# Exploring the barriers for implementing waste trading practices in the construction industry in Australia



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## Abstract

**Purpose** – The construction industry is a major generator of waste, which has a high potential to yield a substantial amount of waste into the economy as a valuable resource. Waste trading (WT) is a sustainable strategy for improving resource utilisation and transitioning the construction industry towards the circular economy. However, resource recovery through WT is greatly impeded by several barriers which have not been highlighted in previous research. This paper aims to determine the barriers for implementing effective WT practices in the Australian construction and demolition (C&D) sector.

**Design/methodology/approach** – To achieve the aim of this research, a triangulation approach of quantitative and qualitative methods has been used. This mixed-method approach combines a comprehensive literature review, a questionnaire survey using an expert forum and semi-structured interviews with industry experts.

**Findings** – This study has explored a wide range of barriers to the practices of WT in the C&D sector, which have been categorised based on six perspectives. From a collective perspective, the technical barriers were found to be most important among other categories. The key individual barriers found in this study include the following: the high cost associated with sorting and processing of waste on-site, lack of consistent waste data and reporting system at project, industry and national level, insufficient secured and established market for reusable/recycled waste materials, lack of communication and coordination among stakeholders, lack of user-friendly and active web-based waste exchange systems (with reliable waste information) and lack of incentives from the government to encourage market development. Overcoming these barriers collectively would enable the wide application of WT, which in turn, would have a positive impact on the economy, environment and efficiency of the industry.

**Research limitations/implications** – The outcomes of this study are based on the data collected only in the state of New South Wales (NSW) in Australia which is considered as the limitation of this study.

**Originality/value** – This study contributes to the body of knowledge of C&D waste management (WM) by providing the theoretical and practical implications of closing the loop material cycle by highlighting the importance of economic and environmental benefits of WT. In this study, WT has been recognised as a sustainable strategy to manage waste by identifying the barriers impeding the wider application of effective trading practices in the C&D sector. The findings are useful to WM businesses engaged to establish new circular business models and to government/regulatory bodies in developing initiatives and incentives aiming to promote WT strategies and market platforms. Further research is suggested to test and validate the findings from other jurisdictions of Australia.

**Keywords** Barriers, Circular economy, Construction and demolition waste, Waste management, Waste trading

**Paper type** Research paper

## 1. Introduction

Conserving the natural resources and reducing the pressure on landfills are being challenged due to continuous growth in construction activities accompanied by the growth of

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urbanisation and industrialisation. Around 800 billion tons of natural resources stock have been occupied by the global construction sector, with a potential increase of 50–75% compared to the increase in overall resource consumption (Schandl and Krausmann, 2017). At the same time, the global construction sector contributes 30–40% of the total solid waste generation and around 35% of which is landfilled (Ajayi and Oyedele, 2017). These figures vary across different countries around the world and are influenced by several factors associated with the profile of the construction industry and the position of the economy, legislation and cultural characteristics of the country (Duan *et al.*, 2015). Given this context, construction and demolition (C&D) waste management (WM) turns into an inter-disciplinary area, giving rise to economic, environmental, institutional, social and political aspects while it is facing challenges from the perspective of engineering, technology, management, policies and legislation (Arshad *et al.*, 2017; Jin *et al.*, 2019).

C&D waste generally comprises of different materials such as inert waste, non-inert non-hazardous waste and hazardous waste, generated from new construction, renovation and demolition activities as well as from natural and unnatural disasters (Chen and Lu, 2017; Faleschini *et al.*, 2017). Evidence shows that the reduction of waste generated from these activities is likely to provide economic, environmental and social benefits while it has led to the need for developing sustainable strategies that tend to minimise the waste by diverting it from landfills (Ajayi *et al.*, 2015). According to Suthar *et al.* (2016), reusing and recycling of solid waste have been advocated as environmentally sound, economically feasible and socially acceptable practices for achieving sustainable goals in urban development.

Waste generators are more likely to adopt sustainable waste minimisation strategies in their WM system if they offer more financial benefits than disposing of the waste as an end-of-life product (Al-Hajj and Hamani, 2011; Oyedele *et al.*, 2013). Waste generated through C&D activities has a diverse range of valuable potential resources. As such, incentivising sustainable behaviour, such as resource production and consumption through reuse, recycling and repurposing strategies, would encourage the waste generators to change their behaviour, to contemplate the waste as a valuable resource and to improve the overall resource management. According to Chileshe *et al.* (2019), the construction sector has paid less attention to redirecting the waste from landfills through best sustainable practices while substantial efforts have been made to promote reverse logistics supply chain (RLSC). Intrinsically, a sustainable methodology that enables the transformation of waste into resources by creating more values to waste using these strategies could provide a resourceful solution to overcome the challenges with the large volume of waste and to achieve the transition towards the circular economy. Waste trading (WT) practices fall under this category of sustainable methodology and it is the last operational phase of RLSC. This type of approach is an alternative method to landfills (Pun *et al.*, 2007) and hence, it can maximise waste diversion and resource conservation practices. Subsequently, WT practices would drive sustainability and circular economy movements from both government and industry perspectives.

