	•		•	•	•		•	•	•	•		•	•	
Reducing waste disposal via landfilling	•	•		•		•			•	•	•		•	•	•	•		•	•	
Reducing waste disposal by preventing Illegal dumping and stockpiling		•								•	•	•		•		•		•		

tential specific conditions and concerns are properly reflected in any policies emerging from this initiative.

5. Conclusions

This research aimed to identify the main opportunities and barriers to minimise C&D waste disposal, through a review of 62 pieces of Australian literature. The limitations of previous studies were outlined, and future research directions were identified to further explore the field of C&D waste management. A circular economy-based model developed in this study, LoWMoR, guided the analysis of the Australian literature review. Overall, this study provides an insight into the C&D waste management situation in eleven stages of the construction materials lifecycle, as depicted in Fig. 2. Key issues related to operations (e.g., lack of operational adherence to the WMP, quality control, inadequate waste sorting and storage facilities, lack of consistent reporting on operations) and laws and regulations (e.g., unsupportive regulatory framework, a ban on waste exports, the complexity of policy establishment) were uncovered across a number of stages in the construction materials lifecycle. Key strategies related to collaboration (e.g., reverse logistics, sustainable procurement, stakeholder engagement, collaboration across key experts, well-coordinated waste transfer), laws and regulations (e.g., upfront levy liability, harmonised levy rates, effective distribution of levy revenues, levy exemptions, EPR) were highlighted in LoWMoR stages. Based on the synthesis of the key findings, the authors provide recommendations on fostering research collaboration; analysis of stakeholders' needs and requirements in devising a waste minimisation plan; and the need for federal government-led harmonisation of C&D waste management systems in Australia.

The study contributes to the body of knowledge in two ways. Firstly, policymakers and authorities can use the developed LoWMoR model to devise action plans for waste minimisation activities; it is also beneficial to research studies seeking to achieve a circular economy and resource efficiency in various industries. Secondly, the study can provide an agenda for further research into Australia's C&D waste management climate. Further research is recommended in the following areas: the benefits of I-UE in the AEC and WMRR industries; the impact of technologies in achieving waste minimisation objectives in Australia; waste minimisation opportunities during construction material transportation; analysing the economic impacts of the framework (e.g., through a LCA or EIA); and the direct impact of sustainability rating tools in C&D waste minimisation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

References

ABS, 2020. Building Activity Canberra, Australia Australian Bureau of Statistics.
Australian Government, 2018. National Waste Policy: Less Waste. More Resources In: GOVERNMENT, A. (ed..
Australian Industry and Skills Committee. 2020. Construction [Online]. Available: https://nationalindustryinsights.aisc.net.au/industries/construction [Accessed].
Azjen, I., 1993. Attitude theory and the attitude-behaviour relation. New Directions in Attitude Measurement. Walter de Gruyter, Berlin Editions1993.
Bagozzi, R.P., 1992. The self-regulation of attitudes, intentions, and behavior. Social Psychology Quarterly 178–204.
Braungart, M., Mcdonough, W., KÄLIN, A., Bollinger, A, 2012. Cradle-to-cradle design: Creating healthy emissions—A strategy for eco-effective product and system design. Birkhäuser.
BRE Group 2019. The true cost of waste.
Brickworks Building Products, 2012. Build for Living: Building a platform of commitment and responsibility Melbourne, Australia BrickWorks.
Caldera, S., Ryley, T., Zatyko, N., 2020a. Developing a marketplace for construction and demolition waste. In: 1st Asia Pacific SDEWES Conference: Engineering a Sustainable Circular Economy: Materials, Energy and Infrastructure Integration for Smart Cities and Industry, pp. 6–9 AprilGold Coast, Australia.
Caldera, S., Ryley, T., Zatyko, N., 2020b. Enablers and Barriers for Creating a Marketplace for Construction and Demolition Waste: A Systematic Literature Review. Sustainability 12, 9931.
Business Chamber, Canberra, 2014. Building and construction waste materials: Reduce, Reuse and Recycle-Opportunities and strategies for the Capital region. Canberra Sustainability Special Interest Group.
Chileshe, N., Jayasinghe, R.S., Rameezdeen, R., 2019. Information flow-centric approach for reverse logistics supply chains. Automation in Construction 106, 102858.
Chileshe, N., Rameezdeen, R., Hosseini, M.R., Lehmann, S., Udeaja, C., 2016. Analysis of reverse logistics implementation practices by South Australian construction organisations. International Journal of Operations & Production Management.
Corder, G.D., Golev, A., Fyfe, J., King, S., 2014. The status of industrial ecology in Australia: Barriers and enablers. Resources 3, 340–361.
Crawford, R.H., Mathur, D., Gerritsen, R., 2017. Barriers to improving the environmental performance of construction waste management in remote communities. Procedia Engineering 196, 830–837.
Darko, A., Chan, A.P., Adabre, M.A., Edwards, D.J., Hosseini, M.R., Ameyaw, E.E, 2020. Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities. Automation in Construction 112, 103081.
Davis, P., Aziz, F., Newaz, M.T., Sher, W., Simon, L., 2021. The classification of construction waste material using a deep convolutional neural network. Automation in Construction 122, 103481.
Davis, P., Simon, L., Sher, W., Tang, P., Newaz, M.T, 2019a. Key Solutions for Construction and Demolition (C&D) Waste Management in NSW. Australia. 43rd AUBEA Conference: Built to Thrive: Creating Buildings and Cities That Support Individual Well-Being and Community Prosperity Noosa, Australia: CQ University.
Davis, P., Simon, L., Sher, W., Tang, P., Newaz, M.T, 2019b. Key Solutions for Construction and Demolition (C&D) Waste Management in NSW, Australia. 43RD AUBEA 612.
Denyer, D., Tranfield, D., 2009. Producing a systematic review. In: BRYMAN, D.A.B.A. (Ed.), The Sage handbook of organizational research methods. Sage Publications Ltd, Thousand Oaks, CA.
Desha, C., Caldera, S., 2019. Foundations and horizons: The critical role of international coursework to engage students in engineering for the 21st century. In: Proceedings of World Engineers Convention.
DI Maria, E., DE Marchi, V., Spraul, K., 2019. Who benefits from university–industry collaboration for environmental sustainability? International Journal of Sustainability in Higher Education 20, 1022–1041.
Doust, K., Battista, G., Rundle, P., 2021. Front-end construction waste minimization strategies. Australian Journal of Civil Engineering 19, 1–11.
Duan, H., Wang, J., Huang, Q., 2015. Encouraging the environmentally sound management of C&D waste in China: an integrative review and research agenda. Renewable and Sustainable Energy Reviews 43, 611–620.
Duran, X., Lenihan, H., O'regan, B, 2006. A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland. Resources, Conservation and Recycling 46, 302–320.
Fini, A.A.F., Forsythe, P., 2020. Barriers to reusing and recycling office fit-out: An exploratory analysis of demolition processes and product features. Construction Economics and Building 20, 42–62.
Forbes, P., Hicks, J., Morrison, M., Sharma, K., 2020. Regional migration in Australia: Labour market response or pursuit of amenity? Australasian Journal of Regional Studies 26, 164.
Forghani, R., Sher, W., Kanjanabootra, S., Totoev, Y., 2017. Consequence of waste levy revocation: case study Queensland, Australia. 23rd Annual Pacific Rim Real Estate Society Conference on The Built Environment and Health, Infrastructure and System Resilience Planning Sydney, Australia Sydney University of Technology.
Forghani, R., Sher, W., Kanjanabootra, S., Totoev, Y., 2018. The Attitudes of Demolition Contractors to Reusing Building Components: A Study in New South Wales, Australia. European Journal of Sustainable Development 7, 364 364.
Forsythe, P., Fini, A.A.F, 2018. Quantifying demolition fitout waste from Australian office buildings. Facilities 36, 600–617.
Forsythe, P. & MÁTÉ, K. Assessing brick waste on domestic construction sites for future avoidance. 41st Annual Conference of the Architectural Science Association ANZAScA, 2007.
