

An examination of COVID-19 impacts on the Australian Construction and Demolition Waste Management and Resource Recovery industry

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ABSTRACT

The COVID-19 crisis has brought unprecedented challenges to many sectors, including housing, building and infrastructure. The Construction and Demolition (C&D) waste management and recovery industry have been affected by this pandemic through a change in waste amount, composition, timing/frequency, distribution and risk, which affects the handling and treatment practices. However, there are limited precedents to assist C&D waste management practitioners to address these pandemic-related challenges. Therefore, this study explores COVID-19 impacts on the Australian C&D waste recycling and construction industry and the practical responses to overcome pandemic-induced challenges. Through a literature review and a series of semi-structured interviews with 27 industry stakeholders, this study established that there is a critical need for leveraging digital technologies, developing business contingency plans, creating coalitions between government and industry, and diversifying supply chains to reduce supply chain risks. This study also uncovered a range of targeted responses and recommendations to deal with pandemic-induced disruptions. Our findings can immediately assist industrial practitioners and government decision-makers in managing the impacts of COVID-19 on the C&D waste management and resource recovery activities.

KEYWORDS

Pandemic, government response, C&D waste, stakeholders, supply chain, Australia

INTRODUCTION

COVID-19 crisis has been sweeping the world. The first case of the novel coronavirus in Australia was reported on 19 January 2020 [1], and the number of cases has continued to rise ever since. The Australian Government's COVID-19 statistics indicate that as of 22 September 2021, Australia recorded 90,372 total cases. While Australia has been one of the few successful countries in containing the diseases, it was estimated to be one of the worst-hit economies in the Australasia region. The predictions suggest a shrink of 6.7% in the Australian economy in 2020 [2]. As a result, many industries have faced many financial challenges; the waste management and resource recovery industry is not an exception. The Construction and Demolition (C&D) waste management and recovery industry have been affected by this pandemic through a change in waste amount, composition, timing/frequency, distribution and risk, which affects the

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handling and treatment practices [3]. Observations from the industry performance worldwide also suggest that the industry operators suffer from unprecedented suffering from the pandemic impact [4, 5],[6]. Countries such as the United States of America (U.S) have ceased recycling programs in some of their cities, as authorities have been concerned about the risk of COVID-19 spreading in recycling centres [7].

Some public and private organisations have attempted to discover the impact on the industry by inviting operators to express how their operations have been disrupted. For instance, a survey by the U.S.'s National Waste & Recycling Association [8] discovered that primary impacts on the industry are employee safety and health concerns, operational best practices, changes in revenues, services, waste streams and waste volumes. The survey also showed that waste hauliers are the most affected operators, staffing is accounting for the greatest short-term impact, and two-thirds of participants indicated moderate to severe operations impacts due to COVID-19 restrictions. Another survey facilitated by Waste Today magazine, showed that around 30% of respondents operating in the U.S. waste management industry had been ordered to close their facilities by state officials or had voluntarily idled one or more facilities. The survey results specific to the C&D waste stream showed that 50% of inbound flow had been affected from moderately to severely. Other reported impacts included 32% cases of layoffs (and a further 21% were considering layoffs), and around 66% of businesses had put one or more purchases on hold. Love and Rieland [9] state that given worker safety concerns, low market prices for scrap materials, a slowed economy and cheaper alternatives for disposal, many communities and businesses across the U.S. have temporarily suspended the collection of recyclables.

With disruptions in waste recovery activities, the environment is under threat worldwide [7]. There is evidence that demonstrates how this impact is damaging the environment. In some UK rural communities, disrupted services have increased waste mismanagement by 300% [10]. Roberts, Stringfellow [11] reported that with fewer options available, traditional waste management practices such as landfills and incineration are replacing more sustainable measures such as recycling, with adverse effects on the environment. Government organisations sometimes exacerbate the issue. For instance, the UK Environment Agency has allowed temporary waste and incineration ash storage at sites that further threaten the environment. In Australia, waste-related industry associations have played a leading role in informing adaptive policies and adjusting to COVID-19 conditions. The Australian Council of Recycling (ACOR) has surveyed pandemic conditions [12]; ACOR suggested that governments should consider the findings as part of the ongoing response to COVID-19 and more broadly. Waste Management Resource Recovery Association of Australia (WMRR) updates the industry on COVID-19 related policies and measures in different jurisdictions. There has been limited research that provides deep insight into the COVID-19 impact on the industry and responses. This study aims to explore COVID-19 impacts on the Australian C&D waste recycling and construction industry and the practical responses to overcome pandemic-induced challenges.

METHODS

Research Context

In Australia, industry activities are regulated at the jurisdictional level. Australia has six states: Victoria (Vic), New South Wales (NSW), Queensland (Qld), South Australia (SA), Western Australia (WA), Tasmania (Tas) and two territories: Northern Territory (NT) and Australia Capital Territory (ACT). One public organisation in each jurisdiction is responsible for governing waste-related activities [13], producing information regarding the COVID-19 impact on the industry. Therefore, where possible, findings on the impact are explicitly provided for each jurisdiction.

Data collection, analysis, and processing

A purposive sampling strategy was deemed as the most appropriate approach given the research timeframe. It was employed to recruit a wide range of participants across the C&D waste supply chain representing five Australian jurisdictions. Recruitment was undertaken according to the Australian National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2007) and university ethical committee requirements at RMIT Griffith Universities. The project industry partners, the Australian Sustainable Built Environment National Research Centre (SBEnc) and the Waste Management and Resource Recovery Association of Australia (WMRR), assisted with the recruitment process by providing their network contact details. WMRR's members consist of businesses and experts who are engaged in recycling and waste management activities. SBEnc members include government, industry, and academia experts involved in built environment issues, most notably C&D waste management. WMRR is the primary industry stakeholder for this work, whilst SBEnc funded the research project.

Since the study required experts in the field, one of the main selection criteria was an adequate experience in dealing with waste management in Australia. Email communication was used as the method of recruitment. An email with the project information sheet was sent to a list of participants compiled by the research team in one round. This covered 60 individuals with relevant experience in waste management and the resource recovery sector. The list consisted of the two organisation members and other experts identified by researchers. A reminder email was also sent to those who did not respond in the first round. Interview participation was voluntary, and attending the interview implies informed consent. The investigators maintained the privacy and confidentiality of all interview information as per the human ethics requirements. The interviewees were conducted online, using the Microsoft Teams application. Each interview took, on average, 45 minutes, involving a brief description of the study objectives and the interview structure. The interview consisted of several questions covering the main issues and opportunities regarding the development of the market for the recycled C&D waste materials. As presented in Table 1, the questions sought participants' experience, their opinion on the impact of COVID-19 on C&D waste recovery activities, and issues around the development of the market for recycled C&D waste materials.

Table 1. The research questions that were used in this study.

Theme	Questions
Experience	<ul style="list-style-type: none">• Could you please introduce yourself and describe your role in your organisation? Prompt: involvement/ experience in C&D waste management• How long have you been involved in C&D waste management?
COVID-19 & waste management	<ul style="list-style-type: none">• In terms of the development of a market for recycled C&D waste products, please share your views on the conditions after COVID-19• How has COVID19 affected your organisation/ industry?• How does the industry respond to COVID during and after the outbreak?

The audio data were carefully transcribed by a professional transcriber word-for-word. The research team further verified the quality of text data. The analysis of transcripts was performed using NVivo Pro 12 application [14]. This application facilitates codifying text-based qualitative data. A thematic analysis method was applied to identify emerging themes [15], with a combination of inductive and deductive reasoning approaches was employed. The analysis began with a deductive or theory-driven coding system (A-priori codes) using the literature review/ interview guide elements while creating additional new nodes (In-vivo codes), inductively from emerging interview data.

KEY FINDINGS

The findings are presented under two key themes: 1) COVID-19 impacts on businesses and the C&D waste industry and the construction industry, and 2) Responses to COVID-19 impacts and lessons learned.

Participants' profile

The primary stakeholders who have a substantial role in the utilisation of recycled products (e.g., government, recyclers, and construction professionals) are well represented in the sample size. As shown in Figure 1, most of the participants were government officials (9), followed by recyclers (8), professionals working in the construction industry (5), experts employed in the construction materials manufacturing sector (3), and consultants with relevant experience (2).

