Research trends in construction and demolition waste management in Australia

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Abstract: Construction and demolition (C&D) waste generation has adverse impacts on the environment. Researchers have identified different methods to improve waste management practices, but waste generation still continues. It is necessary to identify the current trends in waste management to provide better solutions for waste generation. This research aims to provide a holistic understanding of the studies on Australian C&D waste management in the last two decades. For achieving this, trends and directions of Australian C&D waste management from January 1998 to June 2018 were systematically analysed in the research by using diagrams and tables. A total of 24 journal articles focusing on Australian C&D waste management were retrieved from seven international peer-reviewed journals. A framework, integrating with this research's findings, was developed to recommend future research directions for Australian C&D waste management. This framework suggests to find the most suitable waste management approaches by integrating technical and human aspects in waste management practices, consider the lifecycle of construction projects in C&D waste management by involving the circular economy concept and managing all relevant stakeholders in waste management practices. Thus, this study can serve as a guide for practitioners and researchers to provide better solutions in Australian C&D waste management.

Keywords: Australia; construction and demolition waste; construction projects; waste management.

1. Introduction

The construction industry generates a large amount of construction and demolition (C&D) waste and often discards them in an unsustainable manner. Construction and demolition waste is one of the most massive waste flows in the world (Islam *et al.*, 2019). It is estimated that over 10 billion tonnes of C&D waste is generated annually in the world (Wang *et al.*, 2019). When it comes to the Australian context, C&D waste as the second-largest waste stream and it produces approximately 19 million tonnes annually (Pickin *et al.* 2018). The other two core waste streams (i.e., commercial and industrial waste, and municipal solid waste) are generated near 33 million tonnes and 13 million tonnes, respectively (Pickin et al. 2018). Poon *et al.* (2013) also investigated that the average of C&D waste in various countries has come to around 33% of their total waste, but this rate is near 44% in Australia.

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Construction and demolition waste tends to be highly heterogeneous depending on its origin. More than 90% of these comprise of concrete, mortar, brick, block, metal and timber (Islam *et al.*, 2019). The composition of C&D waste could also contain hazardous substances (e.g. asbestos, particulate matters, etc.), which could be toxic and carcinogenic (Gálvez-Martos *et al.*, 2018). Similarly, waste generation has negative impacts on the environment (Mukherjee and Muga, 2009) due to the consumption of non-renewable natural resources and energy; generation of harmful gases; and the land and water pollution (Ding *et al.*, 2016; Marzouk and Azab, 2014; Yuan, 2013; Lu and Yuan, 2011; Yuan and Shen, 2011). Roussat *et al.* (2008) have highlighted that human health also could be affected as a result of hazardous components produced from demolition waste.

So far, several studies, researching an extensive range of topics related to C&D waste management have been published in the literature in the last few decades. However, these studies have different emphases hence the need to synthesise the state-of-art in Australian C&D waste management practices towards improving performance and consolidating on sustainable practices is required. The National Waste Policy has appealed to better support economy, protect people's health, and reduce environmental problems in Australia by controlling and using the value of waste materials moving towards a circular economy (Australian Government Department of the Environment and Energy, 2018). The circular economy concept focuses on closing a loop of one product's lifecycle while maximally maintaining its service value through bringing the product back into its lifecycle loop at the end of the utilisation (European Commission, 2019). This concept can be applied to not only to minimise the use of resources and waste generation but also to maximise the opportunities in recycling area by creating markets and jobs, which will have positive impacts on the economy (European Commission, 2019). However, most previous Australian research has represented a waste management hierarchy as the gold standard; this hierarchy manages waste by using waste avoidance, reduction, reuse, recycling, treatment, and landfill in ascending order of their adverse effects on the natural environment from low to high. It seems that this gold standard which is only based on the environmental preference is out of date for catching up the circular economy. Therefore, it would be useful and effective to evaluate the latest trends of C&D waste management in Australia in order to find possible solutions to improve current waste management practices.

Lu and Yuan (2011) explained that published studies generally indicate changes of interests and attention on some specific subjects as influenced by the respective authors. Furthermore, they revealed that such alternating interests had become a reason for the absence of a systematic study related to C&D waste management in many published studies. Thus, the aim of this research is to provide a systematic review of C&D waste management in Australia from January 1998 to June 2018, and further analyse whether those trends have been discussed and acknowledged in the current literature related to the Australian context.

The rest of the paper is structured as follows: Section 2 describes the research methodology; Section 3 deduces significant findings in light of a systematic and sequential review of the literature to spotlight the C&D waste management; Section 4 reveals future directions for Australian C&D waste management.

