Optimum model for the creation and stimulation of end-markets for C&D waste in Australia

Research Report 4

Tayyab Maqsood
Salman Shooshtarian
Peter SP Wong
Tim Ryley
Savindi Caldera
Malik Khalfan
Rebecca J Yang

SBEnrc P1.75 Creation and Stimulation of End Markets for Construction and Demolition Waste

Date: August 2021

ACKNOWLEDGEMENTS

This research has been developed with funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc) and its partners.

Core Members of SBEnrc include BGC (Australia) Pty Ltd, Government of Western Australia, Queensland Government, Curtin University, Griffith University and RMIT University.

Core Partners: This research would not have been possible without the ongoing support of our core industry, government and research partners:

Project Leader: Tayyab Maqsood, RMIT University

Researchers:
Salman Shooshtarian, RMIT University
Tim Ryley, Griffith University
Savindi Caldera, Griffith University
Peter SP Wong, RMIT University
Malik Khalfan, RMIT University
Rebecca J. Yang, RMIT University

Citation: Maqsood, T., S. Shooshtarian, T. Ryley, S. Caldera, P. SP. Wong, M. Khalfan, and R.J Yang (2021). Optimum model for the creation and stimulation of end-markets for C&D waste in Australia. SBEnrc 1.75 - Creation and Stimulation of End Markets for Construction and Demolition Waste. https://sbenrc.com.au/research-programs/1-75/

EXECUTIVE SUMMARY

This report presents the findings from interviews conducted to capture the C&D waste recovery stakeholders' perceptions of issues and opportunities centring around C&D waste end-market creation and stimulation in Australia. In total, 27 experts with relevant experience from New South Wales, Victoria, Queensland, South Australia and Western Australia were interviewed between May and July 2021. The participants represented government organisations (n=9), the recycling industry (n=8), the construction industry (n=5), construction materials manufacturing (n=3), and consultancy (n=2). Three question categories targeted participants' experience and involvement in C&D waste management; their perceptions of existing and future C&D waste end-markets; and the major enablers and barriers towards creation and stimulation of end-markets.

Drawing on the key findings, a model to optimise the creation and simulation of end-markets for C&D waste in Australia is developed. The information extracted from the analysis of the literature and the interviews is used to develop the model. It maps out how various enablers of market development can be implemented to optimise the interplay among various stakeholders in the C&D waste space. The stakeholders in this model include the government sector (public organisations and policy makers), recyclers, C&D professionals, and sustainability rating system and quality assurance auditors. As proposed in this model, the major improvements should be facilitated by the government sector through various strategies such as sustainable procurement (SP), raising awareness and financial support.

Lastly, a series of recommendations are provided to enable a change in the C&D waste management ecosystem in different states to increase uptake of recycled content in construction projects.

Table of abbreviations

Abbreviation	Extended word
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AEC	Architecture, Engineering and Construction
C&D waste	Construction and Demolition waste
C&I waste	Commercial and Industrial waste
CE	Circular Economy
CP	Circular Procurement
EPA	Environmental Protection Authority
GDP	Gross Domestic Product
GISA	Green Industries SA
GBCA	Green Building Council of Australia
GPP	Green Public Procurement
ISO	International Organization for Standardization
ISCA	Infrastructure Sustainability Council of Australia
kt	Kilo tonne
MSW	Municipal Solid
Mt	Million tonnes
NSW	New South Wales
NT	Northern Territory
NWP	National Waste Policy
OECD	Organisation for Economic Co-operation and Development
Px	Participants X
QLD	Queensland
RCA	Recycled Concrete Aggregate
SA	South Australia
SP	Sustainable Procurement
SPP	Sustainable Public Procurement
SV	Sustainability Victoria
t	Tonne
Tas	Tasmania
UN	United Nations
UNEP	United Nations Environment Program
Vic	Victoria
WA	Western Australia
WMD	Waste Management Document

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

Australia's capital cities have recently experienced unprecedented construction activity to meet the needs of the growing population and keep up with the economic growth[1]. As a result, the management of ensuing construction and demolition (C&D) waste has become an emerging subject in urban areas. Of the countries in the Organisation for Economic Cooperation and Development (OECD), Australia is in the top 10 for levels of solid waste generated. In 2018-19, a total of 27 million tonnes of C&D waste was generated in Australia, of which 14 mt was recovered[2]. To correctly manage this quantity of waste, recycling activities should be encouraged. Currently, there is a limited market for C&D recycled waste materials in Australia, and this research is intended to find strategies that can stimulate the end-market for this waste stream.

2 Methodology

This report builds on the primary data collected through interviews with experts who have relevant experience in managing C&D waste in Australia. The following sections describe the methodology used in this study.

2.1 Data collection

A purposive sampling strategy was the most time-effective sampling approach available. It was employed to recruit a wide range of participants across the C&D waste supply chain. Recruitment was executed according to the Australian National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2007) and RMIT University Human Ethics Committee instructions and requirements. The project industry partners, the Australian Sustainable Built Environment National Research Centre (SBEnrc) 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. SBEnrc members include experts from government, industry and academia involved in built environment issues, most notably C&D waste management. WMRR is the primary industry stakeholder for this work, while SBEnrc funded the research project. In 2020, RMIT (2020-23224-11666) and Griffith both received approval from the relevant university research ethics committees. Please see the appendices for more information.

Since the study required experts in the field, one of the main selection criteria was the adequate experience in dealing with the management of waste in Australia. Email communication was the method of recruitment. In the first round, an email with the project information sheet was sent to a list of participants compiled by the research team. 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 implied 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, which is freely available to everyone. Each interview took, on average, 45 minutes, including 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, issues around the development of the market for recycled C&D waste materials and other information provided by participants.

Table 1. Research questions used in this study.

Theme	Questions
Experience	• 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 and waste management	• 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 COVID-19 affected your organisation/ industry? • How does the industry respond to COVID during and after the outbreak?

Recycled C&D waste market development	• Do you think that creating a marketplace for C&D waste could be used as an intervention to manage C&D waste better? • What is your opinion about the operation of existing end-markets in your jurisdiction? • What can be improved to facilitate creating and stimulating efficient end-markets for C&D waste in your industry/state? • Which C&D waste materials have the most potential for new markets? Prompt: concrete, brick, steel, glass, timber, asphalt and clean fill • In your opinion, how can we enable the creation of a marketplace for C&D waste? • What are the main factors impacting C&D waste end-of-life management? How are they influencing C&D waste management according to the status quo? • What are the main barriers to implementing a sustainable marketplace for C&D waste in your industry/ jurisdiction? • How do you think of the current legislation about C&D waste end-of-life management in your jurisdiction?
Others	• Did I forget anything? Is there anything you would like to share? • Can I get back to you if I have further questions about the data analysis? • Lastly, do you know anyone in the sector who might be willing to participate in our research?

2.2 Data analysis

The audio data (1,000 minutes' worth of 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[3]. This application facilitates codifying text-based qualitative data.

3 Participant profiles

The primary stakeholders who have a crucial 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).

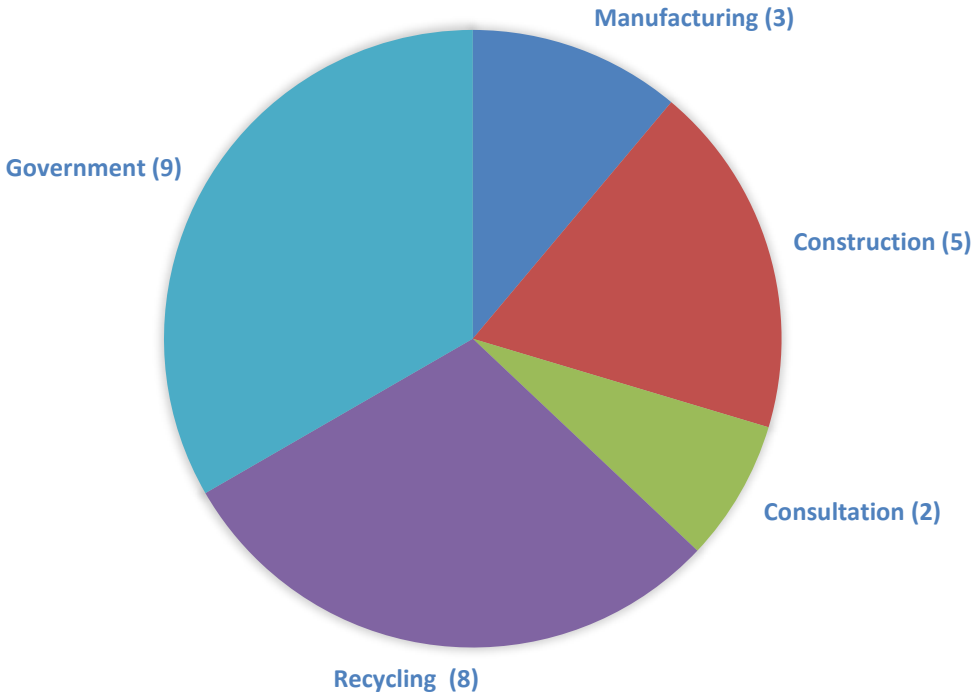

Figure 1. The composition of stakeholder groups among the interviewees

A summary of participant's profiles, including the primary location of their business and the focus of the operation, and their position and length of experience, is provided in Table 2. The locations of the interviewee's businesses were in WA (n=11), QLD (n=7), Vic (n=4), NSW (n=3), and SA (n=1). In terms of gender, five interviewees were female, and the rest were male, echoing the industry gender imbalance.

Table 2. Summary of profiles of interviewees and their organisations

P	State	Stakeholder group	Position	Experience (years)	Recent involvement in C&D waste management
P1	NSW	Manufacturing	State Manager	4	Providing the construction industry with sustainable products and solutions in NSW and Victoria
P2	NSW	Recycling	Director	30	Producing and re-selling quarried and recycled landscape products in NSW; waste management, crushing and landfilling operations, technical management of C&D waste resources in NSW
P3	NSW	Manufacturing	Strategy Business Development Manager	4	Providing the construction industry with sustainable products and solutions, and business development related to C&D recycling
P4	QLD	Government	Sustainability Manager	20	Managing C&D waste associated with large infrastructure projects
P5	QLD	Government	Sustainability Manager	11	Managing C&D waste associated with large infrastructure projects
P6	QLD	Construction	Sustainability Operations Manager	20	Designing, delivering and reporting on activities as a business for sustainability metrics
P7	QLD	Construction	Senior Waste and Resource Consultant	13	Investigating the regulations and legislation in different jurisdictions, the impacts of establishing reprocessing facilities and conducting market assessments
P8	QLD	Government	Environmental Coordinator for transport and Infrastructure	14	Managing statutory approvals for all applicable infrastructure and maintenance activities, environmental matters and contract support for other parts of local council
P9	QLD	Government	Executive Director of Resource Recovery	16	Developing long-term policy levers that can be used to drive positive change and shift behaviour and language from waste to resource recovery
P10	QLD	Consultation	Managing Consultant	10	Providing expert advice on managing different streams C&D waste across infrastructure
P11	SA	Recycling	Chief Executive Officer	10	Resource recovery of C&D waste materials and tyre recycling in SA; sells recycled products in various markets
P12	Vic	Recycling	Chief Executive Officer	18	Recycling C&D waste materials in Vic; has the largest C&D waste recycling facility in Australia
P13	Vic	Government	Environmental Project Advisor	4	R&D and market development for recycled products, resource recovery and facilitating the connection between research institutes and the industry to produce products with recycled contents in Victoria
P14	Vic	Recycling	Sales Manager	8	Liquid waste management, managing crushing and landfilling operations, and technical management of C&D waste resources recovery activities in NSW and Victoria
P15	Vic	Recycling	Managing Director	25	Managing recycling of C&D waste, particularly asphalt, in Melbourne and Brisbane

P16	Vic	Construction	Quality and Environment Manager	18	Monitoring C&D waste disposal and use of recycled contents, and improving recycling waste generated at construction sites in Victoria, South Australia and some contribution to other areas
P17	WA	Consultation	Principal Engineer Pavements & Drainage	13	Providing consultation services pertaining to sustainability in the construction industry and lecturing in the University of Western Australia about C&D waste management
P18	WA	Recycling	General Manager	12	Recycling C&D waste materials in Western Australia
P19	WA	Government	Sustainability Manager	5	Large scale demolition projects across WA with the aim of recycling C&D waste
P20	WA	Government	Senior Development Manager	14	Engaging in residential development sites including demolition of old buildings, remediation of sites and civil bulk earthworks for development
P21	WA	Recycling	Resource Development Manager	10	Recycling and managing C&D waste in Western Australia, and also representing the recycling industry in different state and national committees
P22	WA	Recycling	Director-operations	5	Providing technical solutions to manage the traceability of materials during deconstruction projects
P23	WA	Manufacturing	Technical Manager	15	Managing mix designs in production line and performing troubleshooting and trials relating to quality control for concrete
P24	WA	Government	Manager – Policy	16	Delivering the state waste strategy in two public organisations
P25	WA	Construction	Residential Sustainability Manager	4	Improving sustainability aspects of residential construction projects
P26	WA	Government	Manager of Material Engineering	19	Contributing to planning for creating road infrastructures in Western Australia in a public organisation with some involvement in using recycled products in these projects
P27	WA	Government	Principal Advisor Sustainability	15	Responsible for corporate sustainability in two public organisations, which involves waste management and market development for C&D waste materials

4 Stakeholder perceptions

4.1 New South Wales

The interviewees based in New South Wales were representatives of two private organisations, including one recycling facility and one manufacturing company (Table 2). Three of these research participants held senior leadership and managerial positions at the time of the interview. The interviewees' experience related to the C&D waste management field ranged between 4 (P1) and 30 years (P2). The main focus of participants consists of producing and re-selling quarried and recycled landscape products in NSW (P2); waste management, crushing and landfilling operations, technical management of C&D waste resources in NSW (P2); and providing the construction industry with sustainable products and solutions (P1, P3).

4.1.1 The impact of COVID-19 and responses

The COVID-19 pandemic has created challenges for various sectors, including housing, building and infrastructure. Many businesses have experienced some form of disruption through changes to their working shifts or supply chain interruption. The interview participants shared their lived experiences in the face of these COVID-19 disruptions. While many of them acknowledged the rapid implementation of safety protocols, including changes to shifts, wearing protective requirements and use of hand sanitisers, the overall waste industry processes were insulated because of vertical integration and the continuation of building and construction projects. There was a significant emphasis on rapid interactions and tasks such as prestart checks and cleaning activities. For example, a private sector representative shared,

> *"COVID doesn't affect the basic process, it's only the interaction 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].*

Another private participant highlighted the importance of contingency plans business continuity planning to keep the business running. For example,

> *"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].*

The detailed impact and responses to COVID-19 are tabulated in Table 3.

Table 3. The impact of COVID-19 and the responses to the impact in New South Wales

Participant	Impact(s)	Responses
P1	While this participant's work was not directly impacted, he witnessed a slight decline in demolition type activities from C&D materials received by the site. From an outbound sales point of view, there was minimal impact on the construction market around lockdown, but they managed to continue with sales.	From an operating cost point of view, a decision was made around managing workforces to ensure particular day shift and afternoon shift teams that didn't cross over. There was always a gap between a day shift and an afternoon shift to clean the common facilities. These cleaning procedures increased costs slightly, around labour costs particularly, and the cleaning costs associated with keeping the businesses as free from direct impact from positive cases as possible.
P2	It was evident that some waste streams slowed down in various capitals, depending on the severity of the state government's reaction.	There are rapid interactions and tasks focussed on prestart checks and cleaning. While COVID did not affect the basic process, it only impacted the interaction with the people. Initially, there was a rush on procuring masks and hand sanitisers, but as with all free-market economies, several companies re-tasked their production, and six weeks later, none of them had a problem.
P3	I guess, just the normal impact also throughout the economy. When they say procurement, we did have some tender push for the procurement team to reach out to all suppliers trying to review contracts and rates to align with the new state of the economy. However, I think other than that, construction, as you should know, thankfully was one of the industries that were least impacted by COVID, as it was positioned as an essential activity.	Their leadership team identified the potential impacts that COVID was going to have and made early efforts to 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 excellent continuity plans in place.

4.1.2 Market development in New South Wales

There was consensus among the interviewees on the benefits of developing the market for better management of C&D waste materials in New South Wales (Table 4). Factors such as location, recycling rates, waste levy, incentives and products specification were highlighted as key characteristics to consider when creating end-markets for C&D waste. For example,

> *"And the other element that comes to mind is the incentives on the supply and the demand side of things. So, for the supply, things such as landfill levy fees, we'd put some incentives for the supply of those involved in the recycling operations. Now on the demand side of things is, what more can, or should, governments do in addition to product specifications? Meaning how much should they go into mandating news levels versus incentivising news levels, yeah, those were it" [P3].*

They also expressed their frustrations about the current market regulations and product specifications as impediments to creating end-markets C&D waste. The participant compared NSW with other states and expressed their frustration about the current EPA system. For example,

> *"The extreme is New South Wales, of course, the other states are bit more circumspect and pragmatic, but New South Wales has a serious problem, and the main problem is the concept of asbestos contamination" [P2].*

This participant also pointed out that the current market criteria and specifications are hindering the recycled product market. For example, *"The C&D products are intended to replace natural products, but unfortunately in many cases, the state-based intra-mentalities will apply exactly the same natural material criteria as to recycled material" [P2].*

In terms of the potential market, responses from two participants (P1, P3) underlined the potential market for plastics and timber. Notably, one participant emphasised the importance of having a clean stream of waste to create a value-added product,

> *"The more you can keep them separated, the more opportunity you've got to resource or recycle them up back into a higher value product" [P3].*

Table 4. An overview of market development for recycled C&D waste products in New South Wales

P	Intervention	Operation	Potential markets
P1	This participant explained that the resource recovery rate for C&D materials is quite high in New South Wales, and mature end-markets drive it for the material.	The participant claimed that the end-market use of the product is quite mature in New South Wales. But there is the capacity to improve the market demand through improved product specifications and incentives.	Through their industry experience, the participant stated there was more focus on source-separated concrete brick and asphalt. In terms of exploring other waste streams, it is critical to have methods of separating those resources early on so that they are not co-mingled to allow for better recycling of the materials in their purest form.
P2	This participant expressed their intentions on moving C&D sourced recycled products and the importance of clearly understanding natural and recycled material standards.	The participant indicated that they have a scaling system now, which gives higher scores towards recycled products, so recycled is sought when contractors bid for big infrastructure projects, but it does not have enough weight. He also pointed out that they are not allowed to mix two recycled products in New South Wales. This means that suppliers can safely deliver recycled soil and recycled mulch to a site and mix it.	This participant indicated that nearly 30% of C&D waste is timber in New South Wales, and there is more potential to re-use and recycle this material.
P3	This participant highlighted several factors affecting this intervention: geographic location, recycling rates, product specifications and relevant opportunities in infrastructure projects (i.e., road-based projects) to use recycled contents.	There are regulatory requirements around minimum standards now for C&D facilities. However, within their organisation, they have rigorous inspection and receivable processes. So that starts with our inbound account managers going out to sites where the demolition or the excavation works are being undertaken. Regularly, they check clearance certificates where necessary, where there has been the risk of asbestos associated with the work.	The importance of creating a cleaner waste stream was re-iterated, and as more of the waste streams are separated, the more opportunity there will be to recycle them into a higher value product. Plastics and metals were highlighted as new opportunities for market development.

4.1.3 Improvement areas

The industrial practitioners shared a range of insights linked to improvement opportunities in relation to the creation and simulation of efficient end-markets in NSW. One participant emphasised that the government needs to mandate a certain percentage of recycled content on all government jobs and thereby advance the recycling practices. For example,

> *"You have to make it financially worthwhile to recycle, but you also have to create the regulations such that the markets will be there. Again, you see that not occurring in our state, whereas if they mandated a percentage of recycled content in a finished product on all government jobs, for example, preferential content. That would really further driver recycling" [P2].*

Going forward, business needs to be encouraged to shift from merely being complaint to taking additional efforts to engage in sustainable business practice, that is moving away from *"That compliancy focus for the recycled operations and finding the right balance there between establishing strict parameters for the recycling operations to operate under, versus not making those operations through costing" [P3].*

A more streamlined, harmonious approach to approvals and timeliness of the approvals, and early engagement and support from the regulators, are critical to improving end-markets for C&D waste. These factors will also influence the investment decisions of market players. For example, one participant said, *"Because we'll make the decision that it's worth making the investment as opposed to saying that money is better elsewhere" [P1].*

Furthermore, considering the circular of the economic system and tracing the material movement was also identified as a critical area of improvement. One participant explained, *"The whole circular economy element that we need to think in the 20-year Waste Strategy, that we are going to start seeing more circulatory thinking, which sees materials coming in and out of C&I and C&D, moving through a broader life cycle process for materials" (P1).*

4.1.4 Enablers and barriers towards market development in New South Wales

This section presents key enablers and barriers described by the interviewees. As summarised in Table 5, there are myriad enablers and barriers related to the market development in NSW. The main enablers in NSW were found to have supportive and straightforward policies and specifications augmented with a more streamlined, harmonious approach to approvals, timeliness of the approvals, and early engagement and support from the regulators. In terms of barriers, all responses pointed to the risk of contamination (i.e., asbestos), strict product specifications, lack of data traceability of material movement and irresponsible behaviour of rogue operators. For example, one participant described the impact of irresponsible behaviour of rogue operators:

"Every other state is the rogue operators. It's those that don't follow that strict process, that allows contaminated recycled material to go into the market which then creates the nervousness in the market" [P1].

More understanding of the material movement will provide more opportunities for industries to make their investment decisions because, *"We can then decide where should we continue to invest our time and infrastructure in order to get the most competitive products back into the market? " [P3].*

Table 5. Summary of enablers and barriers specified by the interviewees

P	Enablers	Barriers
P1	▪ Having specifications that facilitate the recycled content ▪ Shift from the compliancy focus for the recycled operations and finding the right balance when establishing strict parameters for the recycling operations ▪ A more streamlined, harmonious approach to approvals, timeliness of the approvals, and early engagement and support from the regulators	▪ Lack of data regarding the long-term performance of recycled materials ▪ Exposure of particularly asbestos contamination within the materials ▪ Irresponsible behaviour of market operators creating nervousness in the market
P2	▪ Employing relevant technologies to support recycling ▪ Legislating a preference for recycled products ▪ Increasing awareness of recyclers network and supply chain ▪ Supportive regulations	▪ The state-based intra-mentalities will apply exactly the same natural material criteria as recycled material ▪ The concept of asbestos contamination ▪ Rapidly anti-business EPA that is run by government bureaucrats
P3	▪ Considering more circulatory thinking ▪ Evaluating the material cycles, especially materials coming in and out of C&I and C&D, moving through a broader life cycle process for materials	▪ The limitations and specifications for recycled products is limiting the value creation opportunity from a more CE perspective ▪ Keeping those resources at the highest value within their life cycle ▪ Lack of understanding of how to create CE with construction materials to really drive a life cycle on those products through design ▪ Lack of information, lack of data and lack of traceability ▪ Lack of understanding of the material movements ▪ Lack of a mature market leads; customers to choose not to use recycled materials because of the risk of contamination ▪ The lengthy periods are taken for approvals from government authorities

4.1.5 Influential factors for materials end-of-life management in New South Wales

The participants discussed several influential factors for materials end-of-life management. These include dealing with many unknown types of material and different consistencies of materials coming in from multiple customers, and the efforts to put through a process and develop a consistent quality product out the other end. The factors specified by interviewees included a mix of limited incentives and investment in innovation in the recycling sector, social and environmental issues, and difficulties to self-regulate. For example, one participant explained the higher-order impacts on the communities if industrial practitioners do not take responsible steps to manage C&D waste throughout the life cycle effectively:

> *"In C&D recycling, you're dealing with lots of unknowns of different types of material and different consistencies of materials coming in from multiple customers that you're trying to put through a process and develop a consistent quality product out the other end. And if you don't care to put the effort in through that process, you will accept rubbish into your site, and contamination, and therefore you are putting that out into the community, which*

exposes the community, which is unacceptable but also puts stress on our industry, as to the standards that are then expected and applied are set to the lowest bar" [P1].

4.1.6 Waste regulations in New South Wales

The responses to the question related to current regulations and policies revealed a variety of aspects. All three participants expressed both positive and negative perceptions of relevant regulations (Table 6). Specifically, Participant 1 described opportunities for overall improvement of existing legislation, stating

"…we see that there's a huge opportunity in continuing the path of what we've done in New South Wales from a national perspective. The hesitation for us comes from the points we've just made around inconsistencies of legislation, inconsistencies of materials in those markets, uncertainty around legislation and the approval processes".

These strict regulations lead to uncertainty to invest, discouraging many players in the market to engage in recycled products business. For example,

"The one thing that does concern us greatly, is the risk of change to the legislation, particularly in the orders and exemptions. The EPA fought rightly or wrongly to make changes to a number of orders and exemptions recently in the end-use space that effectively destroyed that market. So that's probably a risk for us in the regulatory environment is some of the uncertainty around the legislation or the orders and exemptions particularly that sit in the legislative environment to give us that uncertainty to invest" [P1].

This participant highlighted the significant need for policy reform to allow some level of recycling material trials and waste recovery, explaining,

"The resource recovery orders and exemptions for their intention work well but need reform. And that's just about being clear around how the resource recovery exemptions operate and being flexible enough that as the markets start to move— and we're looking at different ideas and uses for recycled materials— that there's sufficient flexibility in that resource recovery order exemption framework to allow for trials of materials " [P1].

Table 6. Summary of participants' opinions on current legislation with respect to market development

P	Policy /Regulations
P1	This participant stated that it is not an attractive sector because it is so highly regulated, and there are high risks of contamination. To address these risks, it is critical to follow appropriate tests and all those processes.
	While this participant acknowledged that legislation has the right intent, he argued that there are some issues with the current EPA, particularly around changes that were made to the POEO Act with asbestos waste reforms. In terms of testing for asbestos, before it arrives at a recycling site, it is a choice of the developer as to whether or not they do the asbestos clearance certificates.
	There are inconsistencies in the legislation around the interpretation of asbestos contamination that need to be resolved. Within this context, dealing with local approvals is a very cumbersome process; for example, it may include approvals from different local and state-level authorities. Getting them all to agree and come together to permit a businesses' intentions in creating those end-markets can be difficult.
P2	The limited representation of scientists and engineers in the NSW EPA was highlighted as a challenge for data communication. This participant viewed this government body as being an emotional or philosophically-based regulator rather than a science-based regulator. This leads to an uncertain external environment for C&D recycling in the Sydney region. It was anticipated that if the existing regulation is enforced, most of the businesses will exit the recycling business because of the significant risk.

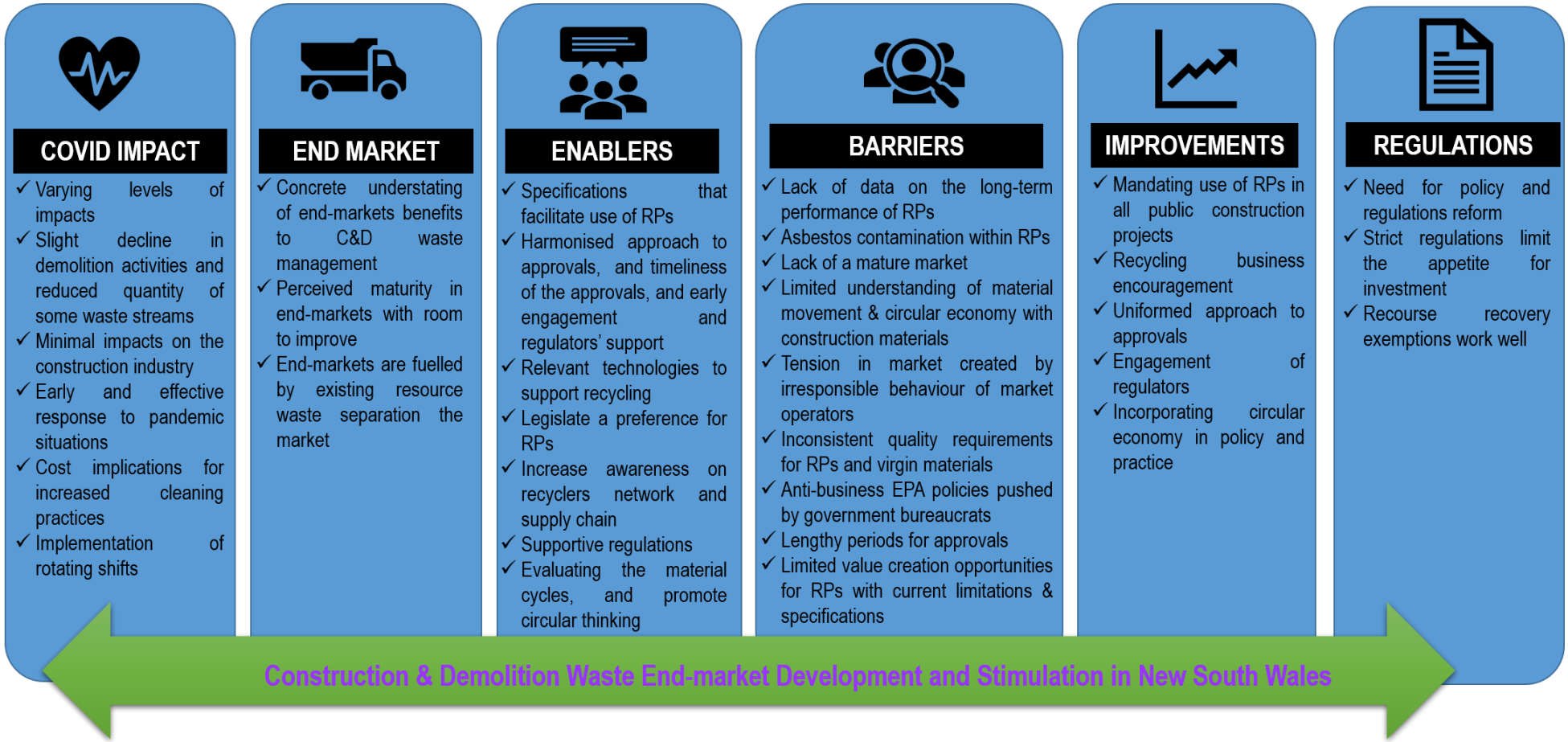

Figure 2. A conceptual model that describes C&D waste end-market characteristics in New South Wales

4.2 Queensland

The interviewees based in Queensland (QLD) represented three government organisations, two private consulting companies and two construction companies (Table 2). Four out of seven participants held senior leadership and managerial positions at the time of the interview. The interviewees' exposure to C&D waste issues ranged between 10 (P10) and 20 years (P4, P6). The main focus of participants includes managing C&D waste associated with large infrastructure projects (P4, P5); developing long-term policy levers that can be used to drive positive change (P9); designing, delivering and reporting on activities as a business for sustainability metrics (P6); investigating the regulations and legislation in different jurisdictions and impacts of establishing reprocessing facilities (P7); and managing different streams of C&D waste across infrastructure (P10).

4.2.1 The impact of COVID-19 and responses

Participants from Queensland shared their lived experiences related to the impacts of COVID-19 on C&D waste recycling activities. While most participants described their rapid responses aligned with emergent safety priorities and supply disruptions, they also noted that this experience has also helped them to uncover a range of opportunities. Most participants experienced some form of supply chain interruption, especially for material purchased from overseas markets. One government participant shared that this was further exacerbated by the number of infrastructure projects that were happening at the same time. Furthermore, on-site engagements, including inspections and surveys, were interrupted. Learning from these COVID realities, participants developed consciousness around the need for business continuity, contingency planning and more transparent, local supply chains.

One private sector participant highlighted the opportunities granted by using real-time data, digital engineering and other online technologies when dealing with such disruptions. 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 re-iterated the importance of leveraging online technologies (P10). One government sector participant shared their experience on leveraging the current digital capabilities of cloud-based technologies to work with clients and colleagues across different states, explaining, *"I think we'd already moved to Adobe Sign prior to 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].*

There was also evidence of efforts to create a coalition between government and industry to collectively address the emergent issues around the pandemic situation. This group consisted of representatives from all of the impacted components of the waste sector to discuss issues and create collective solutions. These questions 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]*. The detailed impact and responses to COVID-19 are tabulated in Table 7.

Table 7. The impact of COVID-19 and the responses to the impact

P	Impact(s)	Responses
P4	This participant explained that there were no remarkable changes in their organisation's functions. As this participant is engaged in a large priority infrastructure project, it continued with no tangible changes.	There were no tangible changes.
P5	There were some supply chain interruptions, especially for material purchased from overseas markets. This was exacerbated by the number of infrastructure projects that were happening at the same time. This participant described that there was some level of interruptions to on-site inspections, especially to cultural heritage surveys.	Increased attempts to use local products as much as possible to reduces supply chain risks. The participant also highlighted the benefits of local procurement as creating jobs and alternative industries. There were also more functions carried out through virtual platforms as they continued their construction; they have predominantly engaged with other colleagues via online communication platforms such as Skype or Zoom. Furthermore, there were opportunities for professional engagement as there were many infrastructure projects and more suppliers were keen to get involved.
P6	This participant indicated that they have managed to operate in all of their projects during COVID disruptions. It has not impacted the ability to continue work; however, global supply chains were challenged.	This participant explained their efforts in trying to diversify the supply chain to mitigate risks. As their business operations located in China provided them with some early opportunities to learn and navigate through disruptions, they were able to be ahead of the curve. There were early efforts to put systems in place for teams, understand their procurement needs and mitigate the risks.
P7	This participant shared their experiences of working remotely, travel restrictions, restricted production, limited material flow and the impacts on markets not been able to export and import as usual.	This participant argued that this situation was an eye-opener, especially to the potential to create a CE system via local markets and to bring the waste and the end products closer together. There was a suggestion of possible government grants and funding for the industry to become profitable and to establish these systems. This participant witnessed more market assessments taking place in Queensland through their firm for industries planning to establish themselves on the market.
P8	This participant claimed that there were minimal impacts. While there was a consideration of whether their construction project should continue, that was managed through targeted risk management strategies. They also experienced some increased levels of efficiency in certain operations due to clear roads and transport networks.	There were COVID protocols for people working on site along with social distancing, with limited visitors.
P9	This participant stated that they were not as heavily impacted as many other areas, and most of the concerns for the waste sector were around	This participant found the responses to be very responsible with a special focus on safe ways to work around waste and deliver essential services in local areas

	transport and sanitation, especially transport related to unknowns (e.g., tissues, masks) at the time. They were unable to mobilise and provide clear information. While there was some resource limitation at the beginning (i.e., sanitisers), this was rapidly addressed by manufacturing hand sanitiser for industrial use. Moving on from there, the local government became very concerned for a while about contact with the public, due to people being bored at home and deciding a trip to the transfer station or a landfill was a great day out. The C&D sector has not witnessed significant impacts in terms of volume reductions and so forth because of COVID. As the construction sector has continued to undertake its work, the waste industry has continued its work accordingly as well. The resource recovery sector was already impacted by paused operations in China, but there were concerns about having to stockpile materials unable to be processed or to get shipping containers to store the materials.	and across borders. From a government perspective, when COVID first started, they created a group of representatives from all of the impacted components of the waste sector to discuss issues and create collective solutions.
P10	The industry broadly has carried on somewhat unscathed compared to other sectors	The participant indicated that the COVID situation prompted more innovation and that they started to do things differently. The shift to online platforms and real-time data and digital engineering are some positive repercussions of this disruption.

4.2.2 Market development in Queensland

There was general agreement among the interviewed stakeholders on the importance of creating a market for better management of C&D waste materials in Queensland (Table 8). Factors such as early engagement of suppliers (P9), waste levies (P7), take-back policies (P6), proximity to waste recovery facilities, waste quantity and material specification (P5) were highlighted as key factors to consider when creating end-markets for C&D waste.

While there are existing companies (i.e., Alex Fraser) that are already established in the market, there is a significant opportunity for more businesses to join them. This will then create the quantum and participants needed for a more sustainable market. The participants also pointed that crating C&D markets can lead to extending the material's life and also reducing the associated greenhouse gas emissions. For example, one participant used a concrete material example, whereby, *"Looking at ways of reusing concrete to just extend that life, because it's got such a big impact on your greenhouse gas footprint, you want to extend that life as long as you possibly can. So, breaking it down and using it for aggregate in different paths, into road base is very important" [P5].*

Another example about using buy-back policies and creating a contractual mechanism to facilitate this material transfer was shared:

> *"The other thing I'd be interested in understanding is buyback. Is there an opportunity for someone like Liberty Steel to buy back their steel once it's reached a certain life point? Or is there a way of creating a contractual mechanism that we say we buy X number of tons of steel, and then we put in a maintenance contract with them that says" [P5]*.

A supportive regulatory regime (P10, P6) will also help to increase the uptake of such recycled products in the market, and it requires careful formulation of specifications allowing recycled contents in civil works and infrastructure projects.

Participants shared several best practices and successful organisations/online platforms that guide waste trading. Planet Ark (P6), WRAP and GIVIT (P5) were some of the shared examples. These are explained in detail in the improvement areas section below. They also highlighted the need for accessible tools to help industrial practitioners easily calculate the carbon footprint of waste material and identity circular economic opportunities.

Table 8. An overview of market development for recycled C&D waste products

P	Intervention	Operation	Potential markets
P4	This participant shared some practical examples of organisations that process waste in Brisbane, meaning that the supply chain has responded to government drivers, particularly to the waste levy.	The waste levy has driven the price for significantly landfilling such that it now enables cost-effective recycling and reprocessing. If it was not for that waste levy, this participant anticipates the market would go back to business as usual and opt for the waste landfilling option.	This participant described that steel, timber, metals, soil and concrete are the dominant waste types in a major transport infrastructure project. More opportunities can be found for plastics and cardboard depending on the volume of waste that is generated in the industry.
P5	This participant expressed their ideas on the markets being very material specific. The smart radius of the recovery sites and discoverability through the internet is impacting the growth of this market.	The current market operations revolve around specific materials. If it is not within a distance of easy transportation, that is very costly for the supplier. This can lead to very 'hit and miss' situations.	This participant indicated that there are established markets for steel and concrete, especially considering that concrete needs to have a long life because it has such a large carbon footprint. While there are very specific markets, there should be more mechanisms to encourage buy-back policies through contractual mechanisms so that the residual materials are managed systematically.
P6	This participant described that while developing these markets is an effective way to manage C&D waste, challenges depend on the geographic location of the facilities. Some of the bigger regions have recycling stations and the ability to manage that, but more regional or remote facilities face numerous challenges.	There is some level of maturity on the basic main key streams of concrete and steel. There are more opportunities to grow markets in areas such as aluminium.	This participant drew on international best practices on low carbon emissions aluminium and claimed that it has 75% post-consumer recycled content within the product mix. This uncovered opportunities for more aluminium recycling in Australia. This participant indicated that the top materials with potential markets for recycling are concrete, steel and aluminium, followed by glass. Furthermore, some of the semi-hard plastics could also be readily recycled. It was also highlighted that take-back policies or takebacks for individual product streams are critical to reducing waste.
P7	This participant drew on her previous experiences of the local council's concerted efforts to recycle C&D waste and direct this material into road construction. With this evidence in mind, this participant viewed	While landfilling is still an easy and affordable option for some entities, connecting with new networks to negotiate where to send this material is necessary.	Crushed concrete has an established market and going forward plasterboard and treated timber can be expanded. It is also important to consider

	creation of a C&D market as a strategic pathway for QLD to manage this waste stream.		energy from waste options that are better than landfilling.
P8	This participant identified more opportunities to develop the market through updated TMR allowing more use of recycled contents (i.e., glass).	As an end-market, there is a more accessible source of crushed glass to be available to asphalt manufacturers, which then catalyses those things becoming more economically viable and then 'business as usual'. The current economic situation is prohibitive as it cost more to put glass in than to not have the glass; looking forward, this participant anticipates that legislative and other guidelines will become more beneficial for such markets.	There are potential opportunities to fully or partially utilise materials such as crushed glass and plastics. The participant shared their experiences in doing trials of plastics and car bumper bars as rubber in asphalt mixes. They have also explored different types of recycled bedding layers in lower-level transport routes. There are future aspirations to try and use more recycled materials in bedding layers rather than using the virgin clays and gravels in lower usage roads.
P9	This participant described this as a positive way forward aligned with Queensland's waste strategy, specifically focussing on reducing the amount of waste going into landfills, creating a CE and building upon the subsequent economic opportunities.	While there has been an increase in opportunity and uptake concerning C&D recovery, Queensland is still quite far behind other jurisdictions, such as Victoria. The participant also emphasised that the bottom line is the factor fundamentally driving businesses.	There is a great potential market opportunity for glass, timber and concrete. While there are mature concrete markets, the glass would lend itself very well to being part of that sector.
P10	This participant acknowledged that developing a market for C&D waste products is a targeted approach for managing this waste stream and shared a few examples of early companies working in this sector (i.e., Alex Fraser).	In Queensland, as the specifications around road-based projects allow recycled contents, this has enabled growth in such markets. Moving forward as those specifications combined main roads adopting ISCA requirements for major projects, the participant anticipates much greater demand for such products.	This participant explained that the quantities of recycling of concrete, asphalt and steel are significant. There are opportunities for materials like timber. However, the material requirements can be varied, through different types of timber, different ways and applications, meaning that matching of waste and needs might become a lot more complex.

4.2.3 Improvement areas

The industrial practitioners shared a range of insights related to improvement opportunities regarding the creation and simulation of efficient end-markets in QLD. These areas include: 1) learning from global precedents and best practices; 2) aligning C&D waste management practices with the QLD waste strategy; 3) creating a CE through identifying waste material; and 4) economic opportunities through appropriate government incentives or disincentives.

Participants shared several best practices and successful online platforms that guide waste trading. For example, Planet Ark (P6), WRAP and GIVIT (P5) were some of the shared successful platforms. Participant 5 shared an example of GIVIT, where businesses can donate material that is not usable for them but valuable for others. Another participant said, "*Planet Ark and others for batteries and cartridges, there already are marketplaces that are really trying to support that, but it's not really joined up as an overall approach" [P6].*

Two government representatives (P8 and P9) highlighted the importance of aligning C&D waste management practices with the three pillars of the QLD waste strategy. The first is reducing the amount of waste that we send to landfills through waste levies and mandated targets or mandated recycled content across a portfolio. The second is creating a CE through identifying waste material with potential for the secondary market and introducing market interventions to facilitate growth in those areas. The third is to build upon the subsequent economic opportunities through appropriate government incentives, or disincentives and cost-competitive compliant recycled products. Case studies and marketing around successful outcomes and where there is economic value can also trigger the industry to opt for more renewable and circular processes.

4.2.4 Enablers and barriers towards market development in Queensland

This section presents key enablers and barriers described by the interviewees. As summarised in Table 9, there are myriad enablers and barriers related to the market development in QLD. The main enablers include improved regulatory frameworks with measurable targets for the industry; coalition between industry, government and academia; SP practices; incentives; understanding of material movement; and industry awareness on the value of secondary material. Furthermore, a funding model to demonstrate the value of using recycled material is essential to encourage more businesses to engage in C&D waste recycling.

One participant stated the incentives are critical to encouraging businesses to engage in the C&D waste market:

> *"There might be some inconveniences, so you need the incentive to be there, which to my mind, the ones that are strong enough to offer that incentive are ISCA and Green Star, and government and major private client mandates around the need to use recycled content materials and a significant percentage of recycled content materials" [P10].*

If C&D waste market practices are to be mainstreamed, there is a need for more relaxed specifications for using recycled waste in construction projects. This will reduce the burden on the waste recycling industry for an actual 'fit for purpose' recycled material. Testing the use of mandatory minimum recycled content targets for government-led construction projects is a targeted way for policymakers to lead by example. This will also encourage increased uptake of recycled materials in any infrastructure project.

In terms of barriers, most responses were related to complex recycled product specifications, timing and logistics, plus risks of asbestos contamination and tight regulations. To overcome these barriers and to allow the growth of C&D waste markets, it is essential to reach a quantum of waste and participants.

Table 9. Summary of enablers and barriers specified by the interviewees in Queensland

P	Enablers	Barriers
P4	▪ Product specifications enabling recycle quarry products in a variety of applications ▪ The specifications need to enable a cost comparable fit for the purpose product ▪ The supply chain has to deliver a safe and reliable supply of that recycled product ▪ Procurement teams need to know to ask the right questions from suppliers	▪ Lack of precedents for new entrants into the market ▪ Criteria requirements for virgin material over recycled material ▪ Traditional procurement practices
P5	▪ Quantum and location ▪ Understanding of material movement ▪ Contractual requirement allowing the use of recycled contents waste levies	▪ Chemicals and materials contamination ▪ Timing and schedule ▪ The locality of that second-hand C&D waste specific performance not meeting the standards
P6	▪ High waste levies ▪ More incentivisation that supports the use of recycled through a tax break or another benefit that actually provides an increase in the business value proposition ▪ The push-pull market where material can be delivered and an increase in the requirements for recycled contents across all specifications ▪ Valuing waste material as an input; that is, making a significant contribution to reducing both emissions and resource usage ▪ A funding model that recognises the benefit without seeing it as just a cost impost ▪ Alignment of improved regulatory frameworks ▪ A more national approach for waste regulation	▪ The risk of asbestos contamination ▪ The regulatory regime in place is unable to give businesses confidence around managing out the risk of asbestos fines. ▪ Inconsistencies of sampling rates across states ▪ Limited post-consumer recycling is being supported at all levels of private sector and government to support ▪ Insufficient facilities to segregate waste in sites ▪ Waste contamination
P7	▪ SP ▪ Setting directives, as in measurable targets for industry and the reporting of those targets to make people accountable for their actions ▪ Go beyond creating guidelines and focus on actioning ▪ Case studies and marketing around successful outcomes and where there is economic value	▪ Perception that it is cheaper and easier to send waste to landfill
P8	▪ Creating a coalition where the government is working with the private sector and the research sector ▪ Amended policies ▪ Building case becomes part of the accepted way of, in our case, infrastructure and maintenance activities anyway	▪ Strict procurement guidelines that more than likely would have been prohibitive ▪ Difficulties in maintaining those engineering standards ▪ Scepticism on whether recycled materials are going to deliver the same outcomes or outputs as the virgin materials
P9	▪ Economic incentives ▪ Mandated targets or mandated recycled content across a portfolio	▪ Complicated nature of a number of levers that need to be pulled to create the market (levies, planning requirements, stakeholder engagement)

	▪ Pushing government departments to demonstrate long term, a percentage recycled content in all of their procurement and their projects ▪ Appropriate project evaluation, to be able to consider a broader lifecycle perspective of the materials ▪ Appropriate planning on how to use recycled materials	▪ Criteria requirements for virgin material over recycled material ▪ Traditional procurement practices
P10	▪ Reaching a quantum of waste and participants ▪ Clear material specifications ▪ Market incentive ▪ Supportive government specifications, the industry frameworks, like ISCA and Green Star	▪ Criteria that would exclude recycled materials ▪ Timing of material movement ▪ Product testing and impacts on timing and logistics

4.2.5 Influential factors for materials end-of-life management in Queensland

Several influential factors for materials end-of-life management were discussed by the participants. These include managing the perceptions about sending waste to landfills versus recycling (P7, P8), and incentives and data for evidence-based decision making (P9). For example, one participant shared that localised recycling can be challenging:

> *"Some of the bigger regions obviously have the recycling stations and ability to manage that, once you start to get more regional, or remote, then the ability to recycle becomes challenging and then you're in this world of landfill versus transporting it to another region to recycle it, which becomes difficult" [P6].*

Another participant added to this by highlighting the role of perception, stating, *"I think that there's a perception that it's cheaper to send waste to landfill, cheaper and easier to send it to landfill. I don't think I have to say anything more than that." [P7]*

To better influence the decision related to end-of-life management of waste material, it is crucial to have more data. One participant suggested,

> *"… it would be really interesting to use some of the data from Green Building Council and ISCA, and look at the projects pursuing those ratings, which I think would be a logical application of these products. They are doing modelling of materials used up front, and they are also reporting on their waste, so you can get an insight quickly into what waste products are being generated and what demand there is for new products" [P10].*

4.2.6 Waste regulations in Queensland

The responses to the question related to current regulations and policies revealed a variety of aspects. Most participants shared their insights on relevant regulations with some comparison with other states. Overall, there were concerns around strict regulations, restrictive specifications, and the critical need for approaches beyond compliance drive and demonstration projects led by the government.

Participant 10 described the restrictive nature of the specifications in Queensland, explaining, "*Particularly in Queensland it's tough because the specifications are quite restrictive, have held things back somewhat in terms of the ability to use a lot of recycled content materials"*. Another participant from the construction sector pointed out that the regulations should be able to give more confidence to the businesses. For example,

> "*At the moment the regulatory regime in place is unable to give us confidence around managing out the risk of asbestos fines. Whilst we can use a certain thing, we can use recycled*

content for fly ash and glass and other things. Directly related demolition waste is a challenge because the sampling rates and then extend to which that's set up across the country, and each state is different" [P6].

The current legislation is more compliance-driven. For example, *"It'll be compliance-driven; legislation always is. I don't think it's going to achieve new outcomes, better outcomes. It's not going to challenge people to do better, it's not the right incentive at the stick" [P5].* Going forward, there should be reformed legislation urging people to go beyond the compliance approach and achieve more advanced outcomes. A government sector participant acknowledged that the regulations are influencing more positive behaviour, especially with targeted guidelines for road infrastructure projects. For example:

"I think they're currently quite good. Again, those TMR guidelines helped us. The waste levy coming in whenever that was coming up to a couple of years ago, that speaks for itself in giving industry impetus to minimizing waste. It's provided more guidance on direction, which is always good for any aspect" [P8].

Furthermore, there is a critical need for local government authorities to demonstrate best practices of using recycled C&D material in their large infrastructure projects and encourage increased uptake of recycled materials in any infrastructure project. Table 10 summarises the participants' responses to the question on waste regulation in New South Wales.

Table 10. Summary of participants' opinions on current legislation concerning market development in QLD

P	Policy /Regulations
P4	According to this participant's point of view, the government has taken actions to ensure the cost of disposal is more expensive than the recycling and reusing industry. Therefore, the value of those environmental and social externalities needs to be factored into a short-term economic aspect like the waste levy to support the industry. It is critical to show the wider economic benefits to make disposal at the landfill a last resort and thereby stimulating the market.
P5	This participant indicated that the challenge with the regulations is that it requires the bare minimum (do no harm) and limits the attempts to do better through better aspirations. Furthermore, she emphasised that it is compliance-driven, and it is not able to challenge people to do better, and therefore, it is not the right incentive.
P6	This participant expressed that the regulatory regime in place is unable to give them confidence around managing out the risk of asbestos fines. While they can use recycled content for fly ash and glass and other material, material related directly to demolition waste is problematic. This is mainly due to the sampling rates and the extent to which that is set up across the country and differences in each jurisdiction. This participant also pointed out that incentivisation in some regions is much better than in others.
P7	This participant shared her previous local council experiences related to the challenges of obtaining approval to use recycled C&D material in new infrastructure projects. It was also argued that the regulation had been a barrier for the industrial practitioners who are keen to move things forward.
P8	This participant was generally positive about the current regulations and emphasised that the TMR guidelines and the waste levies gave the industry the impetus to minimise waste. It has provided more guidance on direction, which is always good for any aspect.
P9	This participant stated that the current regulations address more because of a broader question around the waste. There is a lack of specific targeting C&D waste management, and there are more opportunities to create more comprehensive planning strategies and the development assessment and approval procedures.
P10	This participant described the challenges related to the restrictive nature of regulations (i.e., products specifications have limited the ability to use a lot of recycled content materials). This participant also pointed out that there has been more progress in other states such as Victoria, and to some extent, New South Wales.

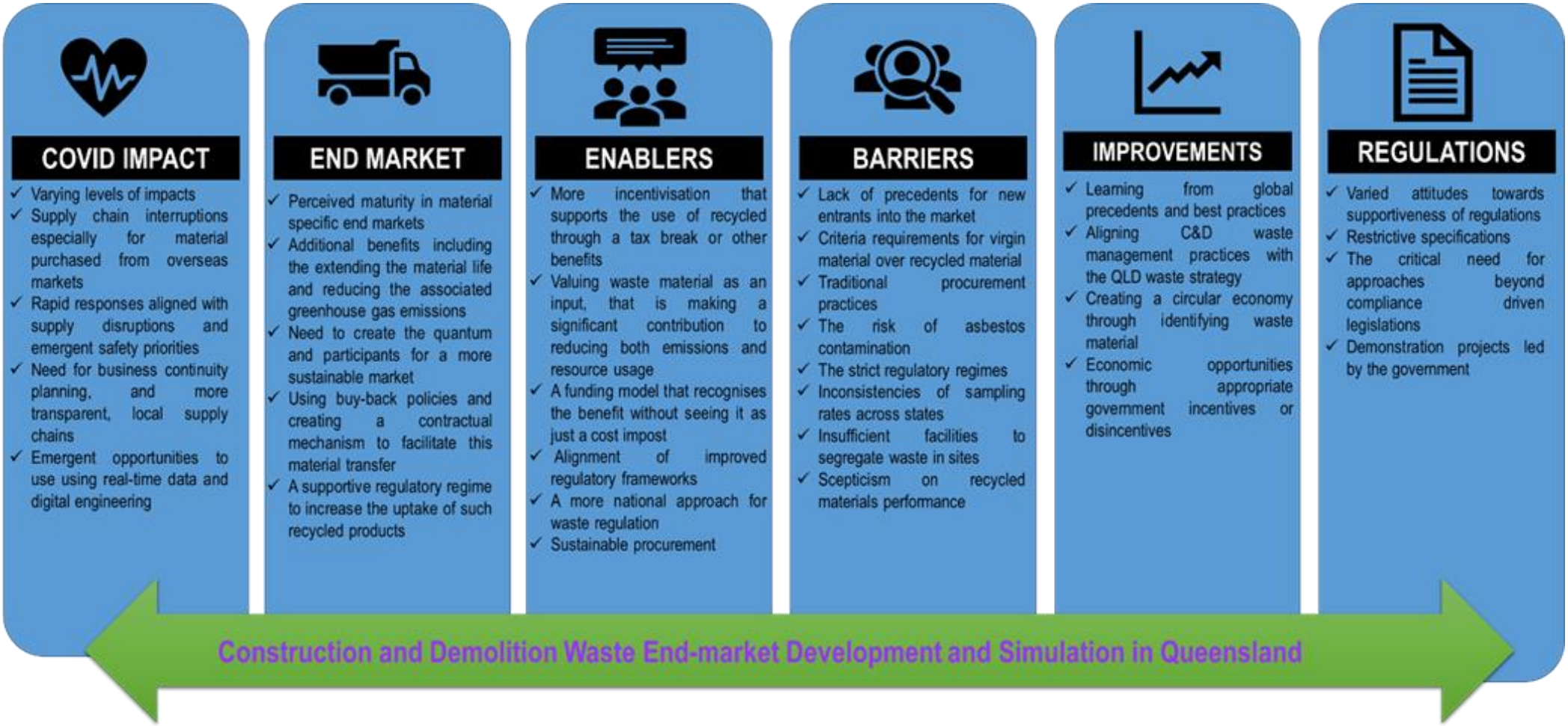

Figure 3. A conceptual model that describes C&D waste end-market characteristics in Queensland

4.3 South Australia

Only one interview was conducted in this state. The interviewee is the CEO of two recycling facilities based in Adelaide, which specialise in C&D waste resources and tyre waste recovery. At the time of the interview, the participant had been involved in recycling activities for about ten years. His primary responsibility was to manage crushing businesses and sell recycled products in various markets.

4.3.1 The impact of COVID-19 and responses in South Australia

The interviewee stated that multiple impacts have been realised in COVID-19 affected period. These include delays in delivering infrastructure projects across the state, delays between the C&D cycles, and the inability to recruit a workforce. The first two impacts have challenged the organisation to manage the mass balance of C&D required for the sustainable operation of the recycling facility. In the interviewee's experience, job keeper/job seeker schemes had the negative impact of labourers choosing not to do hard physical work while they were already being paid. This phenomenon has resulted in a significant increase in workload and the labour hour percentage.

At the industry level, the interviewee stated that during COVID, the industry and government worked well together in response to the issues that came with the pandemic. The interviewee had participated in several industry leadership calls with various state public organisations to communicate issues the industry faced during the affected period. The industry itself was also quick in taking preventative containment measures.

> *"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]

At the organisation level, the interviewee indicated that their approach was to keep the workforce. However, the organisation implemented a 30% pay cut across their businesses to achieve this goal rather than laying off employees. He thinks this approach is fair, understandable to the workforce, motivates them, and enables them to respond quickly to the impacts:

> *"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]

According to the interview, after the outbreak, the organisation has engaged strongly with the government, the industry and their customers. This has resulted in the organisation's ability to keep up with the market, which he described as "*incredibly brilliant "*.

4.3.2 Improvement areas

The interviewee believed that the end-markets in SA are relatively robust and predicted that the incoming market would fine as well. His prediction, however, came with two conditions: 1) enforcing strong regulation; and 2) the provision of an even playing field. In this theme, P11 indicated that developing supportive regulations is the key to create new and stimulate new end-markets. These regulations should be consistent across recycled and quarried materials and encourage sustainable government procurement of recycled materials in civil construction projects. P11 states that recyclers

are to be viewed as manufacturers, and through this lens, the value and quality of recycled products could increase.

4.3.3 Enablers and barriers towards market development in South Australia

The interviewee's response on enablers for market development centres on efforts to activate the sustainable government procurement in buying recycled products and sending them to contractors. P11 suggested that tender documents can specify the requirements of buying recycled products for public construction projects:

> *"… you could have governments buying, you'd have a whole range of quality control mechanisms that are in place to get onto the platform, and then you could have government something buying and directing to a contractor, such as, a big road project, that they have to go to the marketplace and acquire the recycled product and they could say, "Okay, it has to be from this C&D marketplace", so therefore you know that you're driving sustainable outcomes from government procurement".*

The primary barrier was also found to be regulations, according to the interviewee, specifically regulations that do not encourage the implementation of SP policy and exclude recycled products from civil construction projects. In P11's belief, government organisations such as the EPA view recycled products differently and impose more rigorous requirements on them than they do on virgin materials. Furthermore, the participant pointed that innovation is limited as the general perception is that recycled waste is not a manufactured product.

4.3.4 Market development in South Australia

The interviewee indicated that the development of the market would result in better waste management, particularly in stockpiling and product quality areas, and have a perverse outcome through devaluation of commodities. In P11's opinion, market development will minimise the current variation in the quality of recycled products across the waste recycling industry in SA. As indicated by P11, the negative outcome referred to a situation in which recyclers have not been deemed the manufacturer of a product, a factor that might discourage innovation from increasing the product's value. The participant stated that glass has a good potential for market development in SA. However, according to P11, government policies challenge recyclers in approving their usage of recycled glass in roadworks.

4.3.5 Influential factors affecting materials end-of-life management in South Australia

Regarding factors affecting end-of-life management, P11 believed that source separation is central to producing high quality, less contaminated but cheaper products. In P11's experience, current on-site sorting has improved significantly:

> *"Source separation now is much better, so the material we're getting is less contaminated. So, there should hopefully be less sorting and less cost around with that. And so, I think that should mean that we have greater ability, in terms of going forward, we should have more and more improved ability to produce products cost effectively and that are high quality".*

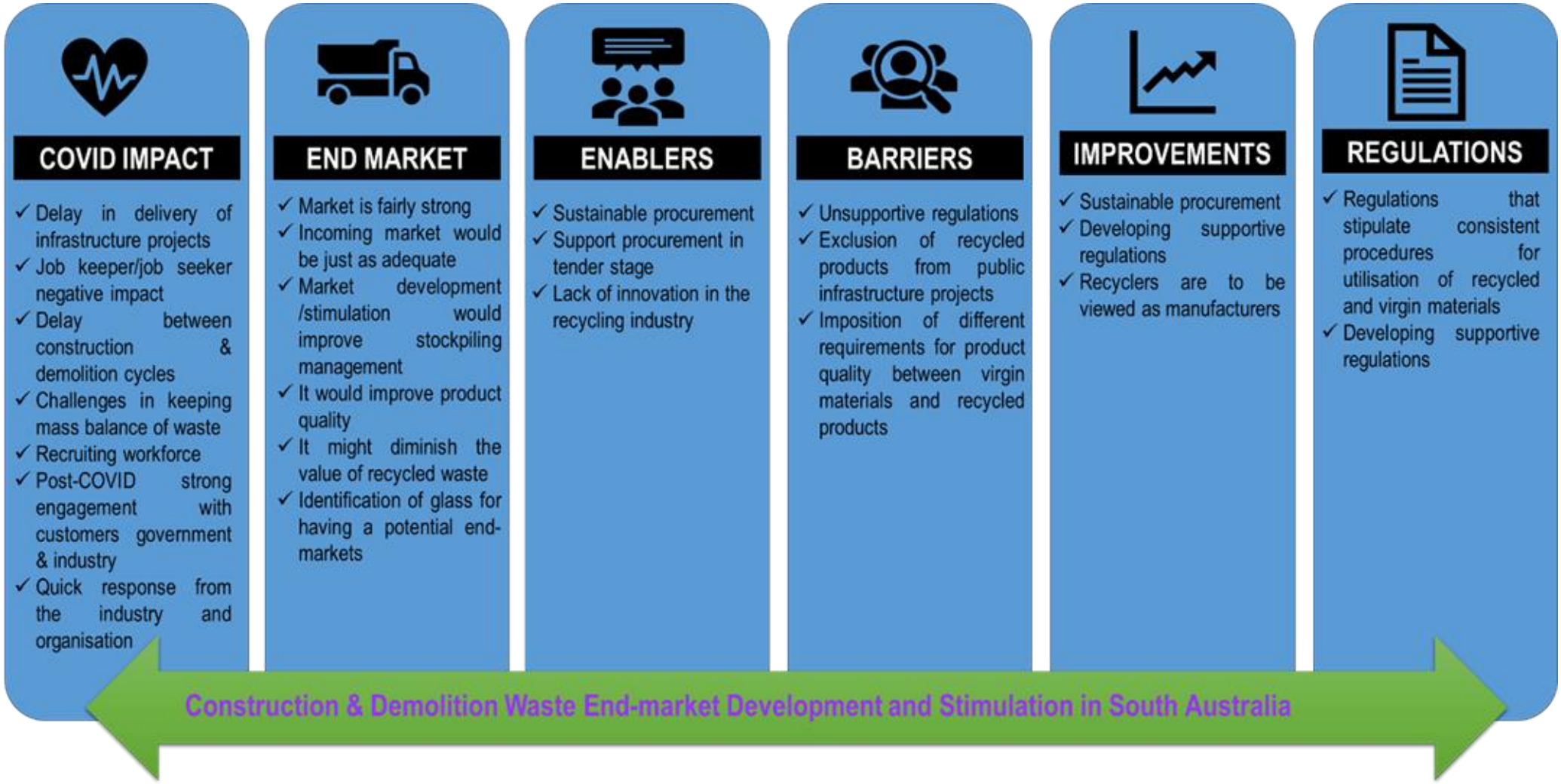

Figure 4. A conceptual model that describes C&D waste end-market characteristics in South Australia

4.4 Victoria

The interviewees based in Victoria were representatives of two recycling facilities, one public (state government) organisation and one construction company (Table 2). Three of these research participants held management positions at the time of the interview, with one working as an environmental project advisor. The interviewees' exposure to C&D waste issues ranged between 4 (P13) and 25 years (P15). The main focus of participants includes R&D of recycled products, market development and resource recovery in Victoria (P13); waste management, crushing and landfilling operations, and technical management of C&D waste resources in NSW and Victoria (P14); managing recycling of C&D waste, particularly asphalt in Melbourne and Brisbane (P15); and monitoring C&D waste disposal and use of recycled contents, and improving recycling waste generated at construction sites in Victoria, South Australia and some contribution to other areas (P16).

4.4.1 The impact of COVID-19 and responses in Victoria

In terms of the impact of COVID-19 on C&D waste recycling activities, the respondents provided varying information. Victoria has had the greatest number and length of lockdowns in Australia since the beginning of the outbreak. These lockdowns have slowed down the operation of some industry sectors. The impact and responses to COVID-19 are tabulated in Table 11.

Table 11. The impact of COVID-19 and the responses to the impact in Victoria

P	Impact(s)	Responses
P13	While P13 work had not been significantly impacted, the organisation funded research projects on C&D waste management were greatly impacted because of extended delays due to lockdowns, issues about budget allocation and uncooperative industry partners with changed priorities. However, the businesses working in the waste management and resource recovery industry have not been impacted.	The participant was not able to comment on this issue, as she was not involved in monitoring different procedures in response to COVID-19 within different originations.
P14	P14's organisation was not impacted; to the contrary, it has been quite busy serving many tier-one companies operating in Victoria, such as level crossing activities at West Gate Tunnel and Metro Tunnel during the COVDI-19 era.	The participant's views on the industry response were related to the individual level, including measures such as social distancing, personal hygiene, taking care of one another and reporting if there is ever an issue with people have symptoms. Also, he mentioned that due to C&D waste recycling employees' unique socio-economic background, the need to repeat the message of the required practices and measures is essential.
P15	While the participant's organisation has been able to keep the operation alive, some impacts were realised that were related to the market activity, which had slowed down due to the economic impact of COVID-19. In the AEC industry, there is a lag in terms of the number of projects starting that is considered an economic slump.	The participant indicated that the response was rapid and reasonably effective, as it was for lots of industries. The organisation measures included implementing many of the typical controls around shared spaces and customer interaction.

P16	The level of impact on the industry was deemed to be great overall. The impact varied in different AEC sectors; while public construction projects continued during the outbreak, the situations with residential and commercial were far worse. Despite the government economic help (e.g., job keeper), the organisation had to reduce employees on some projects. Furthermore, the tenders for construction projects were also reduced. The organisation's ability to keep operating on public projects helped them to survive the situation.	The organisation's actions were very comprehensive due to the fear of being closed down. These actions, which had some cost implications for the organisation, included temperature testing in building sites, allocation of additional staff to each project called COVID monitors—whose job was to walk around the building sites making sure that the lunchrooms always maintained the minimum spacing and that social distancing was maintained and the cleaning regime was adequate. The latter involved getting a sub-contractor to clean shared areas two-three times a day with the correct products per the Victoria's Department of Health and Human Services (DHHS).

4.4.2 Market development in Victoria

All interviewees agreed the development and stimulation of a market would be an effective measure to manage C&D waste sustainably (Table 12). Except for one interviewee (P15), the participants could not evaluate the operation of existing markets for C&D waste sources. However, all four interviewees highlighted the necessity of improvements in the market. P15 mentioned that Victoria's markets performance is good, and many other regions (i.e., other Australian states, the US, the EU and the Middle East) envy what Victoria has achieved in using recycled content in civil construction projects. He linked these achievements to the better scale and economy of existing facilities in Victoria that can produce high-quality recycled products. P14 also added that there are bad and good operators; the big recycling facilities with the largest market share receive negative feedback from authorities.

Regarding the potential markets, responses from two participants (P13, P14) underlined the potential market for glass and plastic in road-based projects. All participants stated that the markets for brick, concrete and steel are well established in Victoria. Notably, one participant (P15) mentioned that all given materials are already being sold and used in road-based projects. However, he highlighted the need to update the recycled materials to add value.

Table 12. An overview of perceptions of market development for recycled C&D waste products in Victoria

P	Intervention	Operation	Potential markets
P13	At their organisation, they have developed a directory of waste materials in the hope that they can better manage C&D waste.	While the participant was unsure about the operation of the existing markets, she shared feedback of some stakeholders, which highlighted the need for support through infrastructure development, financial assistance or help addressing issues around compliance requirements.	Glass has a potential market as their organisation has received a fair few support applications for studying utilisation of recycled glass. The industry is investing in glass recycling facilities and the market, and there would be a huge market (demand) for the product, particularly in road construction. Furthermore, the opportunity for using plastic in asphalt is currently being explored.
P14	The market that is facilitated by authorities would be helpful for C&D waste management, and it gives assurance that provides people with the confidence to operate within a market. To this happen, the participant's advice was the government incentive to push market development for taking up recycled materials in larger infrastructure projects.	The response does not contain a direct comment on this theme. However, the respondent mentioned that there is still a lot that needs to be done; for instance, Victoria lacks a market and demand for recycled concrete. He also added that the current waste regulation regime does not support large producers of recycled materials as opposed to other small operators.	The use of glass and plastic in low-risk concrete applications is a new market development opportunity in this space. As for brick and concrete, their aggregates can be fed back into the concrete production.
P15	The market proves to have positive performance in Victoria and has been an excellent intervention to manage C&D waste materials better. However, in other states, it is underperforming. The participant believes that the markets in other states are driven more by road agencies than environmental agencies. Through SP, road agencies can encourage using recycled content in civil projects.	The participant indicated that Victoria is leading recycled materials in civil projects in Australia and overseas. The advanced facilities have been able to produce high-quality materials. However, its current performance is being jeopardised by the introduction of new specifications limiting the use of recycled materials.	There is a huge market for all materials listed (brick, concrete, glass, steel and asphalt), and in Victoria, they have been sold already for road-based projects. However, an update on the product is needed to add value to these materials. The respondent mentioned that concrete, brick and glass have more potential jurisdictions like Qld.
P16	The market development will bring huge benefits to managing C&D waste materials as long as we avoid poor (contaminated) waste disposal.	Overall, the participant's understanding of existing markets was limited as there is no benchmarking system to measure the operation of the market.	The participant indicated his limited knowledge of the market for the given materials. He added that concrete and brick are routinely being used in road projects, and steel is continually being recycled in Victoria.

4.4.3 Improvement areas

Regarding improvement areas for the creation and simulation of efficient end-markets in Victoria, interviewees had different opinions; this is primarily linked to the needs and requirements of the sector they represent. However, the input from the interviewees who represent three sectors (government, recycling and construction) can help shape the bigger picture. In the government sector, one interviewee (P13) outlined three improvement areas: 1) development of knowledge of feasibility of using recycled materials in different applications; 2) investment in recycling facilities through government support (i.e., Recycling Victoria Fund); and 3) decentralisation of recycling facilities to service the entire state.

In the recycling sector, interviewees from the recycling sector (p14, P15) provided a well-balanced response on improvement areas that correspond to education, encouragement and enforcement. P14 stated attitudinal changes of major stakeholders (i.e., councils, asset owners, VicRoads, Sustainability Victoria, etc.) through raising their awareness about recycled products. The interviewee suggested that opportunities such as roundtable discussions could assist in achieving this aim by communicating information focused on sustainable outcomes (e.g., carbon footprint reduction), financial incentives and the competency of recycled products compared to virgin materials. He anticipated that such information sharing would facilitate decision making towards allowing and sharing the risk of using recycled products among large asset owners (i.e., VicRoads), a phenomenon that would be followed by contractors working in parts of large projects and therefore enabling significant recycled products uptake in Victoria.

Interviewee P15 highlighted the need to build new and preserve well-operated recycling facilities close to metropolitan areas (markets) and to apply stringent enforcement on all recyclers (i.e., registered and unregistered). While the former factor provides a financially competitive advantage over the virgin materials shipped from long-distance quarries, the latter would counter the negative image of recycled products created by poor processing performed by dodgy waste recyclers. This interviewee also mentioned that their organisation had waived the gate fee, making recycling a viable option for waste producers and encouraging site separation. Under such circumstances, a large-scale feedstock is made available that can perfectly compete with virgin counterparts.

Interviewee P16, working in the construction industry, emphasised regulation, accreditation schemes and uniform reporting systems as useful measures. The two first strategies would motivate a construction company to prioritise waste management during the planning stage. Notably, for accreditation schemes that reward sustainable waste management practices in the industry, the interviewee believes that customised, but national rating and reporting systems can significantly change the best management practices for the better.

4.4.4 Enablers and barriers towards market development in Victoria

This section of the report focuses on the major enablers and barriers specified by the interviewees. As summarised in Table 13, various enablers and barriers are reported. The main enablers in Victoria were found to have a diverse nature, including encouragement factors (the development of infrastructure, supporting local government to buy recycled products and a central waste marketplace) education (confidence building, R&D and demonstration projects) and enforcement (supportive and simple policies and specifications). In terms of barriers, all responses indicated that limited knowledge about recycled products could hinder their application in construction projects. Furthermore, except for P13, who referred to higher costs of recycled products, none of the responses involved technical or economic barriers. Interestingly, two recycling representatives argued that recycled materials produced in Victoria have comparable quality and are offered at lower prices compared to virgin materials.

Table 13. Summary of enablers and barriers specified by the interviewees in Victoria

P	Enablers	Barriers
P13	▪ Development of recycling infrastructure ▪ Support research and development ▪ Build confidence for recycled products in the market ▪ Support local governments to use recycled content in infrastructure projects ▪ Development of policies such as Recycled First Policy	▪ Higher cost of recycled products over virgin materials ▪ Limited knowledge about possibilities for using recycled materials
P14	▪ Assurance for using recycled products ▪ Create government-backed successful demonstration projects for learning and promoting purposes	▪ Negative perception towards using recycled products ▪ Lack of education and demonstration of using recycled products ▪ End-users being risk averse
P15	▪ Develop straightforward specifications for recycled products	▪ Lack of comparative studies investigating recycled products quality against virgin materials ▪ Double standards when comparing virgin materials and recycled products ▪ Unreasonable ban on using recycled materials
P16	▪ Develop a central marketplace that advertises current and upcoming C&D waste ▪ Develop a credit program to encourage ethical waste management, including uptake of recycled products	▪ Limited knowledge about available waste and recycled products

4.4.5 Influential factors for materials end-of-life management in Victoria

The interviewees' views on influential factors provide insight into the mechanisms underpinning decisions and behaviour about end-of-life management in Victoria. The factors specified by interviewees included a mix of economic and technical issues, including the scarcity of virgin materials, the increasing cost of extraction and sustainability programs of various organisations (P13), potential and limitation to recycling a waste resource multiple times (P14), the closeness of production to market and the extent of the economy of scale (P15), and limited incentives and investment in innovation in the recycling sector (P16).

4.4.6 Waste regulations in Victoria

The responses to the question related to current regulations and policies revealed different aspects. While one participant (P14) could not provide a comment on current legislation, the other participants had various opinions ranging from positive to negative perceptions of regulations and specifications, respectively (P15), to making overall improvements (P16) and ensuring the guidelines and policies materialise in action (P13). Table 14 summarises the participants' responses to the question on waste regulation in Victoria.

Table 14. Summary of participants' opinions on current legislation concerning market development in Victoria

P	Policy /Regulations
P13	It is not clear how the new EPA act released in July 2021 will be impact the market development. Referring to one recycling company in Victoria, P13 implied the current regulations are unsupportive. Sustainability Victoria has developed policies that assist stakeholders in further developing markets through incentives such as financial support for infrastructure development and/or SP. The Victoria Recycling Policy encourages the increased use of recycled products to drive the market. Other organisations such as Major Projects Victoria have also developed guidelines. The participant indicated that a clear roadmap showing how to put these guidelines into action is still lacking.
P14	No answer is provided.
P15	While the participant found the current legislation adequate, he stated that the new specifications will negatively impact the use of recycled products across Victoria. He did not support mandating minimum recycled content in regulations but instead recommended informing and helping stakeholders to identify opportunities to use recycled content.
P16	Improvements are needed, and one example of this is to accredit companies using recycled content or providing monitory incentives through government leadership.

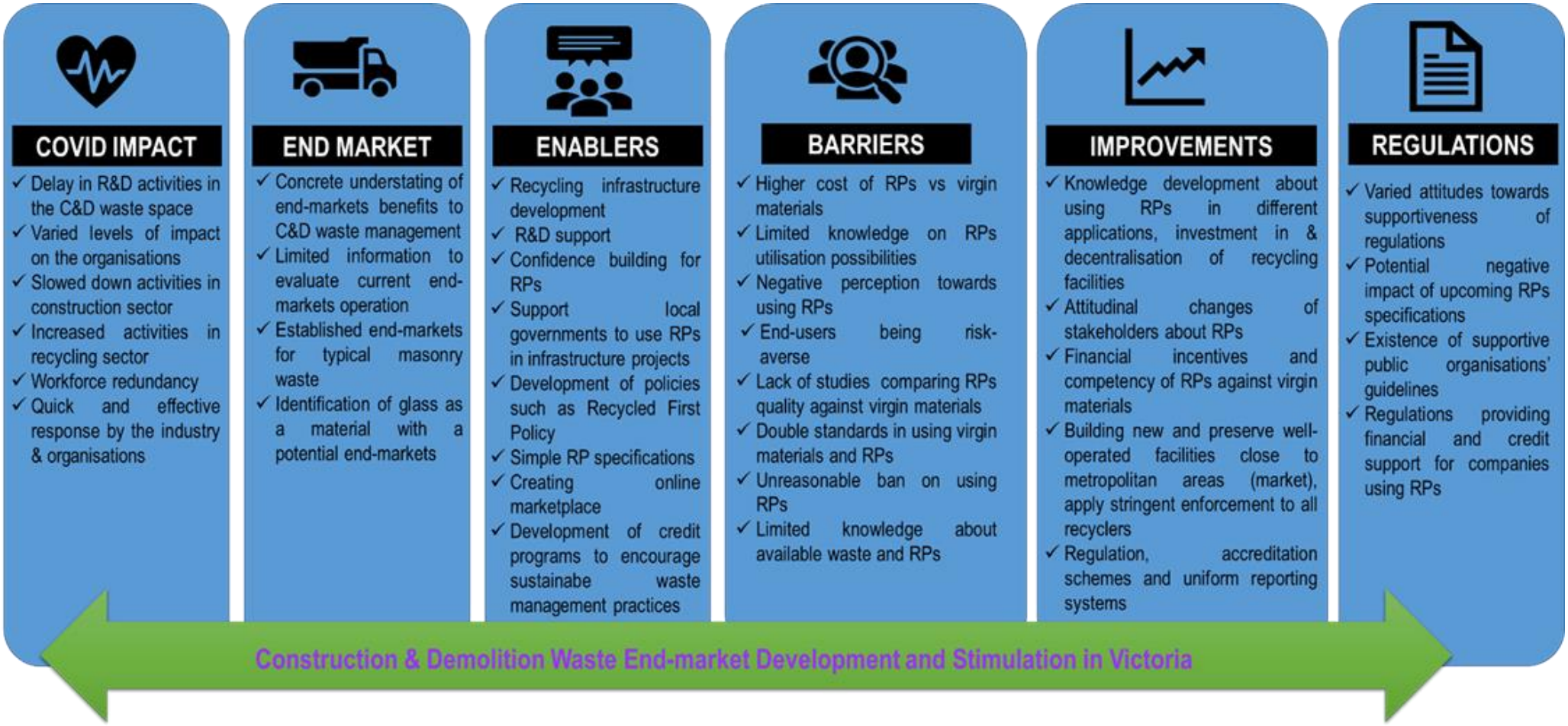

Figure 5 A conceptual model that describes C&D waste end-market characteristics in Victoria

4.5 Western Australia

In Western Australia (WA), 11 participants were recruited who represent various stakeholder groups in C&D waste space. Five of these participants work in government organisations, three represent the recycling industry, one provides waste-related consultation services and one was a technical expert in the construction materials manufacturing industry. As outlined in Table 2, nine interviewees held management positions at the time of the interview, one was a principal engineer and one was a principal advisor. The interviewees' exposure to C&D waste issues ranged from 4 (P25) to 19 years (P26). The main activity of participants includes consultation for and management of C&D waste in the construction industry (P17, P22, P25); recycling C&D waste resources (P18, P21); government-led monitoring deconstruction projects for residential development sites (P19, P20); manufacturing construction materials (P23); contribution to delivering the state waste strategy objectives and market development (P24, P26, P27).

4.5.1 The impact of COVID-19 and responses in Western Australia

Not all respondents could describe what the market development would look like after COVID-19. Participants from the recycling industry did not see any difference in market development before and after COVID-19 (P18), which was also confirmed by two participants representing government organisations (P19, P20), who argued that the lockdown was minimal. Construction is booming in WA. The market for recycled material is seen to be viable before and irrespective of COVID-19. However, two government representatives (P24, P27) mentioned that due to the government COVID recovery plan in response to the COVID situation, including bringing infrastructure projects forward to support local industry, the market would be more contributing more to the C&D waste stream after COVID-19 (Table 15).