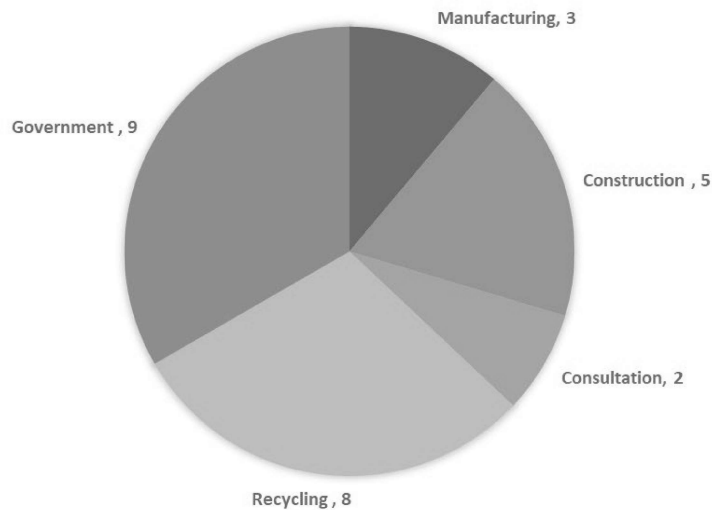


Figure 1. The composition of stakeholder groups among the interviewees

The location of business of the interviewees was in WA (n=11), Qld (n=7), Vic (n=5), NSW (n=3), and SA (n=1). In terms of gender, five interviewees were female. The remainder and the rest were male, which echoes the gender balance in the construction industry.

COVID-19 impacts on businesses and the C&D waste industry

The COVID-19 pandemic has created some form of disruption to the C&D waste industry through changes to their working shifts, supply chain interruptions, delays between the construction and demolition cycles, and the inability to retain or recruit a workforce. The interview participants from different industry sectors and government shared their lived experiences in the face of COVID-19 disruptions. The impact varied across Architecture, Engineering and Construction (AEC) sectors; while public construction projects continued during the outbreak, there were significant impacts on residential and commercial projects. Despite the government economic support packages (e.g., Job Keeper- a payment to help keep Australians in jobs and supported businesses affected by the significant economic impact of the COVID-19), the organisation had to reduce employees on some projects. Furthermore, the amount of tenders for construction projects was also reduced. An organisation's ability to continue operating on public projects assisted their ability to endure the pandemic situation.

While many of the interview participants admitted the rapid implementation of safety protocol, including clearly divided shifts, wearing protective requirements and the use of hand sanitisers, the overall the waste industry addressed many challenges through vertical integration and the continuation of building and construction projects. The following sections describe key impacts with specific examples from the interviewees across the five Australian jurisdictions.

Interruptions to the regular business operations and the urgent need for safety precautions

Changing of work shifts, interactions with people, logistical arrangements, additional safety precautions, and onsite engagements impacted the regular business operations. There was a significant emphasis on rapid interactions and tasks such as prestart checks and cleaning activities. A private sector representative from New South Wales shared, "*COVID affected the interactions with the people. Initially, there was a rush on the masks and the hand sanitisers, but as with all free-market economies, a number of companies re-tasked their production and six weeks later none of us had a problem*" [P2]. Given construction's heavy reliance on onsite and in-person work, COVID-19 lockdowns and social distancing measures have put a great strain on employees within the industry. For example, "*We had a few issues around cultural heritage experts coming up from New South Wales to do cultural heritage surveys. So, certain things become challenging that you can't do virtually. When you're going to do cultural heritage surveys, there are certain experts that are required*" [P5].

A government representative [P8] from Queensland pointed out significant concerns around transport and sanitation. For transport this related to unknown issues (e.g., tissues, masks) at the time. Government was unable to mobilise and provide clear information immediately. While there was some resource limitation at the beginning (i.e., sanitisers), this was rapidly addressed with hand sanitiser then manufactured for industrial use. While paused operations in China already impacted the resource recovery sector, there were concerns about having to stockpile materials unable to process or get shipping containers to store the materials.