GÁlvez-Martos, J.-L., Istrate, I.-R., 2020. Construction and demolition waste management. Advances in construction and demolition waste recycling. Elsevier.
Glanville, K., Chang, H.-C., 2015. Mapping illegal domestic waste disposal potential to support waste management efforts in Queensland, Australia. International Journal of Geographical Information Science 29, 1042–1058.
Gollagher, M., Campbell, J., Bremner, A.-M., 2017. Collaboration achieves effective waste management design at Brookfield Place Perth, Western Australia. Procedia Engineering 180, 1763–1772.
Hall, D., 2010. Waste management in Europe: framework. trends and issues.
Hardie, M., Khan, S., O'donnell, A., miller, G., 2007. The efficacy of waste management plans in Australian commercial construction refurbishment projects. Construction Economics and Building 7, 26–36.
Henningsson, M., Geschwind, L., 2019. Senior industry practitioners as part-time visiting professors: the various benefits of collaboration. Higher Education Policy 32, 109–128.
Herczeg, M., Mckinnon, D., Milios, L., Bakas, I., Klaassens, E., Svatikova, K., Widerberg, O., 2014. Resource efficiency in the building sector: final report. European Commission, DG Environment, Rotterdam.

Jayasinghe, R.S., Rameezdeen, Chileshe, N, 2018. Waste Management Practices in Australia: Comparison of Strategies. 22nd International Conference on Advancement of Construction Management and Real Estate Melbourne, Australia.
Kabirifar, K., Mojtahedi, M., Wang, C.C, 2021a. A Systematic Review of Construction and Demolition Waste Management in Australia: Current Practices and Challenges. Recycling 6, 34.
Kabirifar, K., Mojtahedi, M., Wang, C.C., Tam, V.Y, 2021b. Effective construction and demolition waste management assessment through waste management hierarchy; a case of Australian large construction companies. Journal of Cleaner Production, 127790.
King, S., Lusher, D., Hopkins, J., Simpson, G.W., 2020. Industrial symbiosis in Australia: The social relations of making contact in a matchmaking marketplace for SMEs. Journal of Cleaner Production 270, 122146.
Laviano, H., Jordan, B., Monica, T. & Noor, D. 2017. Waste and recycling industry in Australia: A Submission to the Senate Inquiry.
Le, K.N., Tam, V.W., Tran, C.N., Wang, J., Goggins, B., 2018. Life-cycle greenhouse gas emission analyses for Green Star's concrete credits in Australia. IEEE Transactions on Engineering Management 66, 286–298.
Li, M., Yang, J., 2014. Analysis of interrelationships between critical waste factors in office building retrofit projects using interpretive structural modelling. International Journal of Construction Management 14, 15–27.
Li, R.Y.M., Du, H., 2015. Sustainable construction waste management in Australia: a motivation perspective. Construction Safety and Waste Management. Springer.
Lingard, H., Graham, P., Smithers, G., 2000. Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. Construction Management & Economics 18, 383–393.
Martin, S., 2019. Australia ranked worst of 57 countries on climate change policy Guardian.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Group, P., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS med 6, e1000097.
Newaz, M.T., Davis, P., Sher, W., Simon, L., 2020. Factors affecting construction waste management streams in Australia. International Journal of Construction Management 1–9.
NSW Office of Environment and Heritage 2010. House deconstruction fact sheet: Bricks and concrete removal.
NWR, 2020. National Waste Report. Canberra, Australia: Department of Agriculture, Water and the Environment.
Park, J., Tucker, R., 2017. Overcoming barriers to the reuse of construction waste material in Australia: A review of the literature. International Journal of Construction Management 17, 228–237.
Rameezdeen, R., Chileshe, N., Hosseini, M., Lehmann, S., 2016. A qualitative examination of major barriers in implementation of reverse logistics within the South Australian construction sector. International Journal of Construction Management 16, 185–196.
Ratnasabapathy, S., Alashwal, A., Perera, S., 2020. Investigation of waste diversion rates in the construction and demolition sector in Australia. Built Environment Project and Asset Management.