Table 15. The impact of COVID-19 and the responses to the impact in Western Australia

P	Impact(s)	Responses
P17	COVID is not really an issue that has affected the uptake of recycled crushed concrete in Western Australia. There was an initial shutdown, but it did not affect the industry.	No clear answer provided.
P18	As the waste operation is considered an essential service, the operation had not been affected. Furthermore, self-isolation among the workforce in operation is a norm that minimises the impact. Lastly, incentives in the residential market and not commercial has been counteractive to this impact. In WA, it has been fairly unchanged. Because of the fact that so much civil work is done, businesses can conduct themselves with the right protocols for COVID.	Developing a few protocols in response to COVID-19 situations.
P19	There was some disruption but overall minimal impact on activity, and we have managed to keep things going as the state experienced minimal lockdown.	All the stimulus in terms of housing and economic stimulus has actually increased activity. Generally, the pressure is probably being mainly on the construction industry. Typically, they have had excess materials as opposed to shortages. The extra construction work undertaken is actually used up to stock balls or to have some of those raw materials turned into recycled blocks or recycled road-based materials.

P20	Shortage of resources, both human resources and shortage of materials, particularly steel and timber. Probably pressure on industries that had probably wound down a fair bit, as the state was in a fairly flat market where there had not been much growth, and actually, builders were probably looking for work, whereas now, they have to turn it away. There were some changes regarding how many people could be working on construction sites. For example, particularly building houses, there were limits on the number of trades inside the homes, et cetera. However, that probably, if anything, just exacerbated the general problem with lack of resources and slowing the construction down.	No clear answer provided.
P21	COVID has had no real impact on the company from a construction perspective.	During the outbreak, the company went to the memorandum of understanding to share sources if the situation worsened. There were many releases on planning caveats around the COVID-19 period to try and stimulate the economy, in other words, get people spending money on project planning, which meant a lot of programs suddenly came live in the planning baseline, which overwhelmed the local government approval processes.
P22	COVID-19 has not affected the company's work routine.	Application of the segregation and the work-at-home requirements advised during the lockdowns. The company has staggered staff 50% home, 50% in and following all measures that were recommended.
P23	The company has not been impacted on COVID-19 at all. At the moment, the company is busy such that it has just not had the time, people and resources to keep up with the boom in the construction industry.	The company follows the advice from the state health authorities, such as social distancing, using face masks. The company staggers the times for people to have breaks, X amount of people are allowed to be in a lift.
P24	It had a significant economic impact, and there is probably much pressure on our organisation and on the industry to do better, to recycle more C&D. It is probably partly to do with COVID, but it was a priority before then anyway; it just so happens that some of these infrastructure projects that provide an opportunity to use more material have been brought forward. So, the conditions are even—there is even more pressure, probably than there previously was.	The government's response is to try and fast track infrastructure projects as part of the economic recovery. Those major infrastructure projects provide an excellent opportunity for the government to increase the use of recycled C&D waste.
P25	From a C&D point of view, obviously, the onsite work stops when there is an outbreak, which negatively impacts the project programming and delivery.	Overall, the industry made a good effort to respond to COVID-19. Working from home and preparing for the booming residential market

	However, the residential housing market is doing well, so there has been a positive impact in the broader macroeconomic perspective, and the company is busier than before. At the construction site level, COVID-19, probably more in 2020, definitely caused significant delays that created significant uncertainty within the business, but it seems that it has rebounded in 2021 at the moment in a very positive way.	were strategies that the company undertook to respond to these situations.
P26	COVID-19 has not had a significant negative impact on the use of C&D products in the organisation as the construction industry was designated as an essential activity from the very beginning. COVID has actually led to an increase in the organisation's work. However, the recycling industry suffers from manpower and equipment shortages and lacks appropriate alternative plans, which makes it difficult for them to keep up with the amount of work.	Both the federal and the state governments are using infrastructure construction as a stimulus for the economy. Therefore, the organisation is doing record amounts of work, within the organisation; working from home where possible was the most common answer to this situation.
P27	The impact was more on the change in the priority of the organisation's activities, such as bringing forward infrastructure projects to make sure the economy keeps on ticking over, and there are local jobs and local industry development. Furthermore, skill shortages and capability shortages have made it difficult to procure materials and services quantity and cost-wise in terms of procurement.	The industry has responded positively to keep business going and implement processes and practices to ensure that operations continue in a safe environment and still be productive. It has brought in hygiene habits and so forth, and contact tracing. The government responded to the COVID-19 situation by supporting the use of recycled content and increasing the number of projects, which has broadened the opportunities.

4.5.2 Market development in Western Australia

Market development in WA is a challenging topic as it could be seen differently by stakeholders representing different entities. In Table 16, the opinions of 11 WA participants on market development as an effective intervention for better C&D waste management, operation of the existing market and the potential market for certain C&D waste materials are explored.

Table 16. Summary of perceptions of market development for recycled C&D waste products in Western Australia

P	Intervention	Operation	Potential markets
P17	Creating markets is absolutely essential, and currently, recyclers are stockpiling recycled materials as there is a limited market for their products.	The people in the industry are doing their absolute best to try and market this material. However, there is some reluctance among councils that are the main end-users to procure recycled products that have exact quality as virgin materials and meet the specifications. Furthermore, WA MainRoads currently promotes using recycled products in low-value applications, which should be changed.	There is a potential for new markets and existing markets in brick, concrete, glass and asphalt. Recycled concrete and brick in the state have similar performance as new concrete and have a good market. There is a little bit of an issue about glass with the alkalized selector reaction. There are issues with brick pave roads' performance, and they have to be converted to asphalt. The market for steel can be improved by legislation that stops the demolition of steel structures and rather keeps it intact for reuse.
P18	Without a doubt, the development of the marketplace can result in better management of C&D waste in the state. However, the focus of government should be equally on waste handling and recycled products. With government support, recycled products create a market for themselves.	The existing market operation is very poor, and it can improve by benchmarking it with other states (i.e., Victoria and NSW) and overseas markets.	Steel is an exception because there are already many markets for that, and because that market has been created, there has not been a huge demand to divert. Steel is handled well, as far as recycling is concerned. But certainly, concrete, brick, glass and asphalt can have a potential market. Road base as an end product has the biggest potential here to have an impact, followed by clean fill-sand. There is an issue with recycled sand as its virgin types are abundant, and recycled sand is not as appealing to look at as virgin material. Asphalt is gaining some ground in reusing materials in asphalt production. Glass is the biggest tragedy. Glass, despite having so many fantastic properties, still is not acceptable by government organisations.
P19	The market for C&D recycled products exists in the state. However, they are not as widely known as markets for fresh materials.	The operation of the markets is good and growing, but still, the drivers lack in terms of procurement because it is too easy for people to see access 'business as usual' materials and we have plentiful supplies of those as well.	Brick, concrete, glass and sand have existing markets, but in terms of the ones that probably do have the most potential for the future, in WA those are steel, glass and asphalt.
P20	The elements for the successful development of the recycled C&D waste market already exist in the state. However, fresh materials are being ordered	Market operation is good but can be improved by providing education and information that motivate people to use recycled products at a higher level.	There is no recycling facility for glass in WA. Asphalt is getting reused, but certainly, recycled steel and recycled glass are probably two opportunities for market development. The other materials like bricks and concrete

	routinely. Therefore, the development of a market is a good intervention for waste management if the demand is created for such products. Mandating the use of recycled materials and educating engineers and people who can choose between recycled products and fresh materials is needed to stimulate the market.		that can be crushed tend to be put to use for fairly low value purposes.
P21	With regards to creating a marketplace, the marketplace is already here, and the action needed to solidify that marketplace is to remove risk from the outbound products. However, the ambiguity around the definition of waste in the state, the unwillingness of people to buy recycled products due to risks associated with the definition of waste versus resource, transportation cost, complicated testing requirements and inconsistent testing requirements for fresh and recycled materials, plus location of the cost, can determine if market development can achieve the waste disposal reduction objectives.	Some very good players have been in the space for a long time and have developed a good name. Some recyclers in the state have produced high-quality materials by implementing strict criteria, improving machinery and processing arrangements and getting assessed by independent auditing entities as a government mandatory requirement. The audits provide an open platform that will have a certificate of quality of recycled products (structural and environmental wise) that reassures buyers. The product that the participant's organisation produces gets sold with low margins, which justifies the company's processing costs. However, some companies do not apply strict processing practices in the market, and their recycled products do not meet specifications used in the state. The current market needs to be set up so that suppliers can find clients and their expectations in terms of testing requirements and predict the demand for their product. This can be complemented by implementing a forward supply chain and lifecycle assessing the demolition and construction projects to anticipate the amount of processing waste. This kind of arrangement does not exist in the state for several reasons, including the change of governments and programs thereof and the lack of knowledge of where to build recycling	The market for sand, concrete and drainage rock is established, and the participant's organisation is selling these materials. There is a limited market for glass, which can be provided depending on the clients need. However, it is cheaper to be imported from China than manufactured or repurposed in the state, given the high energy costs. Notably, glass from the C&D waste stream is toughened, which causes issues in particle size distribution. Timber does not really have as much value; it is more of a problem stream in WA because of contamination of products like medium density fibreboard will eventually become the asbestos of the future, because it will flux and does not burn, so it has no value in an incinerator, either. The problem with brick is that it gets mixed with other materials such as timber, making the recycled product a very poor grade material.

		centres. The latter is important to keep up with the pace of urban growth to ensure that end-markets are not affected. The operation of the existing end-markets in WA is affected by the lack of sustainable supply of waste materials to recycling facilities with good practices, as waste may go to other companies that make basic crushing and send it to landfills.	
P22	Market development and stimulation is definitely an effective strategy to manage C&D waste sustainability if set up properly.	There is probably no known marketplace for recycled products. It is a bit focused on perhaps one or two companies who do it and that they can use the concrete or the bricks or whatever. There is no known market for other entities to go and obtain those materials.	Steel, brick, concrete and glass definitely have a potential market because they are the bulkier items and are not hazardous.
P23	The market development is definitely an intervention to create and stimulate the market for recycled C&D waste materials.	The operation of the market is good, but currently, it is all low-value products. However, the demand for recycled content in manufacturing construction materials should be high and consistent across end-users.	In WA, concrete is recycled routinely, and whatever waste concrete comes back, recyclers divide them into aggregate and sand, which can be reused. Apparently, the state does not have the manufacturing to convert glass waste into a usable product for glass.
P24	It probably is an intervention and certainly is critical, and that applies to any recycled material. Recycling does not work unless you have a strong market for the materials that are being recycled. So those materials need to be produced to a particular specification, be cost-effective compared to virgin raw materials, and protect human health and the environment. The government, through different public organisations, is supporting the market to address these issues.	The operation of the market is affected by the inconsistency of waste operating companies. Some of them are proactive and very keen to access markets for government projects, and they are very keen to make sure that their material meets specifications, and others are probably less keen and probably less about making a quality product, and perhaps more about just finding a pathway for the material. Therefore, currently, there are many differences in the recyclers and the materials they were producing to reach different end-markets. In the state, government organisations working together to instil confidence in recycled C&D waste products by having various initiatives, chief among them is the Roads to Reuse Program. This program provides environmental standards for recycled C&D waste, notably in road applications, supporting recyclers to conduct regular sampling and testing, and running an independent audit program.	Steel is pretty much extracted from the stream at the point of drop off and sent straight to recycling markets. Glass, unfortunately overly in WA, there is no recycling facilities that recycle bottled glass back into the bottled glass. Most of the glass that you would find in the C&D stream is different sorts of glass, and there are opportunities to use glass for pretty low value uses such as civil construction. If high-value uses and economically feasible higher-value uses can be found, that would be great, but at the moment, we are struggling to do that. In the participant's organisation, concrete is the focus simply because it makes up a significant proportion of the C&D stream. As for brick and asphalt, there are opportunities for new markets, but that probably goes back to the scale.

P25	A fundamental driver for reducing waste is the cost and also just that it is the right thing to do. If there was a better way to actually utilise materials that still had significant value and avoid them needing to be put in a bin and trucked offsite, if there was a way to recapture some of that value that is a pretty major initiative or incentive to reduce waste.	Despite the participant's limited knowledge of the existing market, their organisation attempts to look for opportunities to use recycled materials if it is not expensive, does not have practical issues and is not difficult to use.	There is a very low market for glass given the state is transitioning to high-performance glazing systems, and the opportunity to recycle glass in terms of glazing has been quite low, given the glass scratching. For brick, there is a really high potential, and it stands out, as it is aesthetically nicer in many respects than new bricks; however, the costs for the supply and removing the lead paint and asbestos is a barrier. Recycled timber is quite difficult to include in a new building; even though it might look nice, there are all sorts of issues with timber warping, including legal issues. Structural steel is probably difficult, given its requirements, if it is damaged and if the structural qualities are maintained.
P26	It is an effective intervention and organically and already exists. However, the issue is to develop the demand for the product or some applications. Creating electronic web-based marketplaces for C&D Waste in WA is needed for people to exchange their waste and recycled waste materials.	Every asset owner has their own opinion, and obviously, that influences their policies and standards, and the result of that is it influences their appetite for the use of C&D waste. For instance, although having the same minister, the WA Main Roads is more progressive with the use of C&D waste than their portfolio partners, the Department of Transport and Public Transport Authority. Therefore, the market is really driven by perception and historical practice.	There is an established market for asphalt, and it is a 'business as usual' product in WA at the moment. However, the volume of the market uptake is not as large as in eastern states, i.e., Victoria and NSW. The market for recycled concrete is growing, but additional improvements are needed to further uptake this material. There is no major recycling facility in WA for glass, and the only option is to send it to SA, which does not occur, so finding an application for glass is important. Some processors, however, convert the recycled glass into sand, which is not preferable due to the abundance of this material in the state. There is some limited waste trading for timber, which is upcycling timber to mulch. Recycled sand has a flourishing market and still has a historically established market due to its economic value.
P27	It helps to manage C&D waste in the state. As soon as you place a value, and you stimulate a value on certain materials, it helps form an industry and form the economy needed to sustain it.	The state is slowly starting to establish end-markets. Main Roads has had to champion the establishment of two key end-markets regarding crumb rubber and crushed recycled concrete, the establishment of environmental specifications and independent auditing when it comes to following the specifications from the industry. The participant's	There is an existing market for concrete, asphalt and clay. In the participant's organisation, clean fill and recycled sand have a special place for application in road projects. Glass has limitations for use in asphalt and concrete, and therefore it is better if the glass is recycled back to glass. The issue with potential markets for these materials is that the

	However, an impediment to forming this market is economy of scale. The organisation is assisting in creating the scale by investing resources such as setting an ecosystem in which buyers receive confidence in using recycled products that are safe from an engineering and health and safety perspective.	organisation required that that process be embedded first before they committed to the procurement. So, it took a little while to work cross-industry and the other regulating agencies to establish that. Probably the one thing that is still an issue is leakages from the landfill levy system at this point in time because there is not a consistent approach, as some C&D waste can be trucked outside the levy area. It creates a scenario where there is leakage from the catchment of the levy, and then also the materials are going to different landfill operators. Therefore, it is not coming back into the system, which needs to be overcome in further changes.	industry is not developed, and there are not many buyers, including a local government that does not support the state government in SP efforts. Furthermore, the recycled materials are mainly used in big projects, and smaller projects cannot use these materials.

4.5.3 Improvement areas

In response to the question regarding improvement areas to create and stimulate end-markets, participants highlighted a wide range of areas that need immediate attention and planning. Most of these areas are related to the role of the state government and publication organisation in driving the improvements. P17, for instance, mentioned the lack of collaboration between end-users (e.g., government organisations) and the research and development sector on leveraging the findings obtained from trials and field experiments by government organisations and industry in large-scale applications. To foster this, the participant suggested that behavioural change in the industry and government should be pursued:

> *"Because there's nothing wrong with the products, nothing wrong at all, it's the people's reluctance to use them…I think that's absolutely essential and if universities can work out a way to change people's attitude towards this product, you know, that's the only thing that I can see that's gonna work now"* (P17).

P18 mentioned the government leadership role in stimulating the market by accepting recycled products and using minimum recycled content. P19 pointed out the government's contribution, such as improvement in procurement policy and specifications for recycled products. P20 indicated that improvement areas should be focused on enhancing authorities' understanding involved in approving developments of recycled product alternative materials to agree with their applications in residential developments. For example:

> *"Better specifications for recycled products. That would go a long way in terms of overcoming some of the resistance in the industry, if we proper risk perspective. The people can be assured that what they're getting is of a suitable calling for the task"* (P19).

> *"…standards and the specifications probably need to be brought into play to recognize the need for the use of recycled materials"* (P20).

P21, who represented the recycling industry, emphasised improvements in the definition and classification of waste and implementing an alternative approach to the current case by case analysis and approval of manufacturing waste products. He also suggested that providing support for recyclers who need to pay for rigid testing regimes for recycled products should be on the radar for further improvements, explaining:

> *"I myself see that (Roads to Reuse Program) as being a positive step, but nobody has done economic modelling on it, and as it stands currently, it makes it financially unviable to sell that product. It increases the cost too much for us. Why sell a product that we've had to pay an extra $2-4 a ton on testing, maybe even double or triple the cost of the material, when we can sell it now and we've got to clear our stockpiles"* (P21).

P22 and P23 indicate the need for improving the government leadership role in raising awareness of the benefits of recycled products. This awareness can take different forms such as recognition, uptake and customised recycled product specifications. Education plays an important role in the latter form, as it gives knowledge to engineers who write specifications and breaks the habit of being risk averse:

> *"I think more government uptake on what are the goals of what that process is trying to achieve. So, government recognition and government advice of the community benefits for that, and awareness in the industry of the availability of certain products through that process. There is no current awareness. So, a two-staged prong government, awareness, and facilitation, and industry knowledge that it exists"* (P22).

> *"So, we're going to get the government on board, they themselves, they should be leaders in this field, but they're the opposite"* (P23).

As indicated by P24, providing clear guidelines, similar to the Roads to Reuse guidelines that offer a whole range of different products and end uses, is a step that government needs to take to stimulate the market for recycled C&D waste. These guidelines help the purchaser to make more informed procurement decisions:

> *"I think that the purchasers need more and more clarity and support for their own procurement. So, they want to see what's the guidance, what can I use the materials for, and have confidence in both the engineering aspects but also the environmental aspects so that they're confident that they're not buying materials that have got asbestos or something like that in them"* (P24).

Furthermore, this participant highlighted the issue of transport cost and maintained that recycled products should be available close to where it is used. P25, who commented on the improvement areas from the construction industry perspective, mentioned two major issues: a design for disassembly and a strong supply chain for recycled products. According to P25, design for disassembly thinking helps with the quality of recycled products supply chain, making waste materials such as engineered timber much easier to be processed. Regarding supply chain, in P25 experience, issues with recycled product supply chain are profound, including the inability of suppliers to provide materials in the quantity and quality required for the construction industry within specified time restraints:

> *"Our subcontractors aren't set up to supply the quantities and the volumes, and what have you, it's a supply chain issue, potentially. I don't know, but anecdotally when we want to do recycled materials it's more expensive, they're generally harder to get, it doesn't fit into our typical project timeline as easily, so there is project risk associated with it, whereas new materials, it all just fits together nicely. So, I don't know, that's my crack at answering that one"* (P25).

P26 and P27, being government representatives, indicated the need for improving understanding of recycled products characteristics, such as providence; dealing with materials falling outside of levied system; and establishment of more recycling facilities supplying recycled products. These were highlighted as major improvement areas to facilitate creation and stimulation of efficient end-markets for C&D waste materials. How the waste is generated, handled and processed needs to be known to those who will use it, including government organisations. This way, the confidence needed to make purchasing decisions becomes available because,

> *"…as soon as you use that 'W' word, nobody wants to know. So, it's really about maybe providing better visibility of what actually C&D looks like, where it comes from, how it's handled, and the very high standards that you're able to achieve"* (P26).

Dealing with material outside of the levied system (waste material leakage) would improve the state's resource efficiency and CE, given the quantity of these materials that could be captured back into the system and reused. More recycling facilities with suitable capacity can meet a potential demand created for recycled products across the state. Therefore:

> *"There needs to be the establishment of more suppliers of the materials. So, so far, we've got a limited number of suppliers of the material in a small area of the state, supplying the materials to achieve broader use, and broader uptake, we would need more suppliers to come online to either treat crumbed rubber and manufacture crumbed rubber to the specifications that we need"* (P27).

4.5.4 Enablers and barriers towards market development in Western Australia

Enablers and barriers towards market development and stimulation were identified in interviews with WA participants. Table 17 summarises participants' responses regarding the major challenges and opportunities for market development in Western Australia.

Table 17. Summary of enablers and barriers specified by the interviewees in Western Australia

P	Enablers	Barriers
P17	▪ A consistent approach in testing requirements and other obligations (e.g., noise management plan) for both recycled and new materials ▪ Revisiting regulations and specifications relating to the type of recycled products application ▪ Increase the knowledge of recycled materials' properties and performance to provide confidence to buyers in buying them	▪ Inconsistent state government's approach in different divisions in supporting using recycled products ▪ Unreasonably complex and testing requirements such as heavy metal concentrations for low-value applications of recycled products ▪ Lack of resource tax on virgin materials
P18	▪ Establishing recycling facilities closer to metropolitan areas to reduce transport cost ▪ Seeking innovation and improve design requirements for infrastructure projects ▪ Motivate local governments as the biggest buyers to use recycled products developing standards at the state level ▪ Advancing the technicality of practices of application of recycled materials that prevent their poor performance (e.g., implementing specific concrete with recycled content laying down technique to prevent cracking)	▪ Conservative approach of public organisations (e.g., WA MainRoads) in using recycled materials ▪ A tendency among stakeholders to shift the problem of waste away from them in any way possible rather than focusing on the quality and acceptance of recycled waste ▪ Lack of clarity on the destination of waste materials (e.g., where and how they recovered) claimed to be diverted from landfills by government organisations ▪ Production of low-quality recycled materials by some waste processors reduces the demand for such products ▪ Availability of abundant cheap virgin materials in metropolitan areas in WA ▪ The lack of appetite by public organisations (e.g., WA MainRoads) to improve design requirements of infrastructure projects to embrace new products such as recycled products ▪ The reluctance of WA MainRoads to use recycled products as a road base ▪ Lack of capability in the state recycling industry to provide enough recycled materials required for large infrastructure projects
P19	▪ Clarification about how decision-makers (e.g., designer, engineer) choose to use recycled materials ▪ Educating stakeholders of potential risks and benefits of using recycled products	▪ Limitations within government procurement policies and standard policies ▪ Lack of knowledge of recycled products characteristics
P20	▪ Creating a centralised platform to increase waste trading among various players ▪ Implementing strict quality control to make sure consistent materials are procured ▪ Fostering collaboration between industry and approving authorities to use recycled alternatives in construction projects	▪ Difficulty in using some recovered waste products (e.g., timber and steel) in mass production in the construction industry due to the inconsistency in size and specifications ▪ The lack of effective implementation of carrot and stick approach in market development efforts and policies in WA ▪ Limited usage of recycled products

	▪ Educating designers who specify construction materials on recycled products alternatives	
P21	▪ Developing measured regulations without an increase in costs ▪ Providing subsidization (e.g., Recycled Construction Product Program) as a good premise, which financially assists customers in purchasing recycled materials (e.g., drainage rock and clean fill sand) for different purposes (e.g., road base) ▪ Developing recycling centres closer to metropolitan areas to improve the economic advantage of recycled products	▪ Virgin material being cheaper than recycled products ▪ Abuse in the use of government financial support for buying recycled products (e.g., paying the fund to consultant and contractor rather than end-users) ▪ Inappropriately designed obligations for processing and using recycled products around residential developments ▪ Unfair competition in using waste materials coming from unlicenced on-site processing and recycling facilities due to cost disparities ▪ Lack of legal definition of waste discriminating in licence requirements for the materials going out of the location of generation for recycling versus the materials kept in the boundary of its location (licence is not required). ▪ Government prohibition of operation of screening or crushing machinery next to residential areas due to noise and dust pollution ▪ Risk of change in the state government policies and priorities over the recycled products with change in political parties ▪ Lack of information-sharing on C&D projects risking long term planning for private sector ▪ Lack of collaboration between stakeholders across waste material supply chain on the waste destination
P22	▪ Creating an online and automated waste trading portal led by government and councils where people can register their waste materials availability and location ▪ Convincing constructors to join waste exchange platform through contract conditions ▪ Educating the consulting engineers and architects to consider recycled waste products	▪ Lack of government effort in raising awareness or government pushing the benefits of waste recovery just like it does in carbon reduction
P23	▪ Improving on-site source waste separation to leave the contamination out of waste mix load sent to recycling facilities ▪ Improving technologies for optimal waste recovery	▪ High cost of waste management ▪ Outdated and rigid government specifications ▪ Lack of facilities for remanufacturing waste materials ▪ The state government inactivity and lack of leadership in pursuing sustainability
P24	▪ Creating material guidance (catalogue) with some clear examples (case studies) of what materials can be used and in what applications to support SP	▪ Lack of confidence in recycled materials, which stems from many years ago ▪ Lack of understanding about what sort of recycled materials are suitable for end-users

	▪ Providing confidence in recycled materials through environmental standards to reassure buyers that these products do not contain any contaminants (e.g., heavy metals, and asbestos) ▪ Implementing an independent audit to verify the quality of recycled content ▪ Raising awareness and promotions of recycled content characteristics to better understand opportunities for using them ▪ Ensuring that supply is reasonably close to where the material is needed to justify transport costs ▪ Facilitate recycled materials competition on their own merits by showing that they are completely suitable for various applications. ▪ Setting clear targets and requirements for preference for recycled materials over virgin raw products and raw materials ▪ Leverage the requirements in contracts to get the construction sector to shift their thinking, such as giving preference to those bidders using recycled content, where possible	
P25	▪ Creating more sophisticated platforms for trading and buying waste materials ▪ Creating a verification system to ensure recycled materials are up to scratch and safe to go into a new building ▪ Providing incentives for developers to motivate them to consider a certain minimum of recycled content at the planning stage ▪ Use of sustainability rating tools by councils to drive the market for recycled content ▪ Increase end-user (e.g., council, community) awareness of the value of using recycled content	▪ Lack of policy mechanisms to help drive SP solutions ▪ Lack of interest in paying more for recycled products that pass the cost to end-users ▪ Lack of collaboration between constructors of assets and those who maintain it ▪ Lack of attention to the recycled content in council's development projects ▪ Developers' inclination to only follow what customers need, which may exclude the use of recycled content ▪ Unavailability of information for the construction industry to judge the use of recycled products and the costs associated
P26	▪ Targeting the extracting maximum value of recycled materials through advanced waste management methods such as upcycling ▪ Seeking long term solutions for large volume waste streams	▪ The lack of willingness to improve processes of construction of public infrastructure projects by organisations that deliver a small number of projects within a certain period ▪ Uncertainty about waste materials origin and handling ▪ Promoting the interim solutions that may preclude the development of better solutions in future

	▪ Supporting initiatives with minimum environmental consequences using lifecycle thinking ▪ Use of sustainable rating tools to enable the public organisations to seek opportunities for reduced waste generation and increased uptake of recycled materials	▪ The reluctance of some public organisations to seek innovations due to imposed inflexible compliance requirements and to be risk averse ▪ Lack of recycling facilities and technologies that enable maximum possible use of waste materials value
P27	▪ SP and setting contract conditions in favour of using recycled products ▪ Work with industry to increase the supply of recycled materials through an optimised supply chain ▪ Government funding to enhance recycling capability in the state ▪ Apply sustainability rating tools (e.g., ISCA) that drive right waste management practices as a benchmark for prequalification of bidders for certain public projects tendering ▪ Sharing the ownership of sustainability rating credits with lead contractors to enable the use of recycled products	▪ The low economy of scale in the market to the market size and the number of players ▪ The small market does not encourage competition and assist in improving the quality of recycled products ▪ Strong and established commercial agreements between end-users and virgin materials suppliers ▪ Difficulty in supply chain optimisation to accommodate new recycled products due to low competition between companies

4.5.5 Influential factors for materials end-of-life management in Western Australia

Regarding factors influencing C&D waste end-of-life management in Western Australia, regulation was frequently cited by the respondent during interviews. For instance, P17 indicated that as the waste materials need a lot of testing and quality control, people are less interested. He also mentioned that specifications (i.e., Specification 501) developed by WA MainRoads considers waste materials as a base course material. This has resulted in local governments being reluctant to explore other possibilities of using recycled products in other states such as Victoria and NSW. P19 also confirmed that the state waste regulation is a hurdle to the effective end-of-life management in WA. P27 indicated that the lack of legal definition of waste in regulations limits sharing certain waste resources between different construction projects.

Uncertainty about waste lifecycle was also mentioned by multiple participants (P18, P19, P20, P21, P24, P26 and P27) as having a great degree of influence on the waste end-of-life management. P18 argued that there are no checks and balances on where the materials are going; P19 stated that a lot of materials that are claimed to be recycled are stockpiled, and it is not known whether they are suitable for use as no one can certify the quality; P24 mentioned the necessity of providing good information and awareness of waste-derived products; and P26 asked for transparency on how waste is managed in terms of dismantling, shipping, inspection, crushing, processing stockpiling conditions and quality assurance processes. Without such information the public organisations such as WA MainRoads cannot accept any recycled products to be used in construction projects. On this note, P20 suggested that sustainability rating tools developed by the Green Building Council of Australia (Green Star) and the Infrastructure Sustainability Council of Australia (ISCA) can provide clarity about the lifecycle of C&D waste materials in buildings and public infrastructure projects. The latter provides benefits in establishing diversion rate, clarity on where waste materials go for recycling and producing high-quality materials, improving the social image of constructors and perhaps leading to economic benefits (P21, P27).

Market stimulation was also considered an influential factor. For P18, the lack of market for C&D waste is a major push back for suppliers; P23 described the current conditions where a viable market for C&D waste could assist the construction industry that is currently struggling to obtain certain fresh construction materials (e.g., steel); and P24 stated that a strong market would provide a level playing field, which would also prohibit some waste operators dodging the rules.

The economics of the waste was also raised by P22 as a major determinant of waste end-of-life. He described how the demolition operators' decisions about the waste generated during demolition are driven by the economic advantage of available waste management methods (i.e., landfilling versus recycling). A key economic factor with the strongest influence, according to P24, is the landfill levy. However, the landfill levy needs to be carefully enforced to make sure that it is achieving its intended purpose. Such a levy should prohibit waste material leakage that might happen in the form of waste transfer from metropolitan areas (with higher rates) to regional ones (with no or lower rates), and illegal dumping and stockpiling (P24). Furthermore, from the developer's perspective (P25), waste end-of-life is managed by a waste operation sub-contractor, and the only influential factors they are concerned about are the cost, labour and quality of source separation (e.g., contamination). Particularly, source separation and the cost associated was mentioned by P23, who believed that divvying up the waste to minimise the risk of contamination is a determinant for effective management of waste end-of-life.

Lastly, two factors mentioned by P27 included setting contract conditions for better uptake of recycled products and capability building in both the human aspect (cultural change) and facilities.

4.5.6 Waste regulations in Western Australia

The responses to the question related to current regulations and policies revealed that not everyone is familiar with the current regulatory framework and relevant efforts to reform them. The majority of responses indicate the need for improving the current regulations. Only a few interviewees (P19, P20, 26 and 27) acknowledged the current reforms at the state level to improve the effectiveness of state waste regulations. Notably, the interviewees with that knowledge were the ones that represent the public organisations that are involved in waste regulation and policy development. This trend clearly represents the fact that current waste policies are not effectively communicated to stakeholders. The responses also highlighted some of the reform priorities in current legislation. These include an emphasis on reusing waste materials and lack of extended producer responsibility policy (P17); waste end-of-life management (P18); proper distribution of landfill levy revenue (P19); encouragement of using recycled materials (P20); focusing on non-hazardous materials (P22); pushing and improving the current regulations during the construction industry's busy periods (P23); clarity on definitions and requirements relating to handling waste materials as opposed to resources (P26); and legislation stimulating market development (P27). Table 18 summarises the participants' responses to the question on waste regulation in Western Australia.