2. Research method

A systematic review was undertaken in this research by analysing journal articles published in seven major international journals from 1998-2018 in order to understand a holistic view of the current C&D waste management studies in Australia. The systematic review was conducted by following the approach adopted by Lu and Yuan (2011). The procedure for retrieving relevant papers involved, setting keyword boundaries (Figure 1) as string 'texts' in the Google Scholar, Scopus and Science Direct database for crucial facets of C&D waste analysis, including waste generation, waste management approach, waste management hierarchy, and sustainability impacts. A 3-step process was followed to ensure that the relevant papers were searched, retrieved, and analysed. The specific processes include selecting scholarly journals, retrieving papers, and analysing content by using NVivo software package.

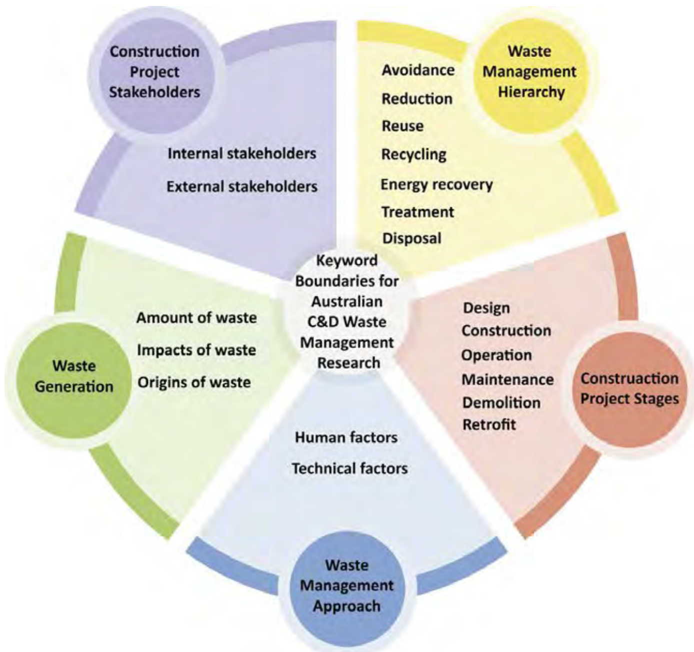

Figure 1: Keyword boundaries of the study

2.1. Selecting scholarly journals and retrieving papers

When selecting the journal articles, this research also considered rationales used by other researchers, who conducted similar studies in the waste management area. For example, Lu and Yuan (2011) and Yuan and Shen (2011) considered eight academic journals in their reviews in waste management. These journals are Resources Conservation and Recycling (RC&R), Waste Management (WM), Waste Management and Research (WM&R), Construction Management and Economics (CME), Building and Environment (B&E), Journal of Construction Engineering and Management (CEM), Automation in Construction (AIC), Engineering Construction and Architectural Management (ECAM). Among of them, WM, WM&R, and RC&R are three internationally reputable scholarly journals, mainly focusing on waste management (Lu and Yuan, 2011), and publishing some articles regarding the C&D waste management (Lu and Yuan, 2011; Yuan and Shen, 2011). According to Yuan and Shen (2011), CME, B&E, CEM, AIC, and

ECAM are also mainstream journals, publishing works related to C&D waste management. Other journals, publishing papers about C&D waste management, can also be potential target journals in this research. These journals are Construction Innovation (CI), Management of Environmental Quality: An International Journal (MEQ), Journal of Industrial Ecology (JIE), and International Journal of Construction Management (IJCM). Thus, the retrieving work started with searching academic articles in the twelve journals via the selected database based on the keyword boundaries. This initial search yielded a list of 21 papers. Authors have checked the above mentioned twelve journals issue-by-issue from January 1998 to June 2018 to identify the papers published in relation to the Australian C&D waste management. After this process, WM, WM&R, RC&R, CME, ECAM, MEQ, and IJCM were identified as the potential journals to include in the review and 3 extra academic articles were identified from this process. It was, therefore, decided to choose these seven journals as final target journals for identifying academic articles relevant to Australian C&D waste management. As a result of that a total of 24 scholarly papers were included in the review.