However, waste minimisation through WT practices has not received much consideration in the C&D waste sector. On the other hand, the recovery of resources has not achieved its maximum level due to several barriers. Limited studies have paid attention to examine the barriers for developing effective trading practices in terms of different aspects and challenges associated with integrated C&D WM. This study, therefore, is an attempt to fill this gap and it aims to determine the barriers for implementing effective WT practices from different perspectives in the context of the construction industry in New South Wales (NSW). This is planned to be achieved by exploring WT as a sustainable waste minimisation and diversion approach.

## 2. Waste trading

According to Hyder (2012), defining waste appropriately enables to determine whether a material is "waste", a "product" or a "resource". This differentiation can have significant impacts on regulations, environment and finance required for the entire WM system which involves different stakeholders such as waste generators, collectors, transporters, processors, disposal operators, landfill owners and traders from the waste generation phase to the final destination phase. Besides, WM is always a challenging task as it is influenced by community demand, government policies and programmes, technological development and market circumstances (Pickin *et al.*, 2018).

The Environment Protection and Heritage Council (2010, p. 361) define waste as:

> "*Any discarded, rejected, unwanted, surplus or abandoned matter … intended for recycling, reprocessing, recovery, re-use, or purification by a separate operation from that which produced the matter, or for sale, whether of any value or not.*"

The recognition of waste as a potential resource has been further acknowledged by Edge Environment (2012), specifying that C&D waste is a general term for a diverse range of materials which can include high-value materials and resources for new construction after segregation. According to Braungart (2013), industrialisation has made industries practice cradle-to-grave patterns of material flow with less attention to the impact on the environment caused by industrial waste. These practices are opposed to the cradle-to-cradle approach in which zero waste is produced as it is based on the closed-loop nutrient cycle of nature (McDonough and Braungart, 2003). This approach is further recognised by the circular economy concept in which waste is kept within the economy by productively circulating it through repeated usage, thus evading landfills. The circular economy aims to convert waste into a valuable resource through reusing, recycling, repairing and reprocessing waste materials and products, unlike the linear economic concept which is based on a "take-make-consume-throw away" pattern (Bourguignon, 2014). These practices have been further promoted by the zero WM strategies that recognise waste as the transformation of resources while the traditional WM system treats waste as an "end-of-life" product (Zaman, 2013).

In alignment with these concepts, waste generated from the construction industry has a high potential to yield valuable resources into economy by either reusing, recycling, repairing, reprocessing or re-manufacturing. Consequently, there is a pressing need to integrate more sustainable strategies into WM processes that enable the transformation of waste into resources by creating end value to waste. Integrating WT strategies into holistic WM could substantially increase the competitiveness of C&D waste materials and contribute to the return of a significant volume of waste into economy. WT is a well-recognised methodology that increases resource efficiency and minimises the environmental impact associated with the waste streams arising from major industrial and consumer activities while contributing to economic benefits (Corder *et al.*, 2014). Hence, it can be considered as an alternative WM method to the disposal method as it diverts most of the waste from landfills, thus greatly contributing to environmental, economic and social sustainability development (GDRC, 2016; Pun *et al.*, 2007). Caldera *et al.* (2020) perceive WT as a targeted intervention that opens up an opportunity for second life to waste that can be used for its original purpose or new purpose.

WT can be considered as a strategy that enables efficient use of waste materials (reusable residual waste and recyclable waste materials/products) and/or recovered energy from waste through buying, selling and/or exchanging options while accomplishing the compliances with relevant waste regulations. Hence, it prompts the circularity of waste from where the waste is generated/stored/recycled to where it is to be consumed to gain economic benefits. Adopting a WT strategy in C&D WM could simultaneously improve the economic, environmental and social performance. In the Australian context, international solid WT has been well established over the past years. However, local markets for the trading of solid waste have not been well established yet, while the market for C&D WT is comparatively limited in balancing the demand and supply. A survey carried out in the Australian C&D waste sector revealed that sustainable material procurement, the imposition of landfill levies and investment in technology and infrastructure are the major factors that influence the establishment of marketplaces for C&D waste (Shooshtarian *et al.*, 2020). Several other factors which influence the construction material supply chain include material procurement, recycling process, plant management, market promotions and government intervention through market-based policy instruments (Caldera *et al.*, 2020; Villoria Sáez and Osmani, 2019).

Although the trading of reusable/recyclable C&D waste materials is relatively not a new approach in the global solid WM system, limited studies have been focused on managing the C&D waste through WT strategies in the construction sector. Barriers to assess the effectiveness of this strategy were not well attended by past studies as different aspects and challenges associated with WM have not been taken into account. This study can be taken as an example of a study that intends to draw insight into the barriers to the effectiveness of the WT approach in the C&D sector and, hence, an attempt to accelerate the industry moving towards the circular economy in C&D WM.

## 3. Barriers for waste management practices

Some past research studies have investigated several barriers that hinder the effectiveness of WM practices, including the barriers for reducing, reusing and recycling waste materials. For instance, the CIB Working Commission W115 in 2014 focused on the barriers for deconstruction and reuse/recycling of construction materials in some developed countries across the world (CIB, 2014). Recurrent barriers for most wasted materials such as masonry, concrete, wood, metal and asphalt have been investigated in Canada, Germany, Japan, the Netherlands, Norway, Singapore, the USA and New Zealand (CIB, 2014). In a study to investigate the opportunities and strategies to facilitate material reduction, reuse and recycling, Zou *et al.* (2014) have identified some barriers in the capital region of Australia using focused group workshops. The major barriers identified in this study include lack of actual data on volume and composition of waste, lack of facilities for recycling, inconvenient location and information of such facilities, waste not being valued as a potential resource, lack of government policies and environmental regulations to drive recycling, low-tipping fees and lack of knowledge and training in WM.

Yuan *et al.* (2011) explored major obstacles to improve the performance of C&D WM and concluded that the lack of attention on design for waste reduction, insufficient awareness and training in WM, lack of established recycling markets and insufficient legislative support from authorities are the most important barriers for implementing effective WM in China. Abarca-Guerrero *et al.* (2017) identified the barriers and motivations of construction waste reduction in Costa Rica with a target to improve the management of construction materials. Based on an analysis of C&D waste generation, waste regulations and major WM practices in an economically developed region of Shenzhen in south China, Yuan (2017) examined the most critical challenges and promising countermeasures of managing C&D waste. Ajayi *et al.* (2015) explored the impediments to the effectiveness of existing WM strategies, as well as strategies for reducing the intensiveness of construction waste. Based on a comprehensive literature review, Park and Tucker (2017) identified the obstacles to the reuse of construction waste from different stakeholders' perspectives in Australia. They emphasised the need for a strategy to escalate the effectiveness of reusable and recycled materials which can replace the usage of the raw material in new construction and renovation activities.

Similarly, Mahpour (2018) identified potential barriers from behavioural, technical and legal perspectives, intending to transition the industry moving towards the circular economy in C&D WM. From a collective perspective, ineffective disassembling, sorting, transporting and recovering processes of C&D waste, limited use of recyclable construction materials and lack of integration of sustainable C&D WM, and ambiguity in the benefits of circular economy in C&D waste were found as the most prominent barriers in this study. Caldera *et al.* (2020) evaluated the barriers to developing a marketplace for C&D waste in terms of market, operational and governance-related factors. The previous studies discussed the barriers to WM in general, but overlooked the barriers of WT practices in terms of different aspects of WM in particular. Hence, this study attempts to fill this gap and aims to explore the major barriers to WT in the context of the Australian C&D sector. Table 1 presents the summary of barriers identified from the literature review. These barriers can be considered as potential for improving WT practices in the C&D sector.

| Barriers | References |
|---|---|
| Absence of a systematic and consistent C&D waste data management system | Zaman and Swapan (2016), Hardie *et al.* (2012), Li *et al.* (2016), Paz and Lafayette (2016), Veleva *et al.* (2017), Yuan (2017), Formoso *et al.* (2002), Lu and Yuan (2011), Villoria Saez *et al.* (2013) |
| Lack of monitoring and tracing of waste flow in WM systems | Gangolells *et al.* (2014), Hardie *et al.* (2012), Lu and Yuan (2011) |
| Lack of established waste database to provide accessible information on quality, availability and benefits of secondary materials | Ajayi and Oyedele (2017), Huang *et al.* (2018), Mahpour (2018), Veleva *et al.* (2017), Bao *et al.* (2020), Yuan (2017) |
| Limited economic and political incentives to promote effective waste management practices and waste trading | Bao *et al.* (2020), Caldera *et al.* (2020), Chen *et al.* (2002) |
| Non-standardised C&D waste data collection and reporting | Veleva *et al.* (2017), Mahpour (2018), Yuan (2017) |
| Lack of established market structure for reusable and recycled waste materials/products and limited market information and access to such markets | Yuan *et al.* (2011), Pun *et al.* (2007), Yuan (2013), Wang *et al.* (2010), Park and Tucker (2017), Ajayi and Oyedele (2017), Pickin and Randell (2017), Caldera *et al.* (2020), Huang *et al.* (2018) |
| Lack of operational efficiency and passive nature of existing waste exchange systems | Nasaruddin *et al.* (2008), Chen *et al.* (2006), Huang *et al.* (2018), Corder *et al.* (2014) |
| Lack of third party verification (auditability) in waste management processes for rating assessment | Hardie *et al.* (2012) |
| Lack of communication, distrust and transparency in waste reporting by stakeholders | Hardie *et al.* (2012), Park and Tucker (2017), Lim (2016) |
| High cost involved in overall management (sorting and processing) and auditing of waste | Park and Tucker (2017), Caldera *et al.* (2020) |
| Lack of adequate knowledge, skills, training and use of advanced technologies to deal with C&D waste management | Mahpour (2018), Udawatta *et al.* (2015), Park and Tucker (2017), Pickin and Randell (2017), Yuan *et al.* (2011) |
| Insufficient material recovery facilities and lack of information about such facilities | Park and Tucker (2017), Huang *et al.* (2018) |
| Lack of intricate coordination between waste provider, user and regulatory bodies | Mahpour (2018), Park and Tucker (2017), Yuan *et al.* (2011), Caldera *et al.* (2020) |
| Lack of knowledge and insight into the circular economy in C&D waste management | Ranta *et al.* (2018), Ritzén and Sandström (2017) |
| Lack of information on construction materials/products from manufacturers/suppliers | Abarca-Guerrero *et al.* (2017), Ajayi and Oyedele (2017) |
| Lack of producer-based responsibility system in the production of construction materials and C&D waste recovery | Ritzén and Sandström (2017), Li and Yu (2011) |
| Limited demand for secondary building materials | Caldera *et al.* (2020) |
| Inadequate policies and legal framework to manage C&D waste | Yuan *et al.* (2011), Ranta *et al.* (2018), Mittal and Sangwan (2014), Abba *et al.* (2013), Bao *et al.* (2020), Li and Yu (2011), Caldera *et al.* (2020), Blaisi (2019) |

**Table 1.** Summary of potential barriers to waste trading practices

## 4. Research methodology

This study primarily adopts a triangulation design approach comprising quantitative and qualitative methods of data collection and analysis (Creswell and Clark, 2007). This mixed-method approach combines a comprehensive literature review, a questionnaire survey conducted during an expert forum and expert interviews to identify and validate the barriers. Initially, a comprehensive literature review has been carried out to identify the barriers to the reuse/recycling of C&D waste, as well as the barriers for implementing effective WM practices in general. Subsequently, a questionnaire was distributed to experts who attended an industry-academic forum to evaluate and rate the importance of each barrier through the questionnaire survey. Following the survey, eight semi-structured interviews have been conducted with experts to validate the results of the questionnaire survey and to add the findings of this study. The interviewees included top-level managers who were asked to provide their opinion and comments on the identified barriers. The interviewees were also asked to add any barriers that they thought were important to embed the application of WT in the C&D sector. Five of the interviewees were from different types of construction projects, which have a high potential for exchanging/trading waste materials, and three interviewees were from WM services. The new barriers identified from the questionnaire survey and interviews are discussed under the relevant categories in the discussion section. Table 2 shows the profile of the respondents involved in both the quantitative and qualitative studies.

**Table 2.** Profile of the respondents involved in quantitative and qualitative studies

| Respondents | Experience (Years) 5–10 | 10–20 | Over 20 | Total number |
|---|---|---|---|---|
| *Questionnaire survey (quantitative study)* | | | | |
| Contractors/Developers | 2 | 9 | 2 | 13 |
| Consultants | | 2 | 2 | 4 |
| Clients/Architects | | 1 | 1 | 2 |
| Manufacturers/Suppliers | 1 | 1 | | 2 |
| Academics | 6 | 3 | 5 | 14 |
| Total | | | | 35 |
| *Expert interviews (qualitative study)* | | | | |
| Project manager (residential development) – PM1 | | 1 | | 1 |
| Project manager (commercial development) – PM2 | | | 1 | 1 |
| Sustainability and research manager (land and property development) – SRM | | 1 | | 1 |
| Senior development manager (land and property Development) – SDM | 1 | | | 1 |
| Environment, approvals and sustainability manager (infrastructure development) – EASM | | | 1 | 1 |
| Environmental sustainability manager (waste management Service) – ESM | | | 1 | 1 |
| Operation manager (waste collection and management Service) – OM | | 1 | | 1 |
| Sales manager (waste recycling service) – SM | | 1 | | 1 |
| Total | | | | 8 |

The barriers collected from the literature have been categorised under six main perspectives: economic, environmental, institutional/organisational, socio-cultural, legal/political and technical. This study adapted the six aspects of the PESTEL (political, economic, social, technical, environmental and legal) model as the initial coding categories to classify the barriers. The PESTEL framework was initially employed for analysing and monitoring the external macro-environmental factors that have an impact on an organisation in a business and marketing discipline (Rothaermel, 2015). However, with a rising cognisance of its viability, its' application has been expanded in several other disciplines including WM (Bing *et al.*, 2016), Ziouta *et al.* (2014). For instance, the PESTEL method has been used to identify the key external factors that influence municipal waste recycling in Europe (Bing *et al.*, 2016). Ziouta *et al.* (2014) applied the PESTEL model for making informed decisions on the selection of the most sustainable recovery options for end-of-life products. Since C&D WM is recognised as an inter-disciplinary theme, involving different aspects and issues such as engineering, technology, management, policies and legislation (Arshad *et al.*, 2017; Jin *et al.*, 2017; John and Itodo, 2013), is required. This study considers the "Institutional/Organisational" category as an additional category of the barriers. Moreover, the political and legal aspects have been combined to be the "Legal/Political" category in analysing the barriers in this study, due to the fact that most of the barriers are quite common in both categories.

Prior to data collection, the survey instrument that involves a questionnaire that has been used to collect the data from the expert forum had been pre-tested for ease of understanding and content validity. Five academics who have expertise in WM and sustainable built environment-related research with a minimum of five years of involvement in the industry have been asked to evaluate the questionnaire for clarity and relevance of the barriers to each category proposed. Based on the feedback received from the academics, the questionnaire has been improved to attain content validity and clarity.

After the questionnaire was pre-tested, the questionnaire has been circulated among a group of experts who have participated in an expert forum conducted at an industry-academic roundtable. The roundtable event has attracted over 40 experts comprising contractors, consultants, architects, clients, manufacturers/suppliers and academics. This study has used a purposive sampling method by targeting experts in the forum based on their experience and knowledge in the field of construction management. Out of the total number of distributed questionnaires, 35 responses have been satisfactorily completed and considered for the analysis. All the academics who have participated in the expert forum possess relevant experience in academia and industry in the construction management discipline. Industry-academic participation is essential especially in educating the need for sustainable building construction. In essence, the inclusion of academic perspectives is apposite to enrich the result of this study as WT is still not commonly practised in the industry.

The participants have been given a questionnaire which comprises two sections: section 1 – the respondent's information – and section 2 – the set of barriers integrated with a five-point Likert scale rating. The collected data have been analysed through descriptive analysis which includes the mean value and the relative importance index (RII) to determine the significance of each barrier and its ranking. The RII is computed based on the following equation;

$$\text{Relative Importance Index (RII)} = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where $W$ is the weighting given to each barrier by the respondents, ranging from 1 to 5, $A$ is the highest weight (5 is the highest weight in this study) and $N$ is the total number of respondents, while $n_1$, $n_2$, $n_3$, $n_4$ and $n_5$ are the numbers of respondents who have scored "1" representing not important at all, "2" representing less important, "3" representing Neutral, "4" representing important, and "5" representing most important.

The analysis of variance (ANOVA) has been carried out to test if there is a difference in the responses between two groups of participants: academics and industry experts. Cronbach's alpha has also been conducted to test the reliability of the measurement instrument. For the qualitative study, the content analysis method has been used to analyse the data collected through the interviews. The findings from the interviews are included in the discussion section.

## 5. Results and discussion

The outcomes of this study are based on the weighted statistical analysis of responses from the quantitative study, the industry-academic expert forum and the qualitative study, the interviews with industry experts. In the quantitative study, altogether, 32 barriers have been evaluated and ranked under six main categories. The result of Cronbach's alpha value for all 32 barriers is 0.85 (the minimum value required is 0.75), which confirms the internal reliability of the barriers included in each category in the survey instrument. The ANOVA test has been performed to ascertain the level of agreement on the importance of the identified barriers based on the two groups of participants. The null hypothesis is that both groups are almost in general agreement in their opinions on ranking the importance of barriers. The results of ANOVA indicate that there is no statistically significant difference of the opinions among these two groups; as the probability value ($p$-value) is not less than 0.05 except for one institutional barrier as shown in Table 3.

The mean value of barriers from each category is computed and used to rank the barriers. The ranking of each barrier is shown in Table 3. From a collective perspective, calculation of the grand mean for each category reveals that the technical barriers, among others, are significantly important barriers that obtain the mean of 3.99. The economic barriers receive the next level of importance with a mean of 3.91. This is followed by the legal/political barriers, institutional/organisational barriers, socio-cultural barriers and environmental barriers with grand mean values of 3.86, 3.86, 3.75 and 3.65, respectively. The six most important barriers to WT from all categories include the followings: the high cost associated with sorting and processing of waste on-site, lack of consistent waste data and reporting system at project, industry and national level, insufficient secured and established market for reusable/recycled waste materials, lack of communication and coordination among stakeholders, lack of user-friendly and active web-based waste exchange systems (with reliable waste information) and lack of incentives from the government to encourage market development. The following sections discuss the implications of all the identified barriers under respected categories.

**Table 3.** Barriers for implementing effective waste trading practices

| Category | Barriers | RII | Mean | Collective ranking | ANOVA $F$ | ANOVA $p$-Value |
|---|---|---|---|---|---|---|
| Economic | High cost associated with sorting and processing of waste on-site | 0.851 | 4.26 | 1 | 1.11 | 0.30 |
| | Insufficient secured and established market for reusable/recycled waste materials | 0.829 | 4.14 | 3 | 0.19 | 0.66 |
| | Lack of information for and access to recycled waste materials markets | 0.777 | 3.89 | 19 | 2.55 | 0.12 |
| | Less market demand for recycled waste materials | 0.766 | 3.80 | 20 | 0.82 | 0.37 |
| | Lack of incentives from the government to encourage reuse and recycling of waste and market development | 0.812 | 4.06 | 6 | 3.91 | 0.06 |
| | Lack of economic penalising methods for waste disposal (low-tipping fee and/or landfill levy) | 0.800 | 4.00 | 10 | 2.92 | 0.10 |
| | Cost of reusing/recycling waste is higher than new materials | 0.709 | 3.54 | 28 | 1.66 | 0.21 |
| | High availability of raw materials with low cost | 0.691 | 3.46 | 30 | 0.83 | 0.37 |
| | Disposing low value/low volume products at landfills rather than stockpiling for recycling | 0.811 | 4.06 | 7 | 0.01 | 0.93 |

*Grand mean for economic barriers = 3.91*

(*continued*)