Table 18. Summary of participants' opinions on legislation affecting C&D waste market in Western Australia

P	Policy /Regulations
P17	The legislation is not strong enough, and current regulations are not directed towards reducing waste. Furthermore, state waste regulations do not emphasise reuse and recycling as they should. Notably, reusing is ignored in regulations, and there is no compulsion against landfilling the resources that could be reused. The lack of extended producer responsibility is another issue that is not regulated under the current legislative framework. Currently, the decision on recycling C&D waste is primarily based on market forces, and it should be modified to be driven by regulations.
P18	There is much room for improvement. For instance, there is too much emphasis on handling waste and not enough on the end product. Until the mandatory legislation that can stimulate the market are introduced, suppliers of recycled materials continue to struggle with accepting their production by end-users.
P19	The current legislation has definitely improved, which has resulted in a significant reduction in waste disposal. However, the issue of redistributing landfill levy revenue continues to act as a barrier in developing markets. Currently, the revenue does not go back to the implementation of waste strategies across the state.
P20	The issue with the current legislation is that the landfill levy as an effective waste strategy is not accompanied by supporting the use of recycled materials. There is excellent potential in WA to use recycled materials as many recyclers in the state have invested in technologies and modern processes to produce high-quality materials, and the legislation should support these efforts.
P21	The end-of-life waste guideline effective a few years ago was a supportive policy instrument that has been removed after a private entity sued regarding the disposal of unprocessed waste that conformed to the policy at that time. The participant preferred policies that drive SP rather than landfill levies. Furthermore, increasing the landfill levy in future legislation risks the operation of recycling facilities due to imposition of the landfill levy on residual recycling waste. Furthermore, specifications on using recycled waste in new construction materials need to capture a wider range of materials in the state.
P22	The current legislation only addresses hazardous materials and focuses on regulated waste categories, and there is no legislation about nonhazardous materials such as C&D waste materials. Legislation needs to be introduced to define expectations of waste management lucidly.
P23	The current legislation on C&D waste, if it exists, needs to be pushed to reflect real-world conditions in the state, given a boost in the state economy and, notably, the construction

	industry. Such a boom in the industry, generating so much waste, and the scarcity of construction resources justify the urgent need for revisiting waste regulations. Conversely, during quiet times, there is less appetite to reform regulations required for addressing resource constraints. In revisiting the legislation, the government should send strong signals to those who oppose reforms, and the industry is accountable for communicating the current issues, such as the shortage of some construction materials that could be fixed by new legislation.
P24	The Department of Water and Environmental Regulation has been leading an initiative called the Waste Reform program since 2019 that implements a series of reforms throughout our Environmental Protection Act. These reforms aim to make the entire material recovery system work better. This initiative attempts to look at the range of regulations out there and ensure that they are updated, more consistent, and more reliant on or supportive of our new Waste Strategy objectives. For instance, a product of these reforms is a paper called "Close the Loop", which aims to move the state towards a more sustainable economy. However, there is some work to be done.
P25	The current regulations are not good enough. The current set up does not require builders and developers to source separate C&D waste and indirectly encourages mixed load waste at construction sites. The government should devise an extremely high penalty for dumping waste in landfill and builders should be strongly incentivised to reduce the amount that is going into landfills.
P26	The policies about waste in their organisation are being reviewed. However, the big problem is the distinction between resource and waste, and eventually, what materials should attract the landfill levy and how a waste ceases to be a waste. Hence, clarity around definition and expectation is a priority in improving waste regulations. Clarification gives a good understanding of waste handling requirements and will result in minimising unsustainable waste management.
P27	The state could probably get better outcomes if we had slightly more clarity on the legislation. Notably, legislation is required to stimulate better management of end-of-life management of C&D waste.

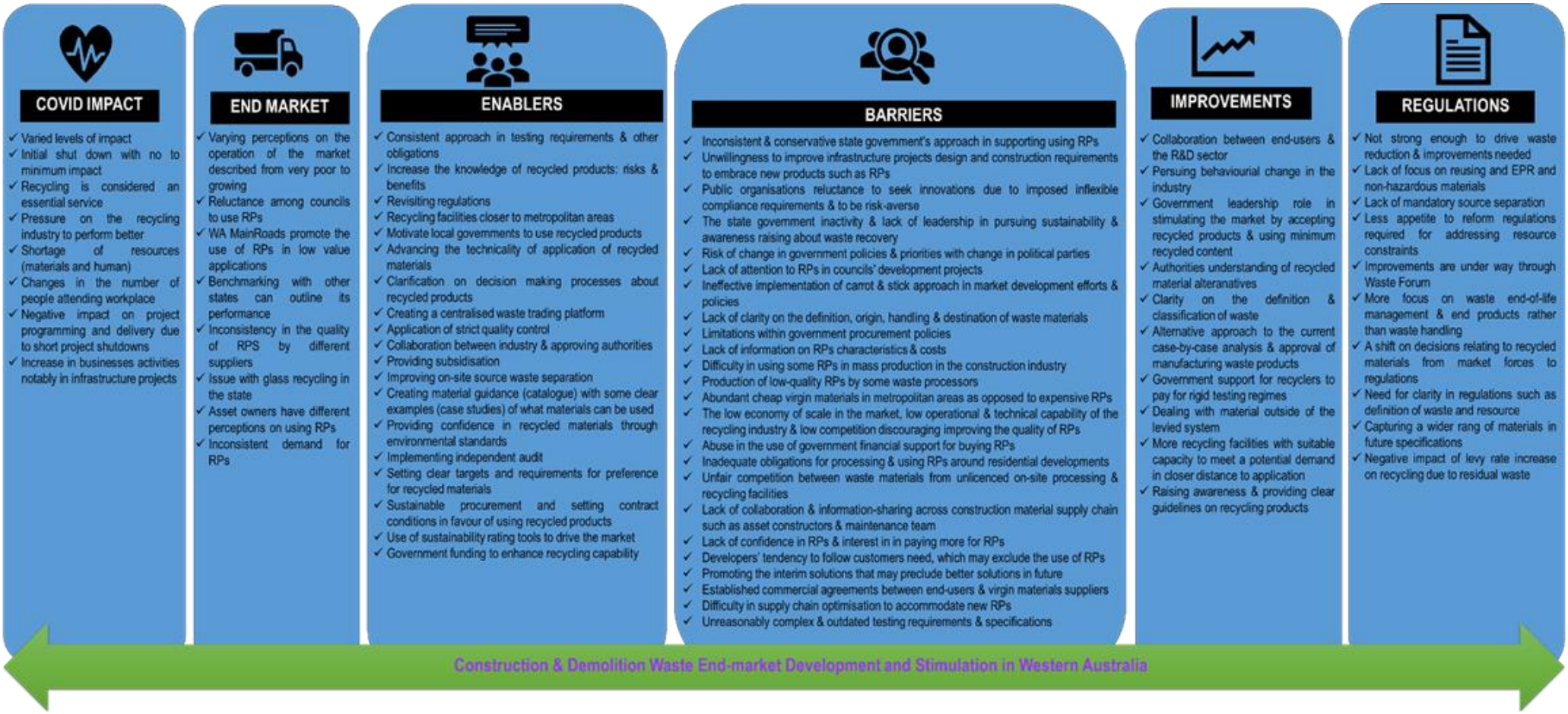

Figure 6. A conceptual model that describes C&D waste end-market characteristics in Western Australia

5 Optimum model for creation and stimulation of C&D waste end-markets

The information extracted from the analysis of the literature and the interviews is used to develop a model to optimise the creation and stimulation of C&D waste end-markets. The model (Figure 7) maps how various enablers of market development can be implemented to optimise the interplay among various stakeholders in the C&D waste space. The stakeholders in this model include the government sector (public organisations and policymakers), recyclers, C&D professionals, and sustainability rating system and quality assurance auditors.

As proposed in this model, the government sector should facilitate significant improvements through primary sustainable procurement strategies, raising awareness, effective recycling approvals, simple and effective material specifications, leveraging contract conditions to use recycled products and financial support. The secondary government enabled improvements include stopping illegal dumping, providing a clear definition of waste, developing supportive regulations, imposing properly designed landfill levy, contributing to a national approach, setting targets to use recycled products and building consistency among various public organisations in valuing (using) recycled products including encouraging local governments to purchase recycled products.

In the recycling sector, the four priority areas are to: 1) invest in advanced processing technologies; 2) develop infrastructure with a suitable capacity to manufacture to the scale of economy; 3) establish such facilities close to metro areas; and 4) generate material catalogues that detail recycled products information. In the C&D industry, for both private and public projects, the improvements include enabling information sharing with the recycling industry, on-site source separation and collaborating with manufacturers to implement an extended producer responsibility policy.

Furthermore, independent auditors should be engaged to assure the quality and performance of recycled materials after testing. Lastly, sustainability rating systems such as Green Star and ISCA should be leveraged to drive change in the waste management ecosystem and endorse the use of recycled products in private and public construction projects.

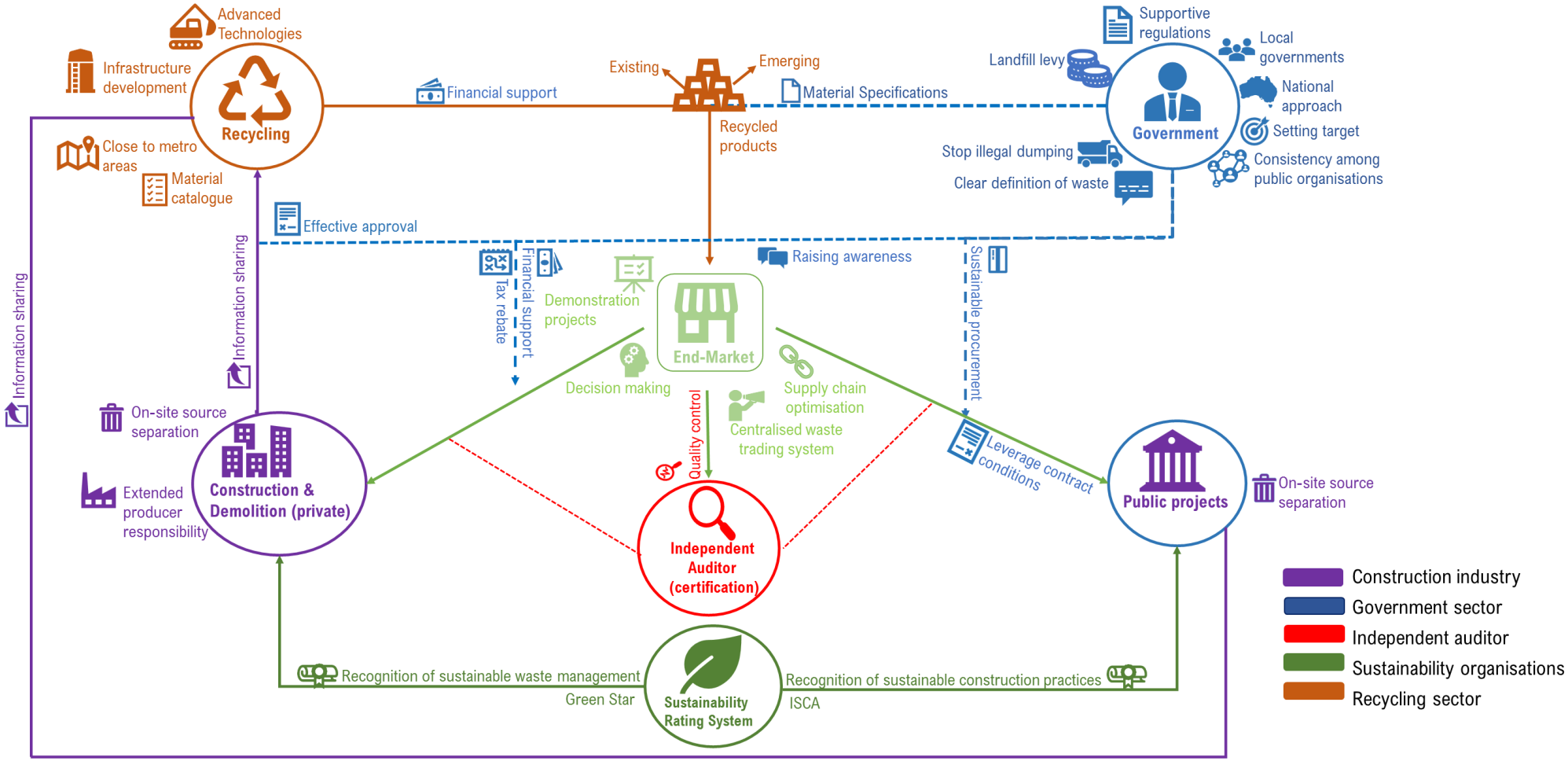

Figure 7. C&D waste end-market creation and stimulation model

6 Concluding remarks and recommendations

The creation and stimulation of end-markets for C&D waste require the involvement of various parties. Drawing on interviews with 27 C&D waste experts in four states (WA, Vic, NSW and SA), this report provides an insight into the main challenges and opportunities in end-market development as identified by key stakeholders. The following sections present an overall picture of a series of issues gravitating around market development and stimulation in Australia. Where possible recommendations for reforms based on comparative analysis of state-based information are provided. While we made every effort to recruit participants representing various stakeholder groups, it is noteworthy that the results presented in this report are indicative and not inclusive.

6.1 COVID impact

The analysis of the responses on COVID-related issues collected during interviews shows that the study states' industries and state governments have successfully responded to the COVID-19 impacts. It seems that recognition of the construction and recycling industries as essential services has enabled them to survive during these challenging times. The respondents provided information on how they rapidly adapted to the rapidly changing situation. Nevertheless, various levels of impact were reported by the research participants. In the recycling sector, it seems that the states of South Australia and New South Wales have experienced a decline in demolition activities resulting in lower levels of incoming waste feedstock required for sustainable operation of their facilities. However, in Victoria and Western Australia, the situation was different, and recycling facilities could receive the necessary amount of feedstock as per their capacity. These varying trends could be related to the high rate of construction activities occurring across the state at the time of the interviews necessitating waste collection and processing.

In the construction sector, respondents from the three states indicate minimal to extensive impact. Notably, in South Australia and Victoria, the level of impact was assessed as great overall but not all AEC sectors were affected equally. The main impacts were the delay in delivery of public infrastructure projects, cost implications for implementing additional hygienic procedures and working with half capacity due to applying rotating shifts.

6.2 Recycled product specifications

Recycled product specifications were among the most frequently cited issues that were considered a significant barrier to stimulating end-markets for recycled C&D waste resources. It seems that while Victoria and Queensland's current recycled product specifications encourage the use of recycled products, they are not considered to be as supportive in New South Wales, Western Australia and South Australia. Hence, it is recommended that these three states compare the performance of their recycled product specifications with those applied in Victoria and Queensland.

6.3 Sustainable procurement

As a major enabler, SP was frequently referred to in response to questions regarding market development and stimulation enablers. From the interviews, it can be concluded that SP has been better practised in Victoria compared to New South Wales and South Australia. This trend could be attributed to the better promotion of the CE and resource efficiency in Victoria. The policy support by public organisations such as Sustainability Victoria (Buy Recycled), Major Road Projects Victoria (Recycled First), and the Department of Environment Water and Planning (Recycling Victoria) played a crucial role in this space. In Western Australia, initiatives such as the Roads to Reuse Program and Waste Forum can inspire other states to create such platforms to connect key stakeholders, encouraging the use of recycled C&D waste products by government organisations.

6.4 Quality assurance

Quality assurance is an important strategy to build confidence in using recycled products. In WA, the use of independent audit entities has been reported to be successful. Other states can learn from this success story to achieve the same results. Quality assurance can occur at different stages, from the time waste is generated to when recycled products are offered to the market.

6.5 Operation of current end-markets

Overall, the interviewees' perceptions of the current operation of end-markets varied. It was noted that there is no tool or benchmark to precisely evaluate their performance. The interviewees indicated that concrete and brick have a mature market in three states and cited that glass and timber are the two waste materials with the most potential for new markets. In terms of performance, Victoria has the most viable market for recycled waste products, which means other states and territories can follow its lead. The proximity of recycling facilities to metropolitan areas compared to virgin materials and emphasis on the use of recycled materials by government agencies such as Sustainability Victoria are among the chief factors that facilitate such outcomes.

7 References

[1] Australian Bureau of Statistics. 2021. National, state and territory population. https://bit.ly/3hwzWM0

[2] Department of Agriculture, Water and the Environment. 2020. National Waste Report. https://bit.ly/3xziTON

[3]QSR International Pty Ltd. (2020) NVivo (released in March 2020), https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home