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Critical Factors for Waste Management in Office Building Retrofit Projects in Australia

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Abstract

Office building retrofit is a sector being highlighted in Australia because of the mature office building market characterised by a large proportion of ageing properties. The increasing number of office building retrofit projects strengthens the need for waste management. Retrofit projects possess unique characteristics in comparison to traditional demolition and new builds such as partial operation of buildings, constrained site spaces and limited access to as-build information. Waste management activities in retrofit projects can be influenced by issues that are different from traditional construction and demolition projects. However, previous research on building retrofit projects has not provided an understanding of the critical issues affecting waste management.

This research identifies the critical factors which influence the management of waste in office building retrofit projects through a literature study and a questionnaire survey to industry practitioners. Statistical analysis on a range of potential waste issues reveals the critical factors, as agreed upon by survey respondents in consideration of their different professional responsibilities and work natures. The factors are grouped into five dimensions, comprising industry culture, organisational support and incentive, existing building information, design, and project delivery process. The discussions of the dimensions indicate that the waste management factors of office building retrofit projects are further intensified compared to those for general demolition and construction because retrofit projects involve existing buildings which are partially operating with constrained work space and limited building information. Recommendations for improving waste management in office building retrofit projects are generalised such as waste planning, auditing and assessment in the planning and designing stage, collaboration and coordination of various stakeholders and different specialists, optimised building surveying and BIM technologies for waste analysis, and new design strategies for waste prevention.

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1 Introduction

The Australian office building market is mature and characterised by a large proportion of ageing properties. In 2005, the average age of office buildings since construction or last refurbishment in Australian major capital cities was 17 years for Melbourne, 19 years for Sydney and 13 years for Brisbane (Mulholland et al. , 2005). As retrofitting is normally needed for a building every 25-30 years because of the physical and functional obsolescence of the building stock (Rey, 2004), a large proportion of office buildings in Australia will need to be retrofitted now or in the next five years. In addition, sustainability calls for building upgrades to reduce the impact on the environment and improve building indoor quality. It drives building owners to upgrade assets, reduce vacancy rates and improve rental income (Wilkinson and Reed, 2011).

The increased number of office building retrofit projects in Australia will strengthen the need for waste minimisation and management, as most retrofit projects involve changes in both external and internal appearance of the building (Holm, 2000). Building material waste from the retrofitting process also demonstrates considerable potential of reusing and recycling. Approximately 27% of materials and components through dismantling can be recovered in the fit-out stage or in other building projects, thus exerting less impact on the environment (BFM and BRE, 2004, Seppo and Arpad, 2003). Even though effective management of retrofit waste in Australia's fast-developing office building retrofitting sector is urgently needed, there has not been any substantial research into ways of achieving it. Although the amount of waste from the construction industry can be found from publications of Australian Bureau of Statistics, there are no published statistics on the amount of retrofit waste in any building or construction sector.

From the variables that influence construction and demolition (C&D) waste management as well as characteristic issues specific to office building retrofit projects, this paper identifies the critical factors influencing waste management in office building retrofit projects in Australia. In the following parts of the paper, it first reviews existing research on waste management in general C&D projects and building retrofit projects. It then introduces the research methodology applied for identifying the critical factors of waste management in office building retrofit projects. This is followed by the analyses and discussions of the factors based on the findings from the questionnaire survey, and ended with conclusions. This paper identifies the important issues of waste management for office building retrofit projects and explores their differences from those in general C&D projects. The reasons for the factors' criticality and solutions to respond to these factors are discussed. The research results are expected to contribute to a better understanding of waste issues specific to office building retrofit projects.

2 Identification of Factors for Waste Management in Construction and Demolition Projects

The construction industry presents significant environmental impact because of various construction and demolition works which generate large amount of waste (Mukherjee and Muga, 2009). In Australia, waste generation in the construction industry in 2009-10 accounted for 31% of total waste generation, which was the highest compared to all the other Australian industries (Pink, 2013). With sustainable construction being recognized and pursued around the world, the topic of C&D waste management including waste prevention, reuse, recycling and disposal has received widespread attention by the government, industry practitioners and academic researchers around the globe (Lu and

Yuan, 2011). These issues have been discussed in both technical and management perspectives (Guerrero et al. , 2013).

Take the technical perspective for example, they have been explored through GPS and GIS technologies for construction waste prevention and evaluation of site material layout (Li et al. , 2005, Su et al. , 2012), low waste technologies for waste prevention in design and construction (Zhang et al. , 2012), and web-based applications and systems in waste estimation and management optimization (Banias et al. , 2011, Li and Zhang, 2013). From the management perspective, previous researchers have examined problems of different project stages with impact on effective waste prevention and management, such as quality of design specification and documentation (Vrijhoef and Koskela, 2000), construction operation and site planning (Poon et al. , 2004a, Poon et al. , 2004b), labour work and construction management (Saunders and Wynn, 2004) and material transportation and handling (Kpamma and Adjei-Kumi, 2011).

