Construction and Demolition Waste Market Development

Research Report No. 4

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SBEnrc P1.65 A National Economic Approach to Improved Management of Construction and Demolition Waste

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Executive Summary

In Australia, construction and demolition activities have substantially grown over recent decades leading to the generation of a large amount of waste. Among available options, the development of end markets for construction and demolition (C&D) waste materials is regarded as a sustainable solution to tackling issues around their management. Despite the promotion of a circular economy and the existence of some trading platforms set to facilitate C&D waste exchange in Australia, no research has been conducted to understand how these platforms are performing and various key stakeholders perceive their role in the C&D waste management system. Hence, this project aims to provide clarity in these areas by achieving the following objectives:

(1) to explore the level of agreement with market incentives approach in Australian C&D waste management system
(2) to identify the most important strategies aiding the development of a national C&D waste market
(3) to compare and model the cost implications of different C&D waste management methods

The study conducted a questionnaire survey in 2019, aiming to capture the main C&D waste stakeholders on market development. In total, 132 responses were collected, and the analytical results show that participants significantly support implementing more market incentives to reduce waste disposal. They also indicate that investment in technology and infrastructure, sustainable procurement and landfill levies are three major influential factors that have a significant impact on market development. Furthermore, an economic evaluation was carried out using a case study to understand the cost implications of recycling versus landfilling in metropolitan and regional areas. The economic modelling revealed that transportation costs are an instrumental factor in the selection of the method to manage C&D waste; they can diminish other benefits such as lower levy rates that would have been obtained in the absence of high transportation costs. The project findings can inform decisions and policies developed in Australia to establish end markets for C&D waste management effectively.

1. Introduction

With rapid urbanisation around the world, construction activities continue to grow to an unprecedented extent. As a result, the construction industry accounts for 35% of the total waste sent to landfill worldwide (Solís-Guzmán et al., 2009, Zheng et al., 2017). For instance, in the UK, 49 Mt of C&D waste was generated in 2014; more than half of this amount was landfilled (Menegaki and Damigos, 2018). In China, the annual C&D waste generation is 2.36 BT (Zheng et al., 2017) and in the US, this figure was 516 Mt in 2017 (US EPA, 2019).

In Australia, construction and demolition activities have substantially grown over recent decades leading to the generation of a large amount of waste (Shooshtarian et al., 2019b). The C&D waste stream; therefore; accounts for 43% of the total waste generated, reaching 20.4 Mt annually (Shooshtarian et al., 2019d). The average annual growth of C&D waste generation is currently at 2%, and about 6.7 Mt of this waste stream is landfilled (Shooshtarian et al., 2020b). The development of a market for salvaged and recycled waste materials (including C&D waste) has been advised as a sustainable solution to reduce waste disposal (Sustainability Victoria, 2016). Hence, multiple pieces of literature, industry reports, policies, strategies; and guidelines have emphasised the necessity of a marketplace in the management of C&D waste (Shooshtarian et al., 2020d, Shooshtarian et al., 2019e, Caldera et al., 2020, National Waste Policy, 2018).

Within the Australian context, the circular economy of waste has five principles, the third of which is to 'increase the use of recycled material and build demand and markets for recycled products; that is, market development (Perey et al., 2018, Florin et al., 2015). In the Australian National Waste Policy (2018), Strategy 14 places emphasis on market development and research (p. 16). Estimations, based on the current solid waste generation rates in Australia, project that Australian recycling capacity must increase by 400% by 2040 to address the issue of solid waste in the future (Environment and Communications References Committee, 2018). Furthermore, the influence of China's new waste policy and anti-waste movements in other countries, including Thailand, Malaysia and Philippines urgently necessitates the development of domestic market capacity in Australia (Shooshtarian et al., 2020a, MarketplaceHUB, 2020). Several internal and external factors strongly influence the development of a domestic market for waste and recyclables. The following are a short review of factors identified to affect market development for C&D waste materials:

National leadership– The Australian federal government is in the best position to respond to market developments by providing recycling regulations that align with the limited constitutional responsibilities of the federal government in the regulation of waste. ***Landfill levy–*** landfill levy is an effective pecuniary impost that if properly designed, can lead to further resource recovery (Yu et al., 2013) and market development (Shooshtarian et al., 2020b). Unreasonable (both high and low-price signal) priced landfill fees and their variation can negatively hinder C&D waste market development (Shooshtarian et al., 2020b, Arslan and Ulubeyli, 2019). ***China's new waste policy–*** Australia exports recyclable material to over 100 countries, with 4.23 megatonnes of recycled materials exported in 2016–17 (Blue Environment, 2018). The introduction of China's new policy (National Sword Policy) has a diverse impact on the performance of the market for C&D waste. While it motivates the development of a market, it will have some negative impact on C&D waste management since the local markets are not yet fully established.
Data and papering– Accurate C&D waste data collection and papering underpin the development of a local market for recyclables. Consistent and updated papering can make it much easier to manage the C&D waste and resource market. Waste data is critical to well-targeted, evidence-based and planned

waste projects and programs (Net Balance, 2009). Data on waste generation, landfill and resource recovery is also essential to the development and implementation of waste policies and programs. Research and development– Any integrated waste management system greatly benefits from research and development (Gálvez-Martos et al., 2018). Almost every single strategy, policy, action plan and regulation on waste management in Australia has highlighted the role of R&D alongside with encouragement and enforcement for effective development and implementation of waste-related plans such as market development (Shooshtarian et al., 2020d). ***Waste management schemes–*** product stewardship, extended producer responsibility (Shooshtarian et al., 2019a) and take-back schemes (Shooshtarian et al., 2020c) are strong motivators for the establishment of a market. It is recommended that these schemes be regulated and implemented nationally because many of the potential participants work across Australian jurisdictions (Environment and Communications References Committee, 2018).

Regulatory support– It is vital that waste regulatory frameworks are set to be in favour of local market development and implementation of an effective circular economy. The issues that must be addressed in this regard are inconsistency in jurisdictional waste regulations throughout Australia, clarification on the waste definition including when waste becomes a resource and is not liable for landfill levy, weak or inconsistent regulations that encourage illegal dumping and stockpiling activities and inconsistent reporting obligations. ***Geographical location and population density–*** Australia is a vast country with a relatively low population. The population is concentrated in capital cities, which challenges market development. As a result, long distances between waste origins, waste facilities and the place that receives recycled and salvaged C&D waste is regarded as a barrier to the development of a domestic market. ***Supply chain–*** Providing an efficient and effective supply chain to the waste and resource recovery industry is instrumental in developing a local market for C&D waste (Shooshtarian et al., 2019e). The supply chain for this purpose needs to consider the principles of the circular economy and be driven by the industrial ecology (symbiosis) concept (The wastes or by-products of one industry are used as inputs in another industry, thereby closing the material loop of industrial systems and minimising waste).
Sustainable procurement (SP)– This can provide an incentive for further waste recovery. It is argued that the implementation of SP has a positive impact on the flourishing of the C&D waste material market. ***Green construction–*** Green construction has proven to hold a critical role in boosting C&D waste market worldwide (Shooshtarian et al., 2019c), notably when it is implemented obligatorily and is a requirement for large-scale or government projects. In Australia, there are two voluntary industry-based rating systems, namely the 'Green Star' (GS) program and 'Sustainability Infrastructure' (SI), which promote the concept of green construction (Shooshtarian et al., 2019c). ***Investments in technology and infrastructure–*** Advances in waste recovery technology and infrastructure are advantageous to domestic market development. Building modern and efficient facilities not only addresses public social and environmental concerns but also provides better services to the waste and resource recovery industry through economies of scale. ***Employment–*** The potential for jobs to be created through a local market is attractive to decision-makers, politicians and different stakeholders (Yuan, 2013, Davis, 2013). The extent to which waste recovery activities can give rise to employment can be assumed to be proportional to the level of support provided by officials in government departments that consist of politicians from major parties in Australia (Jones, 2019). Marketplace Hub has investigated the challenges towards sustainable operation of C&D waste marketplaces and identified eight major challenge groups. Table 1 presents a summary of these challenges.