| Category | Barriers | RII | Mean | Collective ranking | ANOVA $F$ | $p$-Value |
|---|---|---|---|---|---|---|
| Environmental | Lack of demand for sustainable construction from public and private clients | 0.680 | 3.40 | 32 | 0.35 | 0.56 |
| | Insufficient awareness and attention on the environmental impact by the clients, industry and government | 0.714 | 3.57 | 27 | 0.68 | 0.42 |
| | Lack of education on environmental sustainability | 0.794 | 3.97 | 12 | 1.02 | 0.32 |
| *Grand mean environmental barriers = 3.65* | | | | | | |
| Institutional/ organisational | Lack of managerial commitment and support to promote reuse/recycling of waste by waste generators | 0.783 | 3.91 | 15 | 0.78 | 0.38 |
| | Inefficient waste management plans (WMP) and plan review to promote reuse and recycling of waste | 0.731 | 3.66 | 24 | 1.34 | 0.26 |
| | Liability concerns for innovative technologies, user conservatism and obsolete specifications | 0.731 | 3.66 | 24 | 1.34 | 0.26 |
| | Lack of consistent waste data and reporting system at project, industry and national level | 0.846 | 4.23 | 2 | 3.45 | 0.07 |
| | Lack of communication and coordination among stakeholders | 0.817 | 4.09 | 4 | 0.01 | 0.93 |
| | Non-inclusion of "design for deconstruction" as a part of the construction process | 0.806 | 4.03 | 8 | 7.39 | 0.01 |
| | Lack of industrial norms or performance standards and benchmark for waste management | 0.686 | 3.43 | 31 | 4.29 | 0.05 |
| *Grand mean for institutional/organisational barriers = 3.86* | | | | | | |
| Socio-cultural | Cultural resistance to change traditional WM practices (attitude and behaviour) | 0.720 | 3.60 | 26 | 0.84 | 0.37 |
| | Lack of community attention for the impact of waste on the environment | 0.697 | 3.49 | 29 | 1.71 | 0.20 |
| | High undervaluation of waste as a potential resource | 0.754 | 3.77 | 22 | 1.64 | 0.21 |
| | Lack of considerations and insight into the role of waste trading in the circular economy | 0.794 | 3.97 | 12 | 1.32 | 0.26 |
| | Reluctance to adopt new technologies and systems in waste management | 0.783 | 3.91 | 15 | 4.29 | 0.31 |
| *Grand mean for socio-cultural barriers = 3.75* | | | | | | |
| Legal/political | Lack of policies for promoting recycling and resource efficiency through waste trading | 0.783 | 3.91 | 15 | 0.01 | 0.94 |
| | Lack of standards/certificates for the quality assurance of recycled waste materials | 0.800 | 4.00 | 10 | 1.01 | 0.32 |
| | Inconsistent sustainable legislations across local councils and state governments especially for reuse/recycling of waste | 0.760 | 3.80 | 20 | 0.01 | 0.93 |
| | Limited scope and minimal standards of building codes for sustainable construction practices | 0.743 | 3.71 | 23 | 1.47 | 0.23 |
| *Grand mean for legal/political barriers = 3.86* | | | | | | |

(*continued*)

**Table 3.**

| Category | Barriers | RII | Mean | Collective ranking | ANOVA $F$ | $p$-Value |
|---|---|---|---|---|---|---|
| Technical | Lack of the application of smart technologies to improve waste data collection and reporting | 0.783 | 3.91 | 15 | 2.26 | 0.14 |
| | Lack of knowledge and technology application to convert waste into valuable resources | 0.789 | 3.94 | 14 | 1.73 | 0.20 |
| | Lack of user-friendly and active web-based waste exchange systems | 0.817 | 4.09 | 4 | 0.01 | 0.92 |
| | Inadequate experience, skills and training in waste handling methods of on-site workers | 0.806 | 4.03 | 8 | 1.92 | 0.17 |

*Grand mean for technical barriers = 3.99*

**Table 3.**

### 5.1 Technical barriers

This study has found that the technical barriers significantly influence the implementation of effective WT practices in the C&D sector. Technical barriers are mostly related to lack of education, experience, skills, training and integration of smart technologies in managing waste information and materials. The lack of user-friendly and active web-based waste exchange systems is highly hindering the effectiveness of WT in the C&D sector. Lack of knowledge, procedures and technology to convert waste into valuable materials, that is the lack of knowledge on what and how waste materials can be recycled using different methods and how to implement advanced technology to recycle and reuse, as well as lack of waste information flow, easily accessible and active market platforms for secondary materials are all found to be major obstacles for reuse of waste materials. The SM stated that "major challenges we face in trading materials are competing against low-quality material suppliers, it is because it is cheaper to produce low-quality products than high-quality products. Therefore, it is important that contractors/developers within the industry only buy reusable/recycled materials from reputable suppliers to ensure they get a quality product". Thus, providing reliable waste information is critical in WT. Intending to promote the WT practices in the C&D waste stream, Ratnasabapathy *et al.* (2019b) have proposed that Blockchain (a decentralised and distributed data management and transaction technology) based platforms can improve operational efficiency, traceability, transparency and trust in WT processes while facilitating the sharing, reporting and auditing of waste materials without a trusted intermediary. They can also create wider circular business networks.

Other major technical barriers identified in the literature (Abarca-Guerrero *et al.*, 2017) and this study include limited on-site space for waste separation and processing. This site condition, in turn, leads to mixing up and contamination of residual reusable and recyclable waste and undervalues the end-use of waste as a resource. Two interviewees (OM and ESM) indicate that more materials could be recovered in mixed waste if the waste is sorted on-site by following the waste classification guidelines. Further, the SRM, ESM and the two PMs confess that the limited availability of the required technical specifications and guidelines as well as service experience with recycled materials make uncertainties to the quality of recycled materials, thus reducing the social acceptance and demand of such materials on the market. The OM and SM claimed that while markets for metal, glass and timber have been already established, markets for some mostly wasted materials, such as gyprock and ceramics are very limited despite the fact that gyprock is a highly wasted material in residential development.