Ratnasabapathy, S., Alashwal, A., Perera, S., 2021. Exploring the barriers for implementing waste trading practices in the construction industry in Australia. Built Environment Project and Asset Management doi:10.1108/BEPAM-04-2020-0077.
Ratnasabapathy, S., Perera, S., Alashwal, A., 2019a. A review of construction waste data and reporting systems used in Australia. 43rd AUBEA: Built to thrive: Creating buildings and cities that support individual well-being and community prosperity Noosa, Australia CQ University.
Ratnasabapathy, S., Perera, S. & Alashwal, A. A review of smart technology usage in construction and demolition waste management. In: Sandanayake, Y. G., Gunatilake, S. and Waidyasekara, ed. Proceedings of the 8th World Construction Symposium, 8-10 November 2019b Colombo, Sri Lanka. 45-55.
Ratnasabapathy, S., Perera, S., Alashwal, A. M. & Lord, O. Assessment of waste generation and diversion rates in residential construction projects in Australia. CIB World Building Congress: Constructing Smart Cities, 17-21 June 2019c Hong Kong, China. The Hong Kong Polytechnic University.
Reddy, P., Desai, R., Sifunda, S., Chalkidou, K., Hongoro, C., Macharia, W., Roberts, H., 2018. You Travel Faster Alone, but Further Together": Learning From a Cross Country Research Collaboration From a British Council Newton Fund Grant. International Journal of Health Policy and Management 7, 977.
Scarvaci, V., Barrett, C., 2019. RE: Brick supply and lay model.
Scherer, R. C. 2005. Interdisciplinary research collaboration: Voice and Speech Review 4.
Senate Environment and Communications References Committee, 2018. Never waste a crisis: the waste and recycling industry in Australia Canberra, Australia Parliament of Australia.
Shooshtarian, S., Khalfan, M., Maqsood, T., Wong, P.S., Yang, R.J, 2020a. Market development for construction and demolition waste stream in Australia. Journal of Construction Engineering, Management & Innovation 3, 220–231.
Shooshtarian, S., Maqsood, T., Barrett, C., Wong, S.P., Yang, J.R., Khalfan, M., 2020b. Opportunities to reduce brick waste disposal. In: Ali, Ghaffarianhoseini, E., A. (Eds.), Imaginable Futures: Design Thinking, and the Scientific Method. 54th International Conference of the Architectural Science Association 2020 Virtual Conference: Auckland, New Zealand: the Architectural Science Association.
Shooshtarian, S., Maqsood, T., Khalfan, M., Wong, S.P., Yang, J.R, 2019a. Managing construction and demolition (C&D) waste in Australia. CIB World Building Congress 2019 'Constructing Smart Cities'. Faculty of Construction and Environment, The Hong Kong Polytechniques University, Hong Kong, China.
Shooshtarian, S., Maqsood, T., Khalfan, M., Yang, J.R., Wong, S.P.P, 2019c. Landfill levy imposition on construction and demolition waste: Australian stakeholders' perceptions. Sustainability 12, 1–15.
Shooshtarian, S., Maqsood, T., Wong, P., Khalfan, M., Yang, R., 2019b. Review of energy recovery from construction and demolition waste in Australia. Journal of Construction Engineering, Management & Innovation 2, 112–130.
Shooshtarian, S., Maqsood, T., Wong, P.S., Khalfan, M., Yang, R.J, 2019c. Green construction and construction and demolition waste management in Australia. 43rd AUBEA Conference: Built to Thrive: Creating Buildings and Cities That Support Individual Well-Being and Community Prosperity Noosa, Australia: CQ University.
Shooshtarian, S., Maqsood, T., Wong, S.P.P, Yang, J.R., Khalfan, M., 2020d. Extended Producer Responsibility in the Australian Construction and Demolition Waste Management System. Australasian Journal of Environmental Management 13.
Shooshtarian, S., Maqsood, T., Wong, S.P., Yang, J.R., Khalfan, M., 2020e. Review of waste strategy documents in Australia: Analysis of strategies for construction and demolition waste. International Journal of Environmental Technology and Management 23, 1–21.