Table 1. Major categories of challenges to the sustainable operation of waste marketplaces

Challenge category	Description
Price volatility and international competition	Secondary materials often have a hard time competing with the prices of primary raw materials; this may be due to fluctuating commodity prices and/or oversupply due to large import volumes
Lack of knowledge and information	Access to information is a significant hurdle for companies trying to acquire secondary materials including: supply location, quantity and frequency, price transparency and quality; at the same time, companies trying to find alternative uses for their materials often are unaware of interested buyers
Logistics and transport	Irregular delivery frequencies, material transportation permitting, and risk of holding-area contamination all present challenges to logistics companies
Quality	Procurement departments may be hesitant to buy secondary materials because of potential contamination, low or unknown purification rates, no third-party testing, or lack of performance guarantees
Regulatory	Regulations can create challenges for companies trying to exchange secondary materials in transporting across borders, variations in the definition of 'waste' and end-of-life criteria, or in determining what qualifies as hazardous materials
Technical	Processing waste and by-products into marketable secondary materials is not always economically feasible given the technology available; for many materials, improved collection and sorting innovations are needed to put secondary materials on par with virgin material prices
Trust	As with any supplier-buyer relationship, trust must be established before materials or money is exchanged; the exchange of secondary materials requires another level of trust due to quality concerns and poor price transparency
Regular supply quantity	Companies that look to buy secondary materials expect consistent and regularly scheduled supply quantities as they would with primary materials; because companies produce widgets (not waste), they are under no pressure to deliver by-products of regular quantities

Source: https://marketplacehub.org/marketplacestats/

1.1 C&D waste trading platforms in Australia

The first online marketplace for C&D waste materials trading platform, called Yours2Take, was created in 2008 that aimed to provide a means like eBay for waste traders. However, this platform ceased to operate in 2016 for some unknown reasons. Afterwards, two other platforms, called *Waste Choices* and *RecycleBuild*, were developed between 2011 and 2014, which both discontinued in 2016 and 2018. Currently, three active platforms facilitate C&D waste materials; these include ASPIRE, Buy Recycled, and Business Recycling. The latter two platforms are supported by the Victorian and NSW governments. Table 2 summarised the operational model of these platforms.

Table 2. Online markets for C&D waste trading in Australia

Platform name	Operational model
Buy Recycled (https://directories.sustainability.vic.gov.au/buy-recycled)	In 2020, Sustainability Victoria launched an online directory that will feature local, Victorian products containing recycled content. The directory will help the Victoria government source recycled materials. It will be used by state and local government procurers and buyers to help them easily research, review, and access recycled content products.
Business Recycling (https://businessrecycling.com.au)	In partnership with NSW Government (Department of Planning, Industry and Environment), Plant Ark launched Australia's most comprehensive online database that helps small to medium businesses find recycling collection and support services for the workplace. This platform which was founded in 2019 invites providers of recycling and waste disposal services to list their details for free.
ASPIRE (https://aspire.csiro.au)	The Advisory System for Processing, Innovation and Resource Exchange (ASPIRE) is an online marketplace which intelligently matches businesses with potential purchasers or recyclers of waste by-products. ASPIRE was developed by the CSIRO (Commonwealth Scientific and Industrial Research Organisation) under the State Government of Victoria's Digital Futures Fund in partnership with several Victorian councils. Its operation officially kicked off in 2018. This system requires patrons to enter details about the type and quantity of their exchangeable inputs and waste materials (outputs). Using this data, ASPIRE's Supply Chain Options Model determines optimal sources and destinations for the materials, including options for aggregation with other local businesses, appropriate investment opportunities such as compactors for low-density wastes, and local recyclers. ASPIRE is deployed using existing established council and manufacturing business networks, and it supports local government business sustainability programs. It captures and codifies small-to-medium-enterprise (SME) material inputs, outputs (waste and by-products) and processes, and has a powerful optimisation model that takes this data and provides an SME user with three things: 1. Suggested business-to-business resource matches, both substitute inputs or sources and output destinations. 2. Personalised search results to support the suggested matches. 3. Case studies for related resource matches.
GreenHands (https://www.greenhands.net.au)	Greenhands is a free online marketplace for recyclable excavated resources, C&D waste materials, and salvaged goods. It includes a directory of resource/waste facilities, building contractors, construction sites, transporters, skip bins, rubbish removal and plant hire. Builders use GreenHands to source and dispose of materials for projects; it can connect users with builders nearby and trade their excess or recycled materials with them.
Yours2Take	This online platform was an initiative of the Riverina Eastern Regional Organisation of Councils (REROC), implemented in 2008 through its waste forum. REROC is a voluntary strategic alliance of 15 councils located in the eastern Riverina region of NSW. Y2T utilised a platform similar to eBay to allow users to upload items that they want to give away and acquire items that they want.[1] According to the statistics, this platform succeeded to attract 6,500 users since it was launched, with an average of 3,500 visitor registrations per month. During the operation of this platform, more than 1,200 items were given away. This platform was officially closed down in February 2016.
Waste Choices	This platform was launched in 2014 and later discontinued in 2016. The platform was set to improve waste management and resource recovery activities and to help businesses that want a simple, fast, transparent, cost-effective, and compliant solution for waste collection, recycling, treatment and disposal. Through this platform, businesses of any size have the flexibility of posting a one-off project or an ongoing contract for the management of over 30 waste streams. The service seekers could select from a range of competitive bids from 14 national and state-based waste management providers with the flexibility to award a project based on price or reputation of the provider.
RecycleBuild (http://www.recyclebuild.com.au)	This website provides an online platform for trading building materials under three main categories of new, used and unused across Australia. RecycleBuild is a Qld-based company that manages this online marketplace and introduces itself as being "committed to developing and operating websites that actively enable the participation of the building and construction industry to use building materials that reduce the environmental impact our built environment has". This platform provides an opportunity for sellers to advertise their waste for free if they are public or give away their materials. Construction companies and other businesses also can benefit from discounted fees for bulk advertisement. This company sells credit for advertisement and does not charge a commission fee to their account holders. The platform also uses another classification system to categorise the waste that is to be traded, as follows: 1. **Discounted building materials (BMs):** a price that is 20 per cent or more below the recommended retail price. 2. **Superseded BMs:** outdated by new technology, fashion, new stock replacement selling at a discount price. 3. **Slow-moving BMs:** stock that needs to be cleared from storage, selling at a discount price. 4. **Excess BMs:** over-ordered, wrongly ordered, wrongly made, no longer required, selling at a discount price. 5. **Second-hand BMs:** used and selling at a discount price. 6. **Recycled BMs:** where more than 20 per cent of the material is sourced from recycled materials. 7. **Able to be recycled BMs:** material that can be reprocessed for future use. 8. **Leftover BMs:** building site excess; leftover from the construction process. 9. **Manufacturer defect BMs:** not made to order, material carries a mistake, selling at a discount price. 10. **Damaged BMs:** building materials from manufacturers, wholesalers or retailers selling at a discount price. 11. **Damaged BMs:** Manufacturer's defect, broken, knocked, scraped, selling at a discount price.

1.2. C&D waste trading platforms overseas

The four top countries in the development of a marketplace for waste trading include the US, France, the UK, and Canada. According to statistics collected by an online tool called MarketplaceHUB (https://marketplacehub.org), a network of circular economy practitioners, the US with more than 25 major marketplaces across its states, is leading country in following circular economy principles and increasing waste diversion to landfills (MarketplaceHUB, 2020).