2.2. Analysing content by using NVivo

An in-depth analysis of relevant publications is required to extract meaning and validate trends. As content analysis is one of the widely and flexibly adopted research techniques to analyse text data, it was applied to identify the trends and patterns of Australian C&D waste management in this research. Krippendorff (2013, pp. 24) defined content analysis as 'a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the context of their use'. In its most straightforward format, content analysis is the extraction and categorisation of information from documentary sources (Zhou *et al.*, 2015). Saldaña (2016) provided a thorough review of various software programs for content analysis, considering functions, characteristics, and limitations of these software programs. Particularly, NVivo 12 Plus software program has been found useful for importing source materials or bibliographical data from other data sources. Specifically, some essential functions in NVivo 12 Plus software program (e.g. 'Code' and 'Model') provide help for users to classify, organise and manage tremendous amounts of information, and explore complicated relationships in the information. Thus, NVivo 12 Plus computer-assisted qualitative data analysis software was used in this research to analyse the data. A tentative framework matrix was created to analyse the 24 journal articles retrieved from seven selected journals. The first-level nodes and second-level nodes were created to analyse the data on selected papers based on the keyword boundaries. For example, Table 1 summarises the first-level and second-level nodes, which were created to identify project stakeholders related to C&D waste management in the selected time period.

Table 1: A tentative framework matrix developed on NVivo

Year (Continuing)	First-Level Nodes (Continuing)														
	Construction project stakeholders														
	Second-Level Nodes (Continuing)														
	Client/Customer	Owner	User	Architect	Designer/Consultan	Engineer	Office-based	Project manager	Site manager	Worker/Labour	Contractor/Builder	Subcontractor	Government	Supplier	Public
1998-2004	√			√	√				√	√	√	√		√	
2005-2011	√			√						√	√		√	√	√
2012-2018	√	√	√	√	√	√	√	√		√	√	√	√	√	√

3. Analysis and discussion

In order to better understand the overview of current waste management studies in Australia, it is vital to analyse all identified C&D waste management studies systematically. All retrieved papers were classified based on the classification of the selected period divided into three equal analysis periods as 1998-2004, 2005-2011 and 2012-2018. Based on the previous tentative framework matrix, a visual summary was established to assist in analysing and understanding the development of Australian C&D waste management research, as shown in Figure 2. This figure is divided into three main sections: the green section represents the Australian C&D waste management research from 1998-2004; the blue section represents from 2005-2011, and the yellow section shows research from 2012-2018. Each section includes a curve pie indicating a total number of studies published in the selected period with its percentage of total studies published in 21 years. It should be mentioned that the sum of these percentages exceeds 100% as some of these studies focus on more than one area; for example, in the spectrum of C&D waste management hierarchy, the sum of all percentages exceeding 100% because of some retrieved studies focusing on more than one method in the waste management hierarchy.

Figure 2 highlights the C&D waste management hierarchy, construction project lifecycle demonstrating the stages in which C&D waste is distinctive and in which C&D waste management strategies/approaches can be applied. It also emphasises waste management approaches ranging from human factors to technical factors, and construction project stakeholders regarding C&D waste management. The C&D waste management approaches were classified under technical and human factors in line with technical viewpoints (i.e. technologies) and social issue standpoints (i.e. economic or managerial measures) used by Lu and Tam (2013) in their research. In Figure 2, technical factors tend to be measurable, and their impacts are significant, real and explicit; for example, a specific design, infrastructure or principle developed in order to enhance waste management practices. Human factors pertain to be immeasurable, and their impacts are recognised as relations of context, power and identities which can transform waste management practices based on human power; for example, interpersonal skills, relationship management or communities of practice in order to improve waste management practices. Also, fifteen types of stakeholders relevant to C&D waste management mentioned by researchers were identified, as shown in Figure 2. It should be mentioned that among these types of stakeholders, some of the papers only used the term ‘designer’ without a specific clarification; thus this paper kept the term ‘designer’ instead of merging with other different individual stakeholders (e.g. architect, engineer). This paper also combined the term ‘designer’ and ‘consultant’ as they represent the cluster of different stakeholders. Besides, synonymous terms are arranged in the same group (e.g. ‘client’ and ‘customer’; ‘worker’ and ‘labour’).