Shooshtarian, S., Maqsood, T., Wong, S.P.P., Khalfan, M., Yang, R.J, 2019d. Development of a domestic market for construction and demolition waste in Australia. 43rd AUBEA Conference: Built to Thrive: Creating Buildings and Cities That Support Individual Well-Being and Community Prosperity Noosa, Australia: CQ University.
Tam, V., Le, K., Wang, J., Illankoon, I., 2018. Practitioners Recycling Attitude and Behaviour in the Australian Construction Industry. Sustainability 10, 1–23.
Tam, V.W.-Y., Lu, W, 2016. Construction waste management profiles, practices, and performance: a cross-jurisdictional analysis in four countries. Sustainability 8, 190.
Tam, V.W., 2009. Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. Journal of Cleaner Production 17, 688–702.
Tam, V.W., Kotrayothar, D., Loo, Y.-C., 2009. On the prevailing construction waste recycling practices: a South East Queensland study. Waste Management & Research 27, 167–174.
Tennakoon, G., Rameezdeen, R., Chileshe, N., 2021. Diverting demolition waste toward secondary markets through integrated reverse logistics supply chains: A systematic literature review. Waste Management & Research 0734242X211021478.
Teo, M., Loosemore, M., 2001. A theory of waste behaviour in the construction industry. Construction Management & Economics 19, 741–751.
Teo, M.M., Loosemore, M., Masosszeky, M. & Karim, K. Operatives attitudes towards waste on a construction project. In: AKINTOYE, A., ed. 16th Annual ARCOM Conference, 2000 Glasgow, Scotland Glasgow Caledonian University: Association of Researchers in Construction Management, 509-517.
Treloar, G.J., Gupta, H., Love, P.E., Nguyen, B., 2003. An analysis of factors influencing waste minimisation and use of recycled materials for the construction of residential buildings. Management of Environmental Quality: An International Journal.
Udawatta, N., Zuo, J., Chiveralls, K., Yuan, H., George, Z., Elmualim, A., 2018. Major factors impeding the implementation of waste management in Australian construction projects. Journal of Green Building 13, 101–121.
Udawatta, N., Zuo, J., Chiveralls, K., Zillante, G., 2015a. Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: benefits and limitations. International Journal of Construction Management 15, 137–147.
Udawatta, N., Zuo, J., Chiveralls, K., Zillante, G., 2015b. Improving waste management in construction projects: An Australian study. Resources, Conservation and Recycling 101, 73–83.
Udawatta, N., Zuo, J., Chiveralls, K., Zillante, G., 2020. From green buildings to living buildings? Rating schemes and waste management practices in Australian educational buildings. Engineering, Construction and Architectural Management.
Wilmot, K., MCGee, C., Milne, G., 2014. Market Research: Tenancy Fitout Material Procurement Attitudes and Practices. Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia.
Wilson, J.L., Tagaza, E., 2006. Green buildings in Australia: drivers and barriers. Australian Journal of Structural Engineering 7, 57–63.
Wu, H., Zuo, J., Yuan, H., Zillante, G., Wang, J., 2020. Cross-regional mobility of construction and demolition waste in Australia: An exploratory study. Resources, Conservation and Recycling 156, 104710.
Yazdani, M., Kabirifar, K., Frimpong, B.E., Shariati, M., Mirmozaffari, M., Boskabadi, A., 2021. Improving construction and demolition waste collection service in an urban area using a simheuristic approach: A case study in Sydney, Australia. Journal of Cleaner Production 280, 124138.
Zhao, X., Webber, R., Kalutara, P., Browne, W., Pienaar, J., 2021. Construction and demolition waste management in Australia: A mini-review. Waste Management & Research 0734242X211029446.
Zhao, Y., Tang, W., 2021. Design of project cost information management and analysis system based on BIM technology. In: 2nd International Conference on Computers, Information Processing and Advanced Education, CIPAE 2021, pp. 1516–1519 Association for Computing Machinery.
Zuo, J., Zhao, Z.-Y., 2014. Green building research–current status and future agenda: A review. Renewable and Sustainable Energy Reviews 30, 271–281.