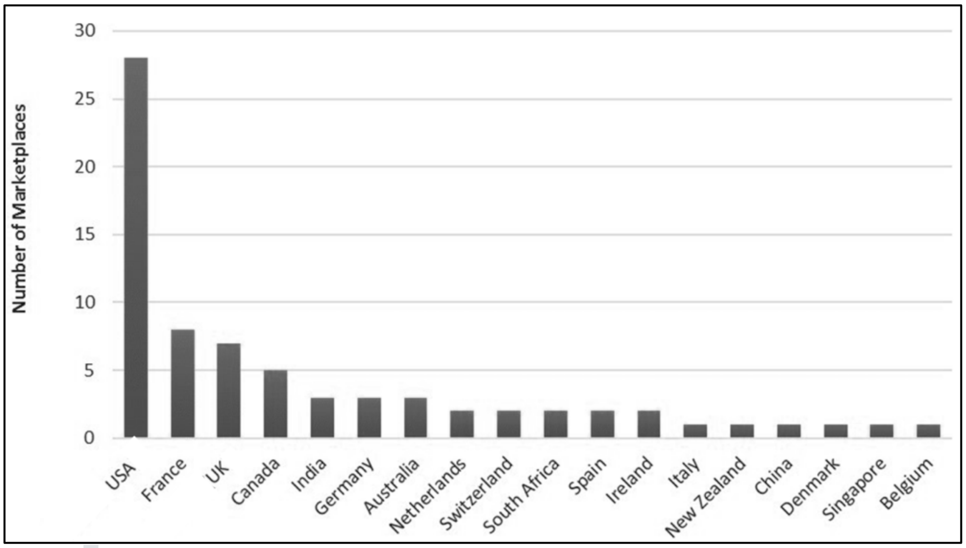

Figure 1. Number of secondary material marketplaces by country in 2016

The top materials being traded across the marketplaces described in Table 2 are metal and alloys. C&D waste holds the sixth position after plastic and polymers, biotic resources, E-waste, and other categories. According to the data collected from 108 marketplaces operating in various geographical locations around the world (MarketplaceHUB, 2020), the four main sources of income for marketplaces are ‘advertising’, ‘funding’ and ‘membership’, and ‘public finance’

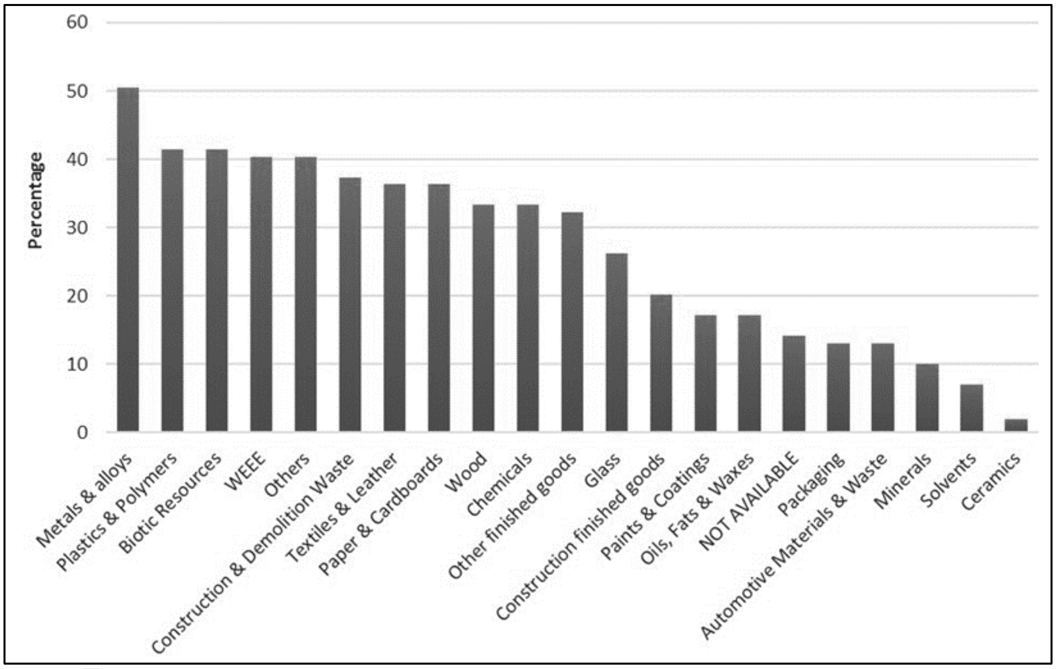

Figure 2. Main materials traded across marketplaces in 2016
Source: https://marketplacehub.org/marketplacestats

Table 3. International online trading platforms for C&D waste

Platform name	Location	Operational model
2Good2Waste	**US**	This platform provides the opportunity to trade waste across selected states. It facilitates resource recovery and promotes an important environmental ethic. The platforms run in three simple stes of finding materials, posting materials and making exchange
Materials Marketplace (https://go.materialsmarketplace.org)	**US**	This national and global platform is developed by the US Business Council for Sustainable Development to facilitate company-to-company industrial reuse. Through a cloud-based platform, this marketplace matches traditional and non-traditional industrial waste streams leading to a cultural shift to a circular, closed-loop economy. It provides an efficient user experience as well as the ability to capture and leverage data to produce actionable insights about materials and their potential uses. The marketplace actively analyses available materials and sends its members curated matches. Currently, more than 2,000 businesses and organisations are registered on this platform. The Ohio division of this platform diverted about 1,525 t and creates $150k in disposal savings and value creation in the first year. The platform has extended its services to a few other countries, namely Turkey, Vietnam, and Israel.
MarketplaceHub International	**International**	The MarketplaceHub is a tool designed to foster sustainable use of resources through accelerating business to business reuse opportunities for secondary materials worldwide. It has developed a map that gives an overview of 108 existing materials marketplaces and industrial synergy networks around the world, searchable by materials or location (MarketplaceHUB, 2020). At the moment, 39 marketplaces can handle C&D waste materials. This online tool also regularly conducts market study and analysis to identify the main challenges to the sustainable operation of waste marketplaces.
Salza (https://www.salza.ch)	**Switzerland**	Salza (https://www.salza.ch), an online marketplace founded in Switzerland, proposes a new internet tool that broadens the current practice of re-use in Switzerland. On this platform, owners can, for a modest allowance, publish a document on the building intended for demolition or renovation. It aims to allow architects, designers and artists to discover valuable elements that could be re-used in a new project. Salza puts the owner and the applicants in direct contact. After negotiations, they agree on all the modalities before dismantling.
Backacia	**France**	Backacia is an online start-up that specialises in the re-use of building components. This marketplace was launched in France in 2017. The products for sale on the marketplace are either from surplus orders or deconstructed buildings of professional quality. The start-up has already attracted numerous customers, won several awards and attracted the interest of large construction groups.
Austin Materials Marketplace (http://austintexas.gov/zerowaste)	**US**	The Texan capital city of Austin was the first to implement a Zero Waste Plan in 2009, a strategy aimed at improving waste management to "reach the City Council's goal of Zero Waste by 2040". The plan highlighted that the economic loss related to the value of materials sent to landfill was more than the US $40 million per year. In 2011, the city adopted the Austin Resource Recovery Master Plan in the quest of accelerating the implementation of the Zero Waste Strategic Plan. The aim was to increase waste diversion to 90 per cent by 2040. In its recommendations, the City of Austin urged to "expand and improve local and regional re-use, recycling and composting programs" as well as "involve the community through collaboration and partnerships to achieve Zero Waste". It is in this context that the Austin materials marketplace was launched in 2013 and considered a tool to foster the implementation of the Strategic Plan. Considered as an instrument to accelerate the application of the US Waste Management Plan, the Austin Materials Marketplace was fully funded by the City of Austin. By contracting the management and operations of the marketplace to the US Business Council for Sustainable Development, the City recognised that success depended on external subject matter experts. As of September 2016, the Austin Materials Marketplace moved to a new revenue model. In reaching a sufficient rate of regular users, it is now able to transition to a network-supported model, gradually making it independent from the City of Austin. Operating costs will now be offset through memberships, advertising and margins on transactions fees, similar to typical privately-owned marketplaces. This example illustrates how marketplace platforms can develop in an enabling policy environment and eventually achieve financial sustainability. Importantly, it shows how marketplaces are recognised as an instrument to implement a government-led initiative in an effort to transition to a greener, more circular economy.
National Industrial Symbiosis Program (http://www.nispnetwork.com)	**UK**	The NISP was designed by International Synergies Ltd to address the challenge of a lack of knowledge and access to information for cross-sector, second-hand material transactions. International Synergies is the world's leader in the practical application of industrial symbiosis (the circular economy in action) methodology, tools and techniques. It provides capacity building, strategic consulting, industrial symbiosis delivery as well as supports software and bespoke business resource solutions. NISP was launched in 2003 and has gained the attention of international organisations, governments and academia. The program produced a resource re-use database and management system – SYNERGie®. This software facilitates resource matching for users using an extensive library of experience. The platform allows companies to identify re-use opportunities and minimise their waste. Additionally, through SYNERGie®, companies are required "to meet quality assurance protocol and audit requirements", a significant hurdle faced by most companies involved in secondary material exchanges. First implemented in the UK, the program has now been replicated in more than 20 countries at the regional or national scale. It successfully engaged more than 30,000 companies on every continent, leading to the waste diversion of 47 million tons from landfill in eight years, which is equal to 42 million tons of CO_2 emissions. This program is often quoted in literature as an example of best practice; the model has even been described by the OECD as "an excellent example of systemic innovation vital for future green growth". This platform has now become part of a larger EC Horizon 2020-funded program – SHAREBOX. The program aims to enable the next generation of industrial symbiosis through "ICT and data intelligence". As part of SHAREBOX, SYNERGie 2.0 will generate automatic suggestions of synergies based on a set of criteria.
Mjunction (https://www.mjunction.in)	**India**	Mjunction, a joint venture by Steel Authority of India Limited (SAIL) and TATA Steel Limited, is currently the largest e-commerce platform for primary and secondary steel in the world. Established in 2001, this Indian marketplace conducts between 700 and 800 auctions each month,[2] making it one of the main actors in online materials marketplaces. Initially focused on steel, Mjunction rapidly expanded to new business lines and now offers e-finance, e-selling, e-sourcing and e-knowledge services for various goods such as steel, coal, automobiles and tea. The success of this marketplace can be partly linked to its e-sales process. The company's e-auction service ensures buyers and sellers a "transparent pricing based on the market situation".[3] This system, in addition to providing information regarding the availability and quality of materials, allows both parties to benefit from a trusted environment and pursue their exchange safely. The forward auction system awards the highest bidder of the material. In this process, buyers and sellers can see the price and the number of parties involved in the exchange at any time. They also can be assisted by 'tele-executives' during the process. This mechanism allows members to save time in the negotiations while being ensured of a fair price. Additionally, Mjunction provides logistics and inspection services. Quality-ensured materials are delivered by Mjunction all over the country. Establishing the e-auction service was neither quick nor easy. Mjunction had to initially overcome credibility issues and prove its platform was reliable and scam-free. After consistent efforts, the company's program matured by 2006.[4] The program is now supported by "standard operating procedures" developed to run the auctions. Mjunction illustrates how secondary materials can be exchanged at a fair price agreed upon by the buyer and seller. It was a pioneer in the e-auction system for steel and maintained its leadership. This system can be a model for other online marketplaces.
SMILE (http:/smileexchange.ie)	**Ireland**	SMILE (Saving Money through Industry Links and Exchanges), founded in 2010, was a resource exchange platform embedded in Ireland's national program for industrial synergies. The program drew on industrial symbiosis to focus on improving companies' abilities to re-use second-hand materials that would have otherwise gone to landfill. The initiative partnered with Ireland's EPA and other councils and boards. According to a report released in 2016, after six years this program attracted 1,400 members, concluded more than 300 successful synergies and diverted 8,000 t of material from landfill. This amount of waste diverted is estimated to have saved €2.1 million for the businesses involved. The process in this platform kicked off with the identification of synergies through the free online platform. Members would then benefit from technical support in completing the transaction. Delivered by consultants based in each of the three waste regions across the country, this service facilitated the exchange by providing materials reprocessing expertise. The other services provided by this platform included sending consultants to visit companies and provide them with personalised feedback regarding their exchange opportunities. The support team also facilitated the negotiations between parties to assist with removing the challenges that typically appear when trading secondary materials. In addition, the program provided opportunities for companies to find their potential partners by holding networking events throughout the year. Using this platform, companies could acquire secondary materials at competitive prices. Often, businesses also saved costs associated with landfilling. According to the program's newsletter, this platform produced some successful results for member companies.