### 5.2 Economic barriers

Economic barriers are mostly associated with the cost involved in WM, current positions of secondary material markets and incentives for recycling and market development (Yuan *et al.*, 2011). Among all economic barriers, the high cost associated with the collection, sorting and processing (recycling) of waste has been ranked as the most important barrier with a mean value of 4.26. Limited space for waste sorting and processing and the cost associated with managing waste on-site act as the barriers for creating end value for waste through reuse/recycling options. These conditions ultimately lead to the increased cost of transportation and disposal of waste. The insufficient secured and established market for reusable/recycled waste materials has been ranked as the third major barrier which has been further confirmed by the operational manager (OM) of one of the waste processing businesses. Though some trading agents are available in the market, the waste consumers are reluctant to approach them due to the lack of trust in the waste information provided and the overhead cost involved in the transaction. Pickin and Randell (2017), claim that even though the construction material recycling industry withstands the recent advances in processing technology, the lack of a secured market for recycled products continues to hinder the development of such a recycling industry in Australia. Similarly, Caldera *et al.* (2020) stress and highlight the necessity for user-friendly waste market platforms that are easily accessible for buyers and sellers. The OM claims that an inadequate supply of materials that have been already sorted to avoid contamination on-site is one of the barriers to the discontinuity in the material supply. This condition, in turn, impedes the resource recovery and market demand for secondary materials among users. Further, Slowey (2018) states that illegal dumping of waste is a major factor that hinders the waste market growth. However, low-profit margins among other factors including lack of standardisation, poor policy enforcement, lack of awareness and lack of resources are also hindering the expansion of the construction waste market (Slowey, 2018).

Behavioural changes made through rewards to adopt improved sustainable practices would help to achieve a more successful circular economy (Mahpour, 2018). Chen *et al.* (2002) also highlight that effective rewarding and penalising systems in monetary terms would motivate project stakeholders to reduce waste. However, the lack of economic incentives from the government to encourage the reuse and recycling of waste and market development is another key barrier identified in this study. As such, incentivising sustainable behaviour such as resource production and consumption through reuse, recycling and repurposing strategies, would encourage stakeholders to change their behaviour towards improving resource management. During one interview, the SM said "the success of waste trading relies on a balance between demand and supply, so trading platforms could help to overcome the shortage of material supply" The SM further explained that the financial assistance by the government is not enough "to be plausible to explore the possibility of recycling waste, for example, recycled glass to make the road base". The PM2 claims that "developers have a lack of attention on sustainable waste management practices due to time and cost constraints; the developer should have an advantage by adopting such practices, and clients will also have the power to initiate, and clients need to be educated to demand sustainable construction".

### *5.3 4.3 legal/political barriers*

Transitioning the construction industry to the circular economy needs adequate policies and a legal framework with the required level of supervision (Mahpour, 2018). Legislative and policy instruments have influenced the key drivers for diverting waste from landfills in several countries (Agamuthu, 2008; Ajayi and Oyedele, 2017; Blaisi, 2019). According to Manowong (2012), the implementation of relevant policies and regulations also helps to enhance the awareness of WM and the willingness of contractors to address WM-related issues. Most jurisdictions in Australia use strategies that guide government organisations and industries in improving WM practices. In particular, strategy 14 developed for "Market

Development and Research", informs all governments and businesses about the requirement to produce and report waste information which aims to improve existing markets and support the establishment of new markets for recycled materials at both national and international level (Commonwealth of Australia, 2018). However, these do not represent mandatory standards but are developed to provide an authoritative reference that can be used to support sustainable recycling and increase economic benefits.

While several policies concerning environmental sustainability and strategies for market development have been developed to increase the reuse and recycling of construction waste, the lack of standards/certificates that assure the quality of secondary materials to fulfil the technical specifications and building codes for sustainable construction practices are the major barriers that hinder the general acceptance and use of recycled materials. Furthermore, lack of a specific governing body for C&D waste at the federal government level, inconsistent landfill levy across different states, lack of specific regulations for reducing landfills of C&D waste, the non-mandatory status of recycling across the states and lack of extended producer responsibility (EPR) driven legal instrument for C&D waste are some of the other legal barriers identified by this study. Additionally, all the managers from the sustainability discipline emphasise that the conservatism of local councils/authorities in accepting different disposal methods of C&D waste needs changes to divert more waste from landfills. The SDM states that "Resistance from local councils to accept clean but not virgin materials as fill is a significant barrier for waste exchange, which means that the Development Application (DA) conditions that require Virgin Excavated Natural Material (VENM) only to be used as fill, where Excavated Natural Material (ENM) would be suitable". This reflects that the lack of consideration in enforcing feasible legislation by the local authorities hinders the WT practices.

### 5.4 Institutional/organisational barriers

The institutional barriers determined by this study are related to waste data, communication among stakeholders, managerial commitment to WM, waste management plan (WMP), industrial norms/standards and benchmark for WM, among others. Lack of consistent waste data and reporting at project, industry and national level obtained the second-highest ranking of barriers (mean = 4.23 and RII = 84.6%). Consistent and timely waste data are essential not only for evaluating and monitoring the progress of WM towards the resource recovery targets but also for the development and implementation of effective waste policies and national standards, which aim to stimulate resource efficiency and the expansion of markets for reusable and recycled waste materials. Such policies and standards could attract new circular business investments and develop targeted strategies to influence user behaviour (Ratnasabapathy *et al.*, 2019a).

Effective communication and coordination among stakeholders who are generally involved in WM would create more opportunities for resource recovery through the circularity of waste. The forward-thinking of circular economy initiatives, such as effective collaboration of stakeholders can develop new materials, products and services out of construction waste that was previously considered to be landfilled. Further, the lack of clients' involvement and leadership in reducing waste has also been identified as the barriers in this study. Moreover, the sustainability manager and PMs emphasise that the WMPs developed as a part of the project's DA for approval from the local council are only preliminary (conceptual) plans and the operational plans need to be developed to achieve the recovery targets set for the projects which need to be regularly reviewed by responsible managers and authorities for all types of waste.