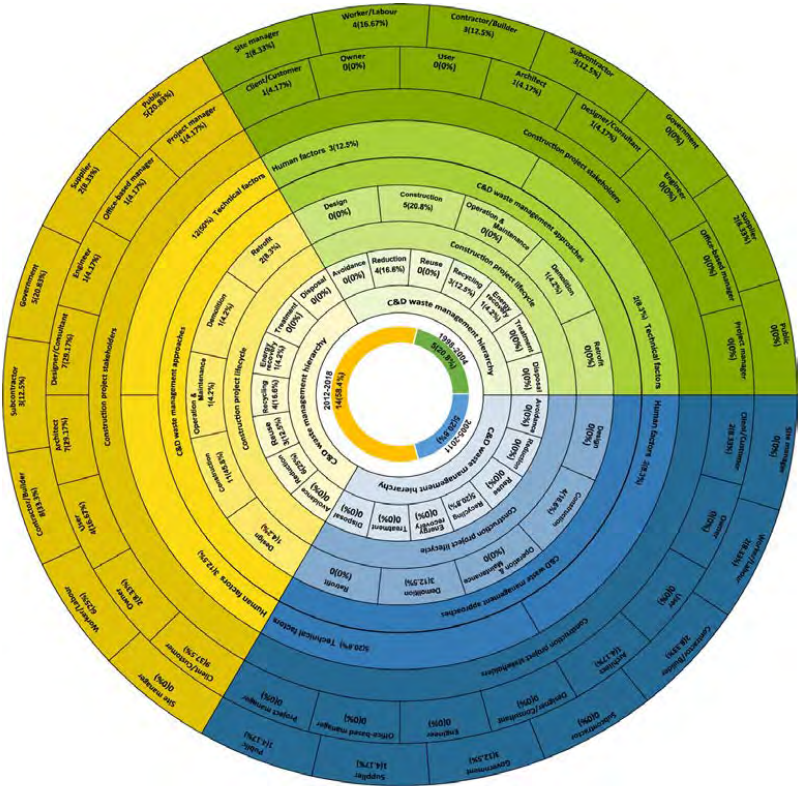

Figure 2: A visual summary of C&D waste management studies in Australia

3.1. Waste management hierarchy and construction project lifecycle

Based on the studies examined, from January 1998 to June 2018, waste recycling (12, 49.9%) and waste reduction (10, 41.6%) have become the predominant waste management strategies, and the reuse of waste has gotten increased attention. These three waste management strategies have less adverse environmental impacts based on the stakeholder preference in the waste management hierarchy. However, waste reduction, reuse and recycling should be considered and be involved in all stages of the construction project lifecycle (Treloar *et al.*, 2003). It also is important to find the most suitable strategies/ approaches for each stage of the building lifecycle, rather than only based on the stakeholder preference. Thus, it can be argued that the circular economy concept can be applied to improve the current C&D waste management practices as this concept tries to merge all best existing strategies to benefit the environment, economy and society, as highlighted in section 1. Majority of studies focused on construction (20, 83.33%) and demolition (5, 20.83%) stages in waste management practices throughout the selected period. However, it is important to consider the whole lifecycle when it comes to C&D waste management rather than only focusing on individual stages. Even at the predesign stage, waste management should be considered as a part of the tender documents to allow adequate time and resources for waste management (Udawatta *et al.*, 2015b). Contractually, it is highly essential to keep agreements and contract documents without any mistake, deficiency, ambiguity and unjust risk transfer for minimising and avoiding any potential to rework and produce waste (Mendis *et al.*, 2013). From the whole building perspective, the maintenance and retrofit stages can also be the best places to minimise and improve the environmental impacts of waste management (Treloar *et al.*, 2003). Thus, it can be argued that embracing a lifecycle perspective on buildings as well as considering the most suitable waste management approaches will further improve outcomes in implementing waste management practices.

3.2. C&D waste management approaches and construction project stakeholders

From January 1998 to June 2018, there was a growing concern to technical factors of C&D waste management approaches, i.e. 1998-2004 (2, 8.3%), 2005-2011 (5, 20.8%) and 2012-2018 (12, 50%). As many researchers tend to focus on identify new technology tools or methods in improving waste management practices (e.g. Wijayasundara *et al.*, 2018, 2016; Arrigoni *et al.*, 2018; Rameezdeen *et al.*, 2016; Tam, Tam and Le, 2010; Tam, 2008; Paranavithana and Mohajerani, 2006). Some authors even tried to develop and test possible technology for improving C&D waste management in Australia. Paranavithana and Mohajerani (2006) put forward a possible application of using crushed demolished concrete elements in asphalt concrete. Arrigoni *et al.* (2018) also examined rammed earth incorporated recycled concrete aggregates with a consequence of which way is a sustainable, resistant and breathable construction solution. Wijayasundara *et al.* (2018) evaluated net benefits of producing recycled aggregate concrete in terms of avoidance of concrete waste landfill, extraction of natural aggregate, and transportation of waste and by-products; they obtained a favourable outcome in the use of manufactured recycled aggregate concrete. However, any innovative technique requires many experiments and examinations before using in real projects. These kinds of requirements may challenge the Australian construction industry to the improvement of eco-efficiency as its limited ability in boosting profits but with its demand for more money in introducing advanced technologies (Hu and Liu, 2017). As a result of that, financial support from external stakeholders is crucial to introducing and applying technologies in sustainable construction practices (Hu and Liu, 2017; Tam, 2008). Therefore, it seems that human factors can influence technical factors in C&D waste management approaches when improving C&D waste management practices.

However, the majority of the C&D waste management research focused on technical factors with a lesser emphasis on human factors, as shown in Figure 2. Attitudes and behaviour of project stakeholders are commonly unsupportive on C&D waste management as the profit-driven nature of the construction industry (Udawatta *et al.*, 2015a). The unwillingness of changing institutions slows down the implementation of technology or practices for minimising waste in construction projects (Park and Truck; 2017). Thus, it is necessary to consider human factors in waste management practices to improve current waste management practices (Hu and Liu, 2017; Udawatta *et al.*, 2015a; Lingard *et al.*, 2001). Although researchers have rapidly increased and expanded their interest to different types of stakeholders, most analyses and concerns to project stakeholders were decentralised in their research studies. Based on the studies examined, from January 1998 to June 2018, around half of them mainly focused on some of the internal stakeholders when considering C&D waste management; for example, contractors (13, 54.17%), clients (12, 50%) and workers (12, 50%). However, external stakeholders (e.g.

owners, public, and government) can also become the primary drives of sustainable construction practices to some extent (Hu and Liu, 2017). It is essential to construct relationships among all project stakeholders by high degrees of involvement, cooperation and sharing risks in construction projects with proper supervision under clear instructions for enhancing the performance of waste management practices (Udawatta *et al.*, 2015b). For example, waste management professionals need to receive elaborate training on waste management procedures and techniques (Udawatta *et al.*, 2015b). It would seem, then, that human and technical factors are equally important in C&D waste management approaches. Both of them could serve as barriers when implementing waste management practices in construction projects (Udawatta *et al.*, 2018). In order to achieve robust C&D waste management, it is necessary to consider both technical and human factors with managing all project stakeholders relevant to waste management in construction projects.

4. Future directions

Based on published studies, the line of investigation of this study unearthed two main research areas that can promise in enhancing Australian C&D waste management, as shown in Figure 3.

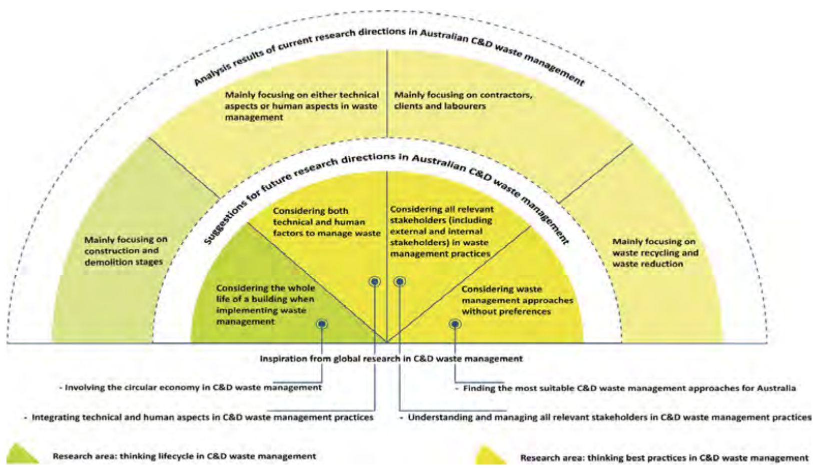

Figure 3: A proposed framework for future C&D waste management practices in Australia

5. Conclusions

This review-based paper was applied to provide a holistic understanding of the research trend in Australian C&D waste management from January 1998 to June 2018. By using qualitative analysis techniques, trends and directions in Australian C&D waste management were systematically analysed and evaluated. A total of 24 academic articles focusing on Australian C&D waste management were screened and retrieved from seven international peer-reviewed journals. Based on these papers, a framework was presented to map out future research directions in Australia's C&D waste management sector. This framework can be used to help in ensuring that a coherent approach to waste management is enacted and monitored in Australia. This framework also can be applicable to the global context as it highlights the importance of considering the involvement of different stakeholders and life cycle thinking in C&D waste management. An improved understanding of the research trends in Australian C&D waste management will preclude a whole lifecycle perspective of buildings when implementing waste management practices in the future. The proposed framework of the research does not seek to inform waste management practitioners about *what to do* but rather provide an avenue for *what they might do to* achieve a more holistic and effective C&D waste management sector. This study, therefore, provides insights and strategies that can be harnessed by researchers, policymakers and practitioners when enhancing C&D waste management practices in Australia.

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