Despite the existence of some trading platforms set to facilitate C&D waste exchange in Australia (Table 2), no research has been conducted to understand how various key stakeholders perceive their role in C&D waste management system. Hence, this study aimed to identify the perceptions of Australian key C&D waste stakeholders on the market development for recyclable materials. The study objectives were:

1. *to explore the level of agreement with market incentives approach in Australian C&D waste management system*
2. *to identify the most important strategies aiding the development of a national C&D waste market*
3. *to compare and model the cost implications of different C&D waste management methods*

2. Methodology

The below is the description of the methodology used in this study to collect quantitative data. The data collection methods included a survey and economic modelling based on a case study.

2.1 Questionnaire survey

A questionnaire survey was performed to achieve the first two objectives of this research. Qualtrics, an online survey toolkit, was used to design the questionnaire (Qualtrics, 2014) and to circulate it among the participants. The questionnaire was reviewed and refined by Australian waste management and construction industry experts. The conduction of the survey was approved by the RMIT University Human Ethics Committee, College Human Ethics Advisory Network (CHEAN) (CHEAN A&B 21847-11/18). The questionnaire contained 46 questions about various aspects of C&D waste management in Australia. However, using the logical skip function in Qualtrics, some questions only appeared to specific group of respondents, making the number of questions to be answered fewer. The online questionnaire consisted of 11 question packages with each package being intended for the investigation of a particular C&D waste management dimension. The question packages targeted participant demographic details, general overview of C&D waste management issues, levy imposition, C&D waste regulation, the impact of (and response to) the China's new waste policy, waste-related advisory/mandatory schemes, C&D waste management practice in construction firms, C&D waste material recycling in recycling facilities, C&D waste and construction material manufacturers, C&D waste and delivery and transport, and establishment of C&D waste marketplace. For this study, only responses from two packages (i.e. participants' demographic details and establishment of C&D waste marketplace) were selected and analysed. In total, these two packages consisted of five questions that were designed to elicit the most relevant information about C&D waste market development. The questions on participants' demographic details sought the participants' field of activity, experience and the primary location of their activity, while other questions focused on participants' agreement and opinion on C&D waste marketplace.

2.2 Economic modelling: A case study

In real-world conditions, there are often many interacting factors that affect the economy and economic activities. These factors include but not limited to fluctuations in economic cycles, location and size of the construction and waste generated, local and national waste management regulations, market conditions such as the strength of supply and demand balance and performance of waste management and recovery industry. Hence, the case study and the estimation associated to it is not indicative of standard practice in the industry as there are several factors that determine a C&D firm's decision as to how to manage their C&D waste. Hence, the interpretation of results should be made with this caveat in mind.

The economic evaluation modelling in this research builds upon a theoretical framework that is developed and applied by Tran5 (2017). To simplify the economic evaluation, several assumptions on the conditions of the study case scenarios are made. The assumptions are based on consultations with experts and previous literature in the C&D waste management context. These assumptions are listed below:

1. The costs of traffic control management are not considered
2. The levy charged for each volume of the waste is based on the state announced levy rate ($65.9: metropolitan; $57.76: regional)
3. The price of recycled material is $50 on average
4. The skip bins only contain C&D waste of 50% of bins nominal capacity
5. Google Maps is used to estimate distances from the waste generation origin, construction site, to various waste landfill and recycling centres
6. The revenue lost from not selling recycled/repurposed materials is defined as the cost of waste materials
7. In this research, the aggregated information represents average values of cost and tonnage for waste materials. This method is better suited to the study scenarios as there is a lack of necessary information about certain waste materials

A case scenario is developed to capture how various the management of C&D waste in Australia economically perform. Table 4 presents a summary of the characteristics of these scenarios:

Table 4. Characteristics of case studies investigated

Project	Characteristics of the project	Waste management strategy
Building a residential complex in Melbourne, Vic	Building a 12-story residential high-rise complex in the inner city of Melbourne	Waste produced from demolition and construction phases in this project are to be sent to a vicinity landfill, recycling facility and a further away from regional landfill

2.3 Data analysis

After screening the survey responses, the selected data was analysed using descriptive analysis. In total, 132 participants took part in this online survey. Frequency distribution was the main statistical measure to compare different categories of responses received from participants. Excel Spreadsheet v. 2016 was used to archive, screen, and analyse the data collected. For the economic evaluation, descriptive analysis is used to compare the economic performance of various waste management methods.

3. Research Results

3.1 Participants profile

To better understand and analyse the responses received from the participants, three questions were formulated to seek participants' demographic data, including the industry and geographical zone in which they perform their main activities and the length of experience. More than 50% of the participants belonged to three sectors: waste recovery (20%), construction (16%), and landfilling (15%). In terms of their length of experience working in C&D waste space, as shown in Table 5, about 44% of participants had fewer than six years, and fewer than 30% of them had worked in an industry related to C&D waste management for more than 15 years at the time of running the survey. More than 60% of participants were based in the two large states of Victoria and NSW (Table 5).

Table 5. Study participants' profile.

Question	Distribution	(%)
Field of activity	Construction	16
	Demolition	8
	Landfill	15
	Legislation	6
	Industry association	6
	Waste recovery	20
	Waste delivery and transport	10
	Consultancy	7
	Manufacturing	4
	R&D	3
	EPA enforcement	5
Experience	<6 years	43.1
	6-10 years	13.7
	11-15 years	16.7
	>15 years	26.5
State/territory	Australian Capital Territory (ACT)	1.8
	New South Wales (NSW)	24.3
	Northern Territory (NT)	6.4
	Queensland (Qld)	16.2
	Tasmania (Tas)	3.6
	Victoria (Vic)	30.6
	Western Australia (WA)	17.1

3.2 Market incentives to reduce waste disposal

Participants were asked to express the level of their agreement with having more market incentives for C&D waste management. The question posed was: Express your degree of agreement on the following statements– More market incentives (e.g. remove regulatory barriers; foster minimum recycled content in products; invest in technologies to recycle and facilitate trade such as trading platforms) can better increase C&D waste reduction, reuse and recycling in Australia. For the first category, the responses showed that the respondents significantly favoured market incentives (Figure 3), with more than 92% level of agreement and somewhat agreement.

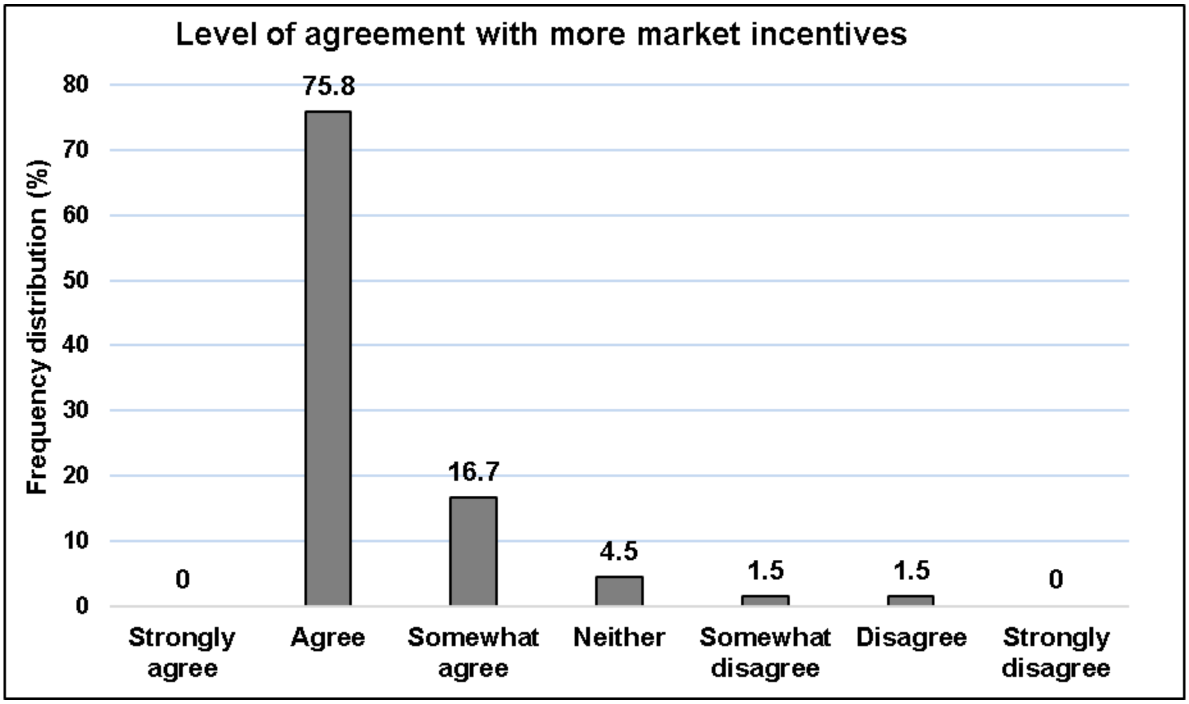

Figure 3. Frequency distribution of agreement level with the increased implementation of market incentives in C&D waste stream

3.3 Factors impacting the development of C&D waste market

Development of a domestic market for recyclables is a sustainable method within the circular economy context (Shooshtarian et al., 2019e). However, as noted, the development of such a market needs to be done carefully. Various factors can impact market development negatively or otherwise. The choices included 'investment in technology and infrastructure', 'virgin material tax', 'product stewardship', 'employment', 'sustainable procurement', 'adequate supply chain system', 'penalty for illegal dumping', 'sustainability rating schemes (i.e. GS and SI)', 'national approach', 'landfill levy' and 'waste data collection & reporting'. As depicted in Figure 4, respondents indicated that ‘investment in technology and infrastructure’ (16.7%), ‘sustainable procurement’ (14.6%) and ‘landfill levy’ (13.2%) are three major influential factors that have a significant impact on market development.

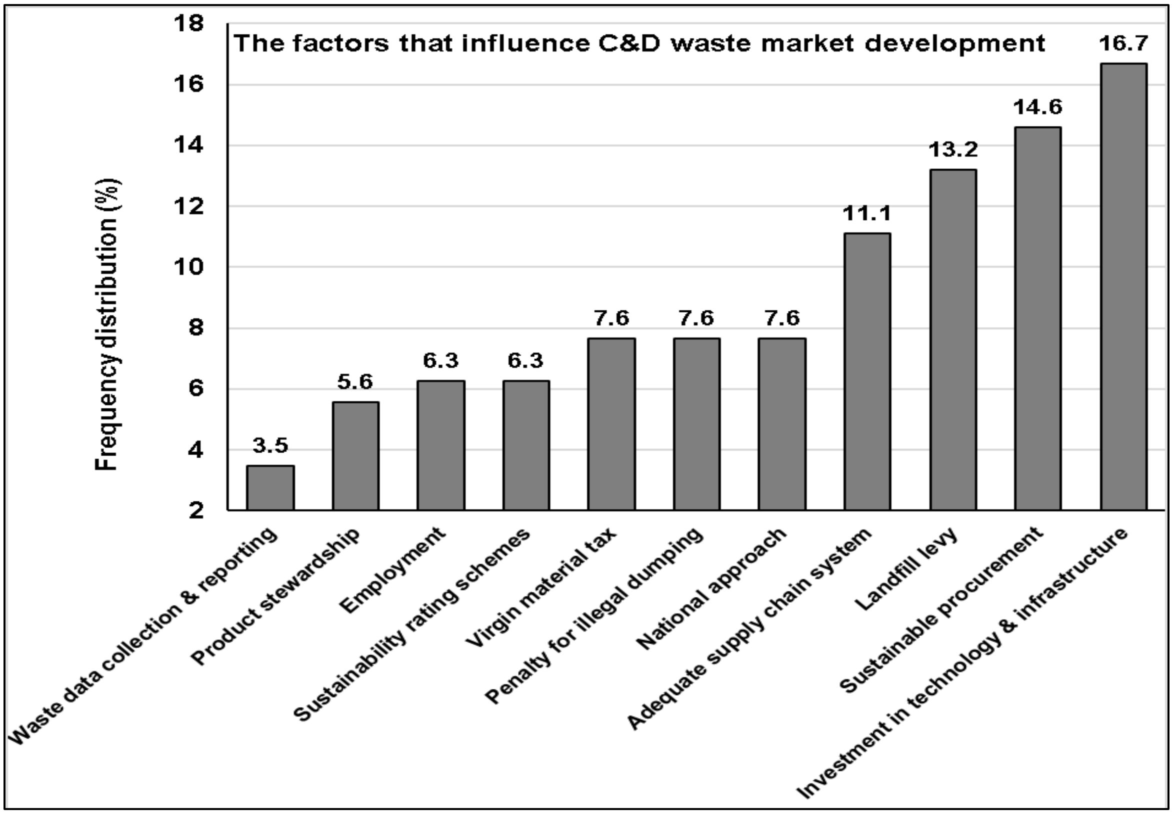

Figure 4. Participants' selection of factors that influence the establishment of C&D waste market.