Supply chain interruptions: Most participants experienced some form of supply chain interruptions, especially for material purchased from overseas markets. One government participant shared that this was further exacerbated by the quantum of infrastructure projects that were happening simultaneously. For example, "*It's also the quantum of infrastructure projects that are happening at the same time, so if you think about, you've got Melbourne metro, Sydney metro, crossover rails, inland rail. There's a lot of major infrastructure projects that are going to be hitting construction around the same time, and that's going to have an impact only on materials*" [P5].

Delays between the construction and demolition cycles: Delivering infrastructure projects across the state and delays between the construction and demolition cycles were highlighted as critical impacts. These impacts created higher-order challenges to the organisation in terms of managing the mass balance of C&D required for the sustainable operation of the recycling facility. The interviewees from South Australia [P11] reiterated that these delays impacted the State's logistical and resource recovery operations.

Pandemic induced human resource challenges: While many participants expressed significant operational difficulties, contractors, especially ones with large workforces, encountered several pandemic-induced human resource challenges. These include pay cuts, laying off employees, or increasing the workload of existing employees. Three interviewees indicated that their response

was to retain the workforce [P5, P6, P11]. However, there was an example of one organisation implementing a 30% pay cut across their business to achieve this goal rather than laying off employees. It was considered a fair approach and enabled them to respond quickly to the impacts. For example, *"I think everyone felt quite together; everyone felt quite bonded by it because everyone was doing it together. And the people that performed more, the people that were in the higher income of the stream gave up more... as an executive team, we didn't have to start picking winners and losers. And I think that was incredibly motivating for our team, and I think it was incredibly motivating from our managers that, here is a company saying we want all of us to be in this together"* [P11]. In the interviewee's experience, Job Keeper/Job Seeker schemes negatively impacted labourers choosing not to do hard physical work while being paid. This phenomenon resulted in a significant increase in workload and the labour hour percentage.

Table 2 synthesises the key impacts shared by interview participants across the five states of New South Wales (NSW), Queensland (QLD), Victoria (VIC), Western Australia (WA) and South Australia (SA).

Table 2. Summary of COVID-19 impacts on businesses and the C&D waste industry

State	Key impacts
NSW	<ul style="list-style-type: none"> • A slight decline in demolition type activities from C&D materials received by the site • Decline of waste streams depending on the severity of the state government's reaction • Review of supplier contracts and rates to align with the new state of the economy
Qld	<ul style="list-style-type: none"> • Supply chain interruptions for material purchased from overseas markets • Limited material flow and increased effects by the quantum of infrastructure projects that were happening at the same time • Interruptions to onsite inspections, especially to cultural heritage surveys • Working remotely and travel restrictions • Restricted production and inability to export and import as usual • Increased levels of efficiency in transportation certain operations due to clear roads and transport networks • Resource recovery sector was impacted by stockpile materials unable to process or get shipping containers to store the materials
Vic	<ul style="list-style-type: none"> • Increasing budgetary constraints • Dealing with uncooperative industry partners with changed priorities. • Decline in market activities in the AEC industry • Delays in several projects starting that is considered an economic slump • Pandemic induced human resource challenges (reduce the number of employees) • Reduced tenders for construction projects
WA	<ul style="list-style-type: none"> • The waste operation continued as it is considered an essential service • Self-isolation among the workforce in the operations • Incentives in the residential market and not commercial has been counteractive to this impact • Limited resources, both human resources and shortage of materials, particularly steel, timber • Reduced the number of people working on construction sites. particularly building houses • Increased pressure to do better, to recycle more C&D material with increasing infrastructure projects • The residential housing market was doing well, and there has been a positive impact in the broader macroeconomic perspective • Changes in the priority of the organisation activities such as bringing forward of infrastructure projects
SA	<ul style="list-style-type: none"> • The job keeper/job seeker schemes negatively impacted labourers' choosing not to do hard physical work while being paid • Increase in workload and the labour hour percentage

Responses to COVID-19 impacts and lessons learned

Participants across the five Australian jurisdictions shared their experiences related to the responses to COVID-19 disruptions and challenges. While most participants described their rapid responses aligned with emergent safety priorities and efficient management of resources, this experience has also helped them to uncover a range of opportunities. Learning from these COVID realities, participants also developed consciousness around the need to leverage digital technologies, developed business contingency plans, created coalitions between government and industry, and diversified supply chains and reduce supply chain risks. The key responses are as follows:

Leveraging digital technologies: The emergent opportunities using real-time data, digital engineering and other online technologies when dealing with such disruptions were highlighted by several participants. For example, *"I think COVID might have positive repercussions for things like smart cities and real-time data, and digital engineering. I think that those shifts would then support this kind of work"*. Another participant engaged in a large transport infrastructure project reiterated the importance of leveraging online technologies (P10). One government sector participant shared their experience on leveraging current digital capabilities of using cloud-based technologies to work with clients and colleagues across different states. *"I think we'd already moved to Adobe Sign before COVID because we work across three different states. And GIS has been used for modelling, I think we were set up quite well, virtually, prior to COVID, simply because of our expansive breadth"* [P5].

Developing contingency plans: The importance of contingency plans business continuity planning to sustain the business was emphasised by two interviewees. For example, one participant shared their experience on developing contingency plans, *"Our leadership team identified the potential impacts that COVID was going to have. We put contingency plans in place, response plans in place very early and had communication out to the sites, the ability to work remotely was responded to quite quickly. So as a business, and in terms of potential impacts, we had really good continuity plans in place"* [P1].

Creating coalitions between government and industry: There was evidence of efforts to collectively create a coalition between government and industry to address the emergent issues around the pandemic collectively. This group consisted of representatives from all the impacted components of the waste sector together to discuss issues and create collective solutions. These issues captured, *"Will there be enough capacity to deal with waste? how to treat mixed waste containing medical waste? What were the risks to landfill operators?"* (P9). There was also evidence from South Australia where organisations have engaged strongly with the government, the industry, and their customers. This has resulted in the organisation's preparedness and to be more resilient in the market. However, two government representatives (P24, P27) mentioned that due to the government COVID-19 recovery plan in response to the COVID-19 situation, which includes bringing the infrastructure projects forward to support local industry, the market would be more flourishing for the C&D waste stream after COVID-19. At the industry level, several interviewees stated that during COVID-19, the industry and government worked well together in response to issues that come with the pandemic. One interviewee had participated in several industry leadership calls with various state public organisations to communicate issues the industry face during the affected period. The industry itself was quick in taking preventative containment measures. For example, *"that's what I think was interesting, I mean you look at it and you thought, and this was in normal circumstances, the entire industry would say they need three years to implement these types of changes and they happened in three weeks. So, for me that was a really interesting phenomenon that we saw right across the industry"* [P11].

Diversifying supply chains and reducing supply chain risks: Diversifying the supply chain and, creating more local transparent supply chains were suggested as key measures to mitigate risks. One participant stated that as their business operations located in China provided them with some early opportunities to learn and navigate through disruptions, they could be ahead of the curve [P6]. There were early efforts to set up teams' systems, understand their procurement needs, and mitigate the risks. Another participant reiterated the importance of reducing risks through creating secondary markets for C&D waste and enabling local supply chains. For example, *"I think any country should be looking at ways to reduce their exposure to supply chain risk, and if you can keep things onshore, that does a variety of things. It reduces supply chain risks, it creates jobs, and it creates alternative industry"* [P5].

Table 3 synthesises a range of responses to the COVID-19 impacts shared by interview participants across the five states of New South Wales (NSW), Queensland (QLD), Victoria (VIC), Western Australia (WA) and South Australia (SA).

Table 3. Specific responses to the COVID-19 impacts across five Australian jurisdictions

State	Key responses
NSW	<ul style="list-style-type: none"> • Managing workforces with clearly defined shifts and cleaning arrangements • Rapid interactions and tasks focussed on prestart checks and cleaning • Procuring masks and hand sanitisers • Putting contingency and response plans in place very early and had communication out to the sites • Creating clear communication channels and formulating clear messages
QLD	<ul style="list-style-type: none"> • Increased attempts to use local products, diversify the supply chain as much as possible to reduce supply chain risks • Leveraging virtual platforms to engage with other colleagues • Creating a circular economy system via local markets and bringing the waste closer and the end products closer • Requesting for possible government funding for the industry to become profitable and to establish • Conducting market assessments to assess the feasibility and to establish in the market • Implementing COVID safety protocols • Focusing on safe ways to work around waste, deliver essential services in local areas and across borders • Creating a group of representatives from all of the impacted components of the waste sector together to discuss issues and create collective solutions • Identifying opportunities related to online platforms and real-time data and digital engineering is positive repercussions of this disruption
VIC	<ul style="list-style-type: none"> • At an individual level, measures such as social distancing, personal hygiene, taking care of one another, reporting if there is ever an issue with people have symptoms • Repeating the message of the required practices and measures due to C&D waste recycling employees' unique socio-economic background • Placing controls around shared spaces, and customer interaction • Allocation of additional staff to each project called COVID monitors
WA	<ul style="list-style-type: none"> • Developed targeted protocols in response to COVID-19 situations • The extra construction work that has been undertaken is used up to stock balls or had some of those raw materials being turned into, such as recycled blocks or recycled road-based • Creating a memorandum of understanding to share sources depending on the situation • Release of planning caveats around the COVID-19 period to stimulate the economy • Application of the segregation and the work-at-home requirements advised during the lockdowns • Followed the advice from the state health authorities such as social distancing, putting a face mask • The government's response was to try and fast track infrastructure projects as part of the economic recovery, which was an excellent opportunity for the government to increase the use of recycled C&D • Working from home and preparing for the booming residential market • The government responded to the COVID-19 situation by supporting the use of recycled content and increase in the number of projects that which has broadened the opportunities
SA	<ul style="list-style-type: none"> • The industry and government worked together to address COVID-related issues • The organisation implemented a 30% pay cut across their businesses to achieve this goal instead of laying off employees

DISCUSSION

Emergent Impact matrix

As outlined in the Results section, COVID-19 impacts on the industry has been diverse in the studied states. The following table provides an impact matrix developed based on interviewees' responses. The impacts are categorised under five scopes: 'construction and waste generation', 'employee engagement', 'transportation', 'processing and recycling' and 'disposal'.

Table 5. Summary of COVID impact matrix in five studied states

Scope	Impact description	States				
		NSW	QLD	VIC	SA	WA
Construction and waste generation	Interruptions to regular business operations	●	●	●		●
	Urgent implementation of safety protocols	●	●	●	●	●
	Decline of waste streams/ limited material flows	●	●			●
	Supply chain interruption	●		●		
	Decline in demolition type activities	●				●
	Economic impacts / budget constraints					●
	Changing of priorities			●		●
	Increased infrastructure development due to government interjections			●		●
	Reduced tenders for construction			●		
	Delays in project planning and delivery			●		●
Employee engagement	Immediate need for remote working arrangements		●			
	Limited onsite engagement		●			
	Pandemic induced human resource challenges (lay offs, pay cuts, increased work loads)			●	●	
Transportation	Restricted travel		●			
	Waste transportation and handling risks					
	Increased efficiency due to clear roads	●	●			
Processing and recycling	Restricted production					
	Decline in demolition type activities/ limited material flow					
Disposal	Stockpiling of materials unable to process		●			

The table shows that the construction and waste generation impact category has the most references in the interviews, followed by employee engagement. Furthermore, only 'urgent implementation of safety protocols' was reported as an impact across all study states. Interestingly, restricted production and decline in demolition activities did not occur during pandemic restrictions. This is mainly related to the State COVID-19 policies that consider construction and recycling essential industries. Going forward, the authors summarise the following adaptive measures based on the findings and key literature:

Adaptive measures

Government information support State and territory governments have dedicated information hotline numbers for businesses affected by COVID-19. These information centres are currently operational in ACT, NSW, Vic, Qld, WA, and N.T. Notably, in Qld, the Chamber of Commerce & Industry Queensland provided dedicated advisory services for small businesses. The Federal government's business hotline also provides support for impacted small and medium enterprises.

Government financial support: State and territory governments have announced financial support for the businesses that are affected by the pandemic (Table 1). As expected, the highest level of financial supports is offered by Qld (\$2.5bn), NSW (\$2.3bn), Vic (\$1.7bn) governments. Qld and ATC governments provide electricity rebates with a specific consumption threshold. All jurisdictions offer payroll tax relief in some capacity (Waste Management Review, 2020) from three to twelve months. The federal government financial support is done through three schemes,

namely the Economic Recovery Package (ERP), Job Keeper Payment scheme (JKP) (Ananda, 2020), and Tax-Free Cash Payment (TFCP). ERP provides support for the Australian economy, including small to medium enterprises, for three years. JKP aims to support employers to keep their staff; the eligible business should prove that their turnover was affected by COVID-19 by a fall of between 15 and 50%. TFCP provides tax-free payments between \$20k and \$100k. The government has committed more than \$4.7m to provide small regional businesses affected by COVID-19 with access to free and confidential financial counselling. In NSW and Qld, affected small businesses can apply for a re-opening grant (a one-off \$3,000) and COVID-19 Adaption grants (\$10k), respectively. Table 1 summarises the current financial supports that are made available by the federal, state and territory governments to tackle the pandemic.

The majority of responses to the ACOR's COVID-19 Industry Pulse Check survey suggested a landfill levy relief for the next 6 to 12 months [16]. Other suggestions include local governments to waive business fees, state and local governments become more flexible on certain facility license conditions for social distancing so the protection of staff can be maintained, landfill levy waiver on contaminated residuals from recycling facilities, payroll tax reductions, deferring business loan repayments, collection time curfews to be lifted so that bins can continue to be collected and further support for tax and super obligations.

Interstate waste movement: The interstate waste movement has been primarily affected by restrictions imposed by Australian jurisdictions. NSW, Qld, Tas, SA, WA, and NT have imposed movement restrictions across borders, but there are exemptions for essential travel, workforce movements, freight, and specific compassionate grounds. For instance, NSW Public Health (COVID-19 Border Control) Order 2020 permits critical services, including construction and the maintenance and repair of critical infrastructure. The NSW Environmental Protection Authority (EPA) information fact sheet (April 2020) specified that the authority does not impose restrictions on interstate transport of waste. In NT and Tas, the interstate travellers to NT must complete 14 days of self-quarantine unless they meet these exemption criteria. Travellers from declared hotspots to Qld are also required to complete 14 days quarantine in government arranged accommodation (at their own cost) unless they are exempted from the requirements. In SA, while the board restrictions are ceased for travellers from WA, Tas and NT, travellers from other states are subject to an assessment of the public health risk. In WA, restrictions are in place which disallows people to enter the state without an exemption.

CONCLUSIONS

This study contributes to the field by addressing the gap identified in the body of knowledge regarding the impact of COVID-19 on the industry within the Australian context. This paper is the first Australian study investigating COVID-19 impacts on C&D waste management and the resource recovery industry. In addition, each of the dimensions of the issue and the corresponding impacts and adaptive measures can provide researchers with a narrower field of study for further exploring the nature of each item and identifying factors that control and shape each one. This study suggests the following recommendations to further assist the industry with sustainable operation during these challenging times:

1. Consideration of the industry as an essential service in all Australian jurisdictions
2. Landfill levy relief for the next 6 to 12 months to stop illegal dumping and stockpiling
3. landfill levy waiver on (contaminated) recycling residuals
4. Collection time curfews to be lifted so that bins can continue to be collected

Despite the value of the study, some limitations might be considered in applying the findings. The key limitation among all is the variability nature of measures and initiatives taken to navigate the industry's operation through the pandemic outbreak. While the study capitalises on the interviewees' knowledge and experience, the results should be read with this caveat in mind. Another limitation concerns the information released by the review date. The impacts of the COVID-19 pandemic are yet to be known, and there are limited sources that provide insight into this issue. However, these limitations do not question the value of study in providing lessons for other contexts and acting as the groundwork with rich and deep insights from key stakeholders towards further discussions and scientific debate on the topic. The results are expected to be considered in the development of adaptive policies and measures that can shape a uniform response to support the sustainable operation of the industry.

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