### 5.5 Socio-cultural barriers

In the Australian context, C&D waste materials, except metal, are not recognised as a potential resource and this perception hinders the redirection of other waste from landfills

(Zou *et al.*, 2014). The overall analysis of the data revealed that the highly undervaluing waste as a potential resource is an important barrier that hinders the implementation of WT. Furthermore, lack of considerations and insight into the role of WT in the circular economy, the reluctance to change the traditional WM practices and adopt advanced technologies and methods in WM are other important barriers. The attitudes and behaviours of stakeholders need to be changed to accept the transformation of traditional WM practices which treats waste as an end-of-life product (Zaman, 2013) rather than as a potential resource. The culture that does not recognise the cost of managing waste and its end value as a potential economic resource, as well as the lack of attention paid to the economic and environmental benefits of WT is another recurrent barriers validated by this study.

### *5.6 Environmental barriers*

Barriers of the environmental category are not ranked high, except the lack of education on environmental sustainability, which has been ranked 12th among other barriers. Other barriers of this category include lack of demand for sustainable construction from clients and insufficient awareness and attention of the stakeholders on the impact on the environment. Environment-related factors are mostly associated with the waste disposal process at the landfills, which incurs an indirect cost for treatment, cost of labour and high pressure on landfill capacity. Increasing the levy fee for disposal of C&D waste would result in diverting more waste from landfills, thus enhancing the potential use of the waste as a valuable resource and therefore, reducing the impact on the environment (He *et al.*, 2018). The industry experts recognise that lack of regular inspection, improper maintenance of regulatory infrastructure for waste disposal and inconsistent disposal fee for landfill waste across the Australian jurisdictions inhibit the diversion of waste from landfills. Similarly, Caldera *et al.* (2020) found that the improper infrastructure for disposal and lack of treatment facilities are key operational barriers for developing the marketplaces for C&D waste.

In summary, out of these first six key barriers, three barriers are from the economic category, two are from the institutional/organisational category, and one is from the technical category. These results indicate that the effectiveness of WT practices is mostly impeded by the above three categories in the Australian context. However, the grand mean analysis and expert interviews have confirmed the significance of the legal/political barriers in WT. Collaborative efforts are therefore essential to overcome these key barriers, which, in turn, would encourage the stakeholders to promote WT practices and help the industry to expand the circular flow of waste by transforming it into a valuable resource and accelerating the construction industry to move towards the circular economy in C&D WM.

## 6. Conclusions and recommendations

This paper has determined the barriers of WT for C&D waste in Australia. Evaluation of overall barriers from a collective perspective has revealed that the technical barriers significantly impede the application of WT practices followed by the economic barriers, legal/political barriers and institutional/organisational barriers among other categories. In terms of individual barriers, the most important barriers validated in this study include the following: (1) the high cost associated with sorting, testing and processing of waste on-site; (2) lack of consistent waste data and reporting system at project, industry and national level; (3) insufficient secured and established market for reusable/recycled waste materials and lack of information and access for such market; (4) lack of communication and coordination among stakeholders; (5) lack of user-friendly and active WT platforms with consistent and reliable waste information; and (6) lack of incentives from the government to encourage WM and market development. The evaluation of the barriers and newly identified barriers assist in determining which aspects need to be highly considered in promoting effective C&D WT strategies and improving the operational efficiency and transparency which are lacking in the existing WT practices.

The findings of this study contribute to the body of knowledge of C&D WM by highlighting the barriers of WT and ways forward to implement this innovative strategy in practice. The findings are useful to WM practitioners/businesses and government bodies in assisting to establish new circular business models. The government or regulatory bodies can propose policies and develop sustainable strategies and initiate incentives that aim to improve resource efficiency and sustainability by promoting WT practices in the construction sector. The study suggests that overcoming the identified barriers collectively would accelerate the use of efficient market platforms for C&D waste and drive a shift towards the circular economy in C&D WM from both industry and government perspectives. Easy access to reliable WT platforms established with a high level of operational efficiency and transparency would help to overcome the institutional and technical barriers and improve economic performance. Technology-enabled market platforms are emerging to facilitate online trading among waste generators and waste consumers. The application of a distributed ledger technology, considering C&D WT as a use case, would be useful to enable peer-to-peer WT among waste generators and waste consumers. It is expected that this type of platform could ease the complexity in communication and collaboration associated with the existing WT platforms by eliminating the middleman in trading. These platforms are also expected to provide an easily accessible and reliable marketplace with improved efficiency in terms of traceable waste information, cost and time.

This study has limitations in terms of the type and size of the sample used to collect the data. The data collection has been conducted in NSW which is the fastest growing economy in Australia and the highest generator of C&D waste among other jurisdictions. Though the barriers that have been found by this study are specific to the state of NSW, the findings can be generalised to other states as the barriers have been systematically grouped under six major perspectives which highly influence the effective management of C&D waste. However, since there is an inconsistency in policies and legislation, generalising the finding in the legal/political perspectives may not be acceptable. Further research is therefore required to test and validate the potential barriers in other jurisdictions and countries, which will, in turn, contribute to creating a framework of common barriers for the construction industry in Australia.

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