3.4 Economic performance of various waste management techniques

This section of the report aims to cast light on the performance of a marketplace in the management of C&D waste in Australia. The third objective of this report is to conduct a feasibility study on creating a marketplace to connect organisations and industries across jurisdictions for trading waste. Particularly, the section presents comparative results of different waste management options using a hypothetical case study in a Melbourne inner suburb was considered to compare ‘landfilling in metropolitan’, ‘recycling’, and ‘landfilling in regional areas’. Waste disposal to a landfill is used as the base of comparison.

The comparison among various C&D waste management methods will help provide economic information to conduct a feasibility analysis for developing a marketplace to trade C&D waste. A hypothetical case study in a Melbourne inner-city suburb was considered to compare: 1) landfilling in metropolitan areas; 2) landfilling in regional areas, and 3) recycling. Waste disposal to a landfill is used as the base of comparison.

3.4.1 Landfilling

Landfilling is the worst option for the management of the C&D waste stream, according to the waste hierarchy model. To evaluate the economic aspects of this management option, a case scenario of construction of a high-rise residential building in the inner city of Melbourne (Suburb: South Yara) is analysed. The C&D waste composition of the potential waste that is produced in the pre-construction and construction phases of this project, is tabulated in Table 6:

Table 6. Waste generated during demolition and construction

Material	Quantity
Pre-construction/demolition	
Asbestos contaminated debris/waste	205,000 kg
Brick	3,000 kg
Clean fill	20,000 kg
Concrete rubble	2,000,000 kg
Tile	350 kg
Non-ferrous metal	6, 000 kg
Steel	120,000 kg
Construction	
GIB plasterboard sheet	45,000 kg
Timber	224, 000 kg
Plaster	1,500 kg
Brick	1,000 kg
Tile	900 kg
Steel	2,710 kg
Cardboard	1, 130 kg
Hardfill (mix of a few masonry materials)	20, 000 kg
General	100,000 kg
Total weight	2, 499,460 kg ~ 2,500 t

In this scenario, the waste generated in the project is sent and disposed of in the nearest landfill, Altona North Landfill, that accepts C&D waste materials. Figure 5 depicts the travel distance and the time for transferring the waste from the construction site to the intended landfill.

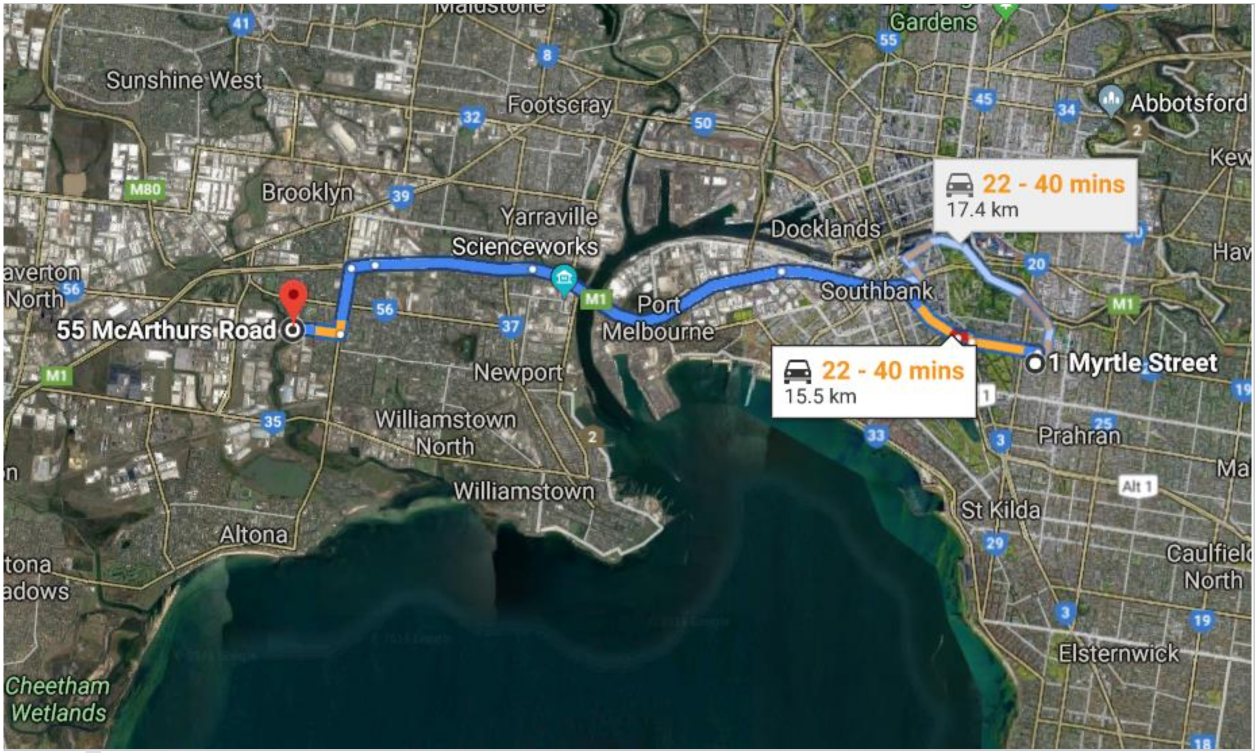

Figure 5. The 'origin- to-destination' travel distance/time of the study C&D waste load.
Source: google map (2019)

Furthermore, the figures presented in Table 7 outline the base cost rates that are used in the calculations for economic modelling of C&D waste landfilling. The cost structure represents three cost clusters namely waste collection, waste transport, landfill charges.

Table 7. Base rates used to estimate waste management costs

Description	Index	Amount	Unit
Charge-out rate per machinery (including labour)	Cr	150	$/h
Average fuel capacity of the machine		450	L
Haulage cost per trip	H	12.5	$
Diesel fuel (based on 25 L/h)	F	1.5	$/h
Loading capacity	C	20	t/skip
Loading factor	lf	1.5	N/A
Landfill levy rate in metropolitan Victoria	LL	65.9	$/t
Landfill levy rate in regional Victoria	LL	57.76	$/t
The number of machines	Ma	N/A	N/A
The unit cost of collecting waste	Uc	19	$/t
Total haulage cost per trip	H	371	$/t
The unit cost of waste sorting at a landfill	Us	49	$/t
The total time that is taken to sort out the waste load	T	1	Hour
Distance from a construction site to a landfill/recycling facility	d	N/A	km

The unit costs and base rates are current as of 2019 and are based on Rawlinsons (2018)[6]

The charge-out rate (Cr) presented above is for machinery and labour, average fuel capacity of machinery and cost for diesel fuel. According to Rawlinsons, the average Cr is $ 150 per hour.

Collecting waste costs
The unit cost of collecting waste (Uc) is estimated in three steps using the following equation:

$$\boldsymbol{Uc = \frac{H}{C}} \qquad \textbf{Equation 1}$$

Where H is haulage cost per trip and C is the truck capacity.

Step 1: To calculate haulage cost per trip the following equation is used

$$H = d \times hr \times lf \quad \textbf{Equation 2}$$

Where d is the distance from the construction site to the nearest waste management facility, hr is haula ge rate and lf is loading factor for C&D waste. In the study case d is 16.5 km on average (Figure 5), hr is $12.5 per km, and lf is 1.5 for C&D waste.

$$\mathrm{H}= 16.5\ (\mathrm{km}) \times 12.5\ (\$/\mathrm{km}) \times 1.5= 309.37 \sim \$310$$

Step 2: To calculate the unit cost of collecting waste the above rates are replaced in Eq. 1

$$Uc = \frac{\$310}{20\ (tonnes)} = \$\ 15.5$$

For the total waste generated in the project, the total waste collection cost is:

$$2{,}500\ (\mathrm{tonnes}) \times 15.5\ (\$/\mathrm{t}) = \$\ 38{,}750$$

The unit cost of energy
Collecting and landfilling the waste requires machinery at two stages: carting the waste away and proces sing the waste at the landfill. The machines consume energy and its associated costs are calaculated in t wo steps as follows:

Step 1: to calculate total trips (T_{trip}) for sending the case study's C&D waste to landfill Equation 3 is used

$$\mathrm{Ttrip} = \frac{W}{c} = \frac{2500}{20\ (\frac{tonnes}{truck})} = 125 \quad \textbf{Equation 3}$$

Step 2: to calculate the unit cost of energy used that the following equation is used

$$\mathrm{Uen} = \frac{Tmachine \times F \times cf}{w} \quad \textbf{Equation 4}$$

Based on Rawlinsons' construction cost guide, the fuel capacity of a truck/large machine is 450 L.

$$Uen = \frac{125\ (machine)\ \times 450\ (L) \times 1.5\ (\$/L)}{2500\ (tonnes)} = \$33.75\ (\frac{\$}{tonne})$$

Therefore, for the total volume of the waste, $84,375 is spent on the energy.

Landfill levy

Levy is only imposed on the unrecyclable materials, even at landfills, there is a degree of recycling. In this research, it is assumed that 30% of the waste disposed of to landfill is not subject to landfill levy, which is equal to 750 t. Currently, in Victoria, the landfill levy for metropolitan areas is $65.9 per t for C&D waste stream. The landfill levy cost for the total waste in this case study is:

$$1{,}750\ (\mathrm{t}) \times 65.9\ (\$/\mathrm{t}) = \$\ 115{,}325$$

Total cost for landfilling

According to the calculations above the total cost of landfilling of C&D waste generated in this case scenario is $238,450 consisting of $38,750 (cost of waste collection), $115,325 (cost of waste landfilling), and $84,375 (cost of energy used). Table 8 presents the cost structure of the landfilling of the waste generated in this case study.

Table 8. The cost structure for waste landfilling

Cost description	Cost (AUD $)
Cost of waste collection	38,750
Cost of waste landfilling	115,325
Cost of energy used	84,375
Total	238,450

3.4.2 Recycling

Cost of sorting waste at the construction site

There are three steps to determine waste sorting. To calculate waste sorting cost (Us) at the construction site the following equation is used :

$$\boldsymbol{Uc = \frac{TCr \times T}{Ws}} \quad \textbf{Equation 5}$$

Where TC_r is the total charge-out rate, T is the total time taken to sort out the waste load, and W the weight of waste.

Step1: The first step is to calculate charge-out rate. TCr is calculated using the following equation:

Step1: $TCr = Ma \times Cr$

Where Ma is the number of machines operating at a landfill to process waste, these include trucks and specialised machinery. According to the literature review, for the specified quantity of waste in this case study, 13 machines will be required. Cr is the average charge-out rate that is assumed to be $150. From the equation above (Eq. 6) the total Cr is estimated to be $1,950 per hour.

$TCr = 13 \times 150$ = $1950 ($/h)

Step 2: The next step is to estimate the total time for waste sotring at the construction site, the assumption is that it takes half an hour (Ts) to sort one 20-t capacity skip bin full of waste. The following equation is used to estimate total time (T):

$$T = \frac{w \times Ts}{c} = \frac{2500\ (tonnes) \times 0.5\ (hour)}{20\ (tonnes)} = 62.5\ hours$$

Step 3: The last step is to use the estimated figures above to calculate waste sorting cost (Us) in Eq. 3.

The total cost of sorting waste at the construction site is \$49 × 2500 tonnes = \$ 122, 500

Cost of waste collection

For the total waste generated in the project, the total waste collection cost is:
2500 (tonnes) × 12.5 (\$/tonnes) = \$ 38,750

The unit cost of energy

Collecting and recycling the waste requires machinery at two stages: carting the waste away and process ing the waste at the recycling facility. The machines consume energy and it is associated costs are calaculated in two steps as follows:

Step 1: to calculate total trips (T_{trip}) needed to send the case study's C&D waste to the recycling facility is calculated using Eq. 3

$$\text{Ttrip} = \frac{W}{c} = \frac{2500}{20\ (\frac{tonnes}{truck})} = 125$$

Step 2: to calculate the unit cost of energy, the following equation is used:

$$\text{Uen} = \frac{Tmachine \times F \times cf}{w} = \textbf{Equation 7}$$

Where $T_{machine}$ is the number of machines used in the project, F is the average fuel capacity of a large machine/truck, and cf is the cost of diesel fuel. According to the literature review, for the specified quantity of waste in this case study, 13 machines are needed. Therefore, in total, 138 machines ($T_{machine}$) are used in the project.

$$T_{machine} = T_{trip} + M_a = 125 + 13 = 138$$

Based on the Rawlinsons' construction cost guide, the fuel capacity of a truck/large machine is 450 L.

$$Uen = \frac{138\ (machine)\ \times 450\ (L) \times 1.5\ (\$/L)}{2500\ (tonnes)} = \$37.26\ (\frac{\$}{tonne})$$

Therefore, the total energy associated costs for the study waste quantity is \$93,150 as per the following calculations:

2500 (t) × \$37.26= \$91,150

Cost of waste recycling

When proper waste sorting at the construction site takes place, a larger amount of waste could be recycled. For modelling purposes, we assume that 65% of the waste generated could be recycled. The recycled rate, therefore, is 65% of total waste recycled (SM). As a result, the total quantity of recyclables in this project in 1,625 t as per the following calculations:

$$SM = w \times RR = 2500 \times 65\% = 1625 \text{ (tonnes)}$$

Assuming it takes 1 hour to recycle C&D waste, the total hours (Tr) required to recycle waste is:

$$Tr = SM\ (tonnes) \times 1\left(\frac{hour}{tonne}\right) = 1625 \times 1 = 1625 \text{ (hours)}$$

Therefore, the unit cost of recycling is estimated using the following equation:

$$Urc = \frac{Trc \times Cr}{SM} = \frac{1625\ (hours) \times 150\ \left(\frac{\$}{hour}\right)}{1625\ (tonnes)} = 150\ (\$/tonne)$$ **Equation 8**

Therefore, the total cost for recycling is \$243,750. The remaining part of the waste load (875 t) has to be landfilled as it cannot be recycled. The cost for landfill for this waste is 875 (t) × \$65.9 (\$/t) = \$57, 662.

Benefits of recycled waste materials

As mentioned above, only 65% of the materials (1,625 t) sent to the recycling facility can be recycled and turned into new marketable products. As the mixed load contained several different materials with varying value, \$50 per t was assumed to be a realistic average monetary value of these materials. Therefore the revenue that can be captured from recycling is:

$$1625\ (tonnes) \times 50(\$) = 81,250$$

To determine the economic viability of recycling in C&D waste management system, it costs and associated benefits were quantified and presented in Table 9.

The total cost that this method of waste management will have is \$ 474, 563, which in comparison with landfilling is 99% more expensive.

Table 9. The cost and revenue of recycling of C&D waste

Cost/revenue description	Amount (AUD \$)
Cost of sorting waste at the construction site	122,500
Cost of waste collection	38,750
Cost of waste recycling	243,750
Cost of landfilling of unrecyclable waste	57,662
Cost of energy used	93,150
Revenue from selling recycled materials	81,250
Total	474, 563

3.4.3 Transferring waste between metropolitan and regional areas

Changes in the costs

To understand how waste transferring, as a common practice, is economically feasible, a cost estimation for transferring waste to a regional landfill was carried out. In the Victorian regional areas, a cheaper rate ($57.76) applies to C&D waste compared to the metropolitan areas ($65.9). Figure 6 shows the location of a regional landfill in Ballarat and the construction site.

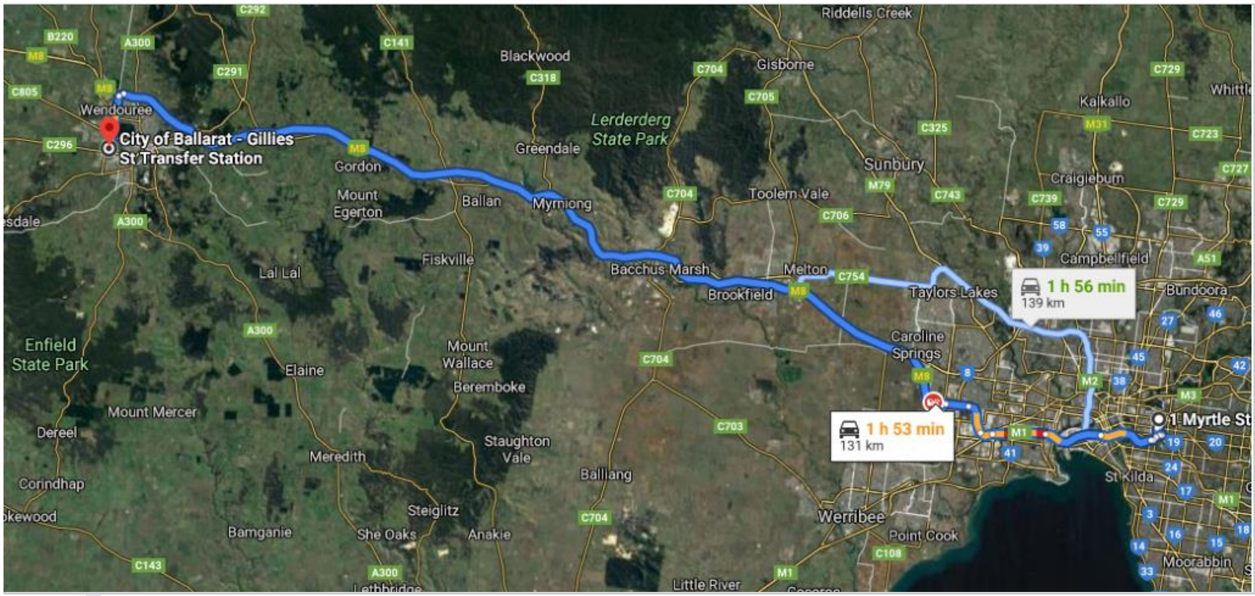

Figure 6. The 'origin- to-destination' travel distance/time of the study C&D waste load.
Source: google map (2020)

In this comparison, only two factors will differ, landfilling costs and the cost unit of waste collection. In terms of landfilling costs the new cost will be 1,750 (t) × 57.76 ($/t) = $101,080. As for waste collection, the following calculations show a significant increase in the costs after a new distance is substituted in Eq. 2:

H= 135 (km) × 12.5 ($/km) × 1.5= 2,531.25 ~ $2,530

Step 2: To calculate the unit cost of waste collection the above rates are replaced in Eq. 1

$$Uc = \frac{\$2530}{20\ (tonnes)} = \$\ 126.5$$

For the total waste generated in this case study, the total waste collection cost is:

2500 (t) × 126.5 ($/t) = $ 316,250

As shown in Table 10, the final cost for this waste management method is $501, 705. This cost is likely to be a major deterrent to landfilling in Victoria regional areas despite having lower levy rates. The total cost is 5.7% more than recycling in a nearer facility.

Table 10. The cost structure of waste landfilling in regional Victoria.

Cost description	Cost (AUD $)
Cost of waste collection	316,250
Cost of waste landfilling (tax levy)	101,080
Cost of energy used	84,375
Total	501,705

4 Discussion

4.1 Primary strategies to develop and stimulate markets

The results of the survey targeting key C&D waste management stakeholders showed that they significantly agree with more market incentives and indicated that investment in technology and infrastructure, sustainable procurement and landfill levies are three major influential factors that have a significant impact on market development and operation. Technically, several waste minimisation practices and strategies, such as extended producer responsibility, depend on the availability of technologically advanced local infrastructures (Shooshtarian et al., 2020c). The use of new technologies, such as Building Information Modelling (BIM), Geographical Information Systems (GIS) and the blockchain can solve several issues towards the successful operation of a market for recyclable C&D waste materials.

The Australasian Procurement and Construction Council Australian and New Zealand Government Framework for Sustainable Procurement is implemented by the federal government to pursue three aims when procuring goods, services, works, and utilities. These aims involve the reduction of environmental impacts, social impact, and economic impacts through the procurement process. This framework also shares some premises with the circular economy in considering alternatives to the 'take, make and dispose of' approach. According to this framework, the government has a decisive role in providing a market driver for increased use of recycled materials in the goods and works that it procures. Therefore, the federal government and some state governments developed SP guidelines to coordinate their decisions and actions towards SP and the purchasing of recycled materials. In 2012, the state government of SA was the first authority to release a Sustainable Procurement Guide. One year later, in 2013, the federal government also released the first Australian guideline on SP. This work was further complemented by state-specific guidelines to tailor sustainable procurement requirements in the ACT (2015), NSW (2017) and WA (2017).

There are multiple other sources that necessitate having a landfill levy in place in regard to market development (Shooshtarian et al., 2020b). For instance, several submissions to Environment and Communications References Committee (2018, pp. 65-67) indicated that levy revenue could be used to invest in the development of a market for recycled materials through low-interest (subsidised business) loans or financial incentives and R&D. The National Waste and Recycling Industry Council firmly believes that market distortions take place due to variation in landfill levies across jurisdictions (Environment and Communications References Committee, 2018, p.59).

4.2 Policy development

The results of the study contribute to policy development activities across the Australian states and territories. Notably, those public agencies that are responsible for strategising market development in Australian governments can benefit from the input provided by participants about the main priorities and key improvement areas that affect market development and stimulation. At the time of writing this report, several public agencies such as Green Industries (SA) and Waste Authority (WA) have released consultation papers to obtain expert and public opinions about waste management priorities and action plans. The submissions are supposed to be adopted for and inform policy development in the given states and territories.

4.3 An economic evaluation of C&D waste management methods

Comparison among the three scenarios in the case study reveals important information about the major implicit and implied factors that can influence decision-making processes in the construction industry. Findings regarding these major factors include:

1. Landfilling the waste, if it is not too far away, is still a more economically viable option compared with waste recycling; this case study showed that landfilling is 99 per cent cheaper than recycling.
2. Transportation costs are an instrumental factor in the selection of the method to manage C&D waste; they can diminish other benefits such as lower levy rates that would have been obtained in the absence of high transportation costs.
3. A higher landfill levy is a strong disincentive tool to encourage recycling activities.
4. Without a healthy and sustainable market, the minimum benefits that are currently attainable will be diminished, which further deteriorates the imbalance between recycling and landfilling in favour of landfilling.
5. 5. A consistent method for valuation of intangible costs such as the achievement of a reputation for further recycling needs to be offered by the federal government.

5 Conclusion

This study surveyed 132 Australian key C&D waste stakeholders regarding their perceptions on the market development for recyclable materials. Sustainable procurement, the imposition of landfill levies and investment in technology and infrastructure were identified as the main drivers for the creation and stimulation of markets for recycled materials. Further research is required to understand how the application of these strategies can be optimised and to ensure that the desired outcomes will be achieved. Furthermore, the disproportional frequency of responses from various stakeholders made it difficult to infer a meaningful relationship between participants' profile (location, experience, and activities) and their responses to questions related to market development. It is recommended that future research projects focus on identifying the interaction between these factors. Lastly, it is suggested that further studies investigate the performance of existing marketplaces operating across Australia to find opportunities for further improvements. The economic modelling revealed that transportation costs are an instrumental factor in the selection of the method to manage C&D waste; they can diminish other benefits such as lower levy rates that would have been obtained in the absence of high transportation costs. The project findings can inform decisions and policies developed in Australia to establish end markets for C&D waste management effectively. The study results could be used by policymakers and decision-makers to develop policies that will facilitate effective management of C&D waste stream in Australia.

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