The relationship between waste handling and project work processes has been modelled and simulated to explore effective waste management approach. Typical studies in this area include a Building Information Modelling based system to optimize construction work flows, facilitate waste planning and reduce waste generation (Sacks et al. , 2010), waste management mapping models to visualize and improve the flows of construction processes and waste management activities (Ming et al. , 2006, Shen et al. , 2004), and a waste quantification and management model with consideration of involved project works (Solís-Guzmán et al. , 2009). The modelling and simulation techniques have also been applied in the assessment of waste management strategies to facilitate decision-making, in terms of the effects on waste reduction (Yuan et al. , 2012), economic viability (Duran et al. , 2006, Yuan et al. , 2010), social performance (Yuan, 2012), and environmental impact (Coelho and de Brito, 2012, Ye et al. , 2012).

Existing research reveals factors important to C&D waste management. The lack of motivation to minimise waste and low level of recognition of importance of waste minimisation lead to various problems in the waste management practice (Redmond et al. , 2008, Zurbrügg et al. , 2012). This may result from the lack of relevant knowledge and training and lack of rewards for effective waste management (Lu and Yuan, 2010, Parker et al. , 2009). This may further depend on capital, resources and technique allocated for waste monitor and minimisation (Burke and Gaughran, 2006). Effective waste management during C&D projects requires collaboration between different project stakeholders (Terje and Morten, 2007). In the design stage, incompleteness or error in design, specification and contract documents, design changes and last minute client requirement changes can all lead to waste generation (Lu and Yuan, 2010, Poon, Yu, 2004a). In the construction stage, appropriate site planning and selection of construction methods can contribute to waste minimisation and handling (Poon, Yu, 2004b). Problems in work progress and project management, such as rework of defective items, inefficient work arrangements and lack of supervision and control, will cause waste generation and challenge both work delivery and waste management (Bossink and Brouwers, 1996, Kpamma and Adjei-Kumi, 2011, Poon, Yu, 2004b). A list of factors important to C&D waste management is summarised in Section 4.1. While office building retrofit projects encompass all of these factors, they do possess unique characters therefore warrants the need for further exploration on waste management.

3 Identification of Factors for Waste Management in Office Building Retrofit Projects

Past research on building retrofit projects mainly discussed design, assessment and decision-making of retrofit strategies (Daly et al. , 2014, Wilkinson and Reed, 2011), but waste issues were rarely considered to be influential during early retrofit project planning. Decision tools, such as TOBUS, EPIQR and an on-line tool for existing building survival strategies by ARUP Australia, were developed to assess building conditions and compare possible retrofit scenarios (ARUP, 2013, Balaras et al. , 2002, Caccavelli and Genre, 2000, Caccavelli and Gugerli, 2002, Rey, 2004). Neither of these tools has the ability to consider waste issues in the retrofitting scenario therefore will not inform waste planning and management processes. Yang and Lim (2007) looked into stakeholders' decision making process on alternatives of retrofit solutions and covered a complete range of planning issues including waste management and recycling. But they did not venture into the waste generation and management processes concerning with specific retrofit project characteristics. In a recent research effort, a BIM based system was developed for demolition and renovation waste planning (Cheng and Ma, 2013). But the result is applicable to dealing with waste issues on the level of a city rather than a project.

A retrofit project is comprised of both removal of existing fixtures and installation of new ones (BFM and BRE, 2004). By definition, a retrofit project is similar to a combined demolition and new build project, therefore general C&D waste management rules and practices are also applicable to building retrofit projects. However, a retrofit project involves an existing facility which may need to remain fully or partially operational (Perng et al. , 2007, Su, Andoh, 2012). It will impose much more constraints on both occupants and builders during project process (Ali, 2010, Sanvido and Riggs, 1991). So space confines can be an important factor affecting waste handling as it requires extra coordination of work sequence and logistics (Glardon et al. , 1995, Juan, 2009). According to many studies, retrofit work is a risky, complex, less predictable and poorly planned task, which needs greater coordination than demolition and new build (Egbu, 1994, Egbu et al. , 1998, McLennan et al. , 1998, Rahmat, 1997, Reyers and Mansfield, 2001). This is because there is often a lack of "as-built" drawings with insufficient information about the existing building and cost uncertainty (Dulung and Pheng, 2005, Holm, 2000), leading to difficulty in waste estimation and planning. The uncertain project nature usually leads to changing client demands and emerging problems during work progression (Egbu, 1997, Reyers and Mansfield, 2001). It requires integrated planning of project delivery and waste generation process in advance to achieve waste minimisation and increase waste recovery (Li and Yang, 2014). Retrofitting can also be dangerous and costly because it sometimes involves the disposal of hazardous substances such as asbestos, especially in office buildings constructed from 1950s to 1970s (Egbu, 1997). The highly labour-intensive retrofit work with extensive involvement of small and specialist subcontractors will require greater coordination than general construction projects and well planned process for better control (Dulung and Pheng, 2005, Holm, 2000, Juan, 2009).

Office buildings located in cities' Central Business District have further physical site constraints and regulatory control, which affect site planning, work delivery and waste handling during retrofit work delivery (Douglas, 2006). An office building retrofit project may involve changes in the internal fitout, building fabric, or both, depending on the project scale (Holm, 2000). In Australia, the structural elements removed in an office building such as aluminium, structural steel, steel reinforcing, bricks and concrete, receive a significant level of recycling (Hardie et al. , 2006). However, little recovery is made from the removal of most internal fittings and finishes as they tend to be designed as short life consumables and are typically installed and demolished according to the rotating needs of new tenants (Forsythe, 2010). Design and specifications for recoverable materials and components in office building fitout will effectively contribute to waste minimisation.

The above characteristics make waste management in building retrofit projects more specific and challenging compared to new building and construction projects. These characteristics are summarised in Section 4.1. Combing factors identified from both Section 2 and Section 3, it is possible to formulate the essential waste management issues to allow the evaluation and determination on the critical factors influencing waste management.

4 Research Methodology

A paradigm is a theoretical framework which includes a system by which people view events. It is important because it determines not only what views are adopted, but also the approach to questioning and discovery (Zorpas, 2010). There are several categories of research paradigms: positivism, interpretivism, and models and hypotheses (Fellows and Liu, 2008). In this research, interpretivism is the most suitable. The interpretivism paradigm is particularly valuable for research in management by indicating that reality is constructed by the persons involved. Researchers should determine truth and reality from the participants' collective perspectives (Fellows and Liu, 2008).

Following the interpretivism approach, this research first reconfirmed the validity of existing waste management factors relevant to retrofit projects through a literature study. It then employed a questionnaire survey to collect opinions of building professionals about both the frequency of occurrence and importance of the factors. Statistical software was used to perform a series of analyses to identify the most critical factors for waste management in building retrofit projects, and to evaluate the differences of respondents' opinions on these factors based on their project roles and work natures.

4.1 Selected factors for waste management in office building retrofit projects

Based on the literature review, waste management in office building retrofit projects is not only affected by the factors common in all building and construction projects, but also the particular characteristics of project delivery. From the body of literature covering both C&D waste management and retrofit project characteristics, this study identified 39 waste management factors including 26 common factors and 13 characteristic factors specific to office building retrofit projects (Table 1). The common factors are those related to waste management in general C&D projects, while the characteristic factors are specific to office building retrofit projects with influence on waste management.

{insert Table 1 here}

4.2 Questionnaire survey

The criticality of each identified factor needed to be measured in order to determine the most critical factors influencing waste management in office building retrofit projects in Australia. A questionnaire survey can provide data necessary to obtain measurable impact results for analysis and it can provide less biased results compared to other instruments (Kothari, 2005, Phillips and Stawarski, 2008). It was therefore selected for this research.

The questionnaire was designed to solicit information of both the Frequency and

Importance of each factor in Table 1. Frequency means the probability of occurrence and Importance refers to the impact of the factors to waste management. Five levels (1 to 5) applied to each indicator, including "never, seldom, occasionally, often, always" for Frequency and "not at all important, slightly important, some importance, important, very important" for Importance. A Likert scale applied to most questions relating to frequency and importance. Open ended questions allowed respondents to provide additional information or comments.

To ensure a broad range of representation, the survey sample was established from databases of two prominent industry associations: Master Builders Australia (MBA) and Green Building Council of Australia (GBCA). Master Builders is the major Australian building and construction industry association. Its members represent 95% of all sectors of the building and construction industry. GBCA is concerned with trends of sustainable retrofit and the compulsory waste component for green building assessment. Its members are professional individuals with experience in green building retrofit and driving the transition of the Australian property industry towards sustainability. From the two industry databases, 120 industry practitioners were randomly selected then approached by email. They were based in major capital cities with well developed commercial property market, including Sydney, Melbourne, Brisbane and Adelaide. 49 valid responses were returned, representing a response rate of 41%. While a larger sample may yield more accurate results, the target sample population is small due to the specific focus on office building retrofit projects. According to Moser and Kalton (1971) and Fellows and Liu (2008), this response rate from such a sample is considered satisfactory and suitable for the statistical measures used in this research.

The respondents included 31 project managers (comprising chief engineers and chief architects), 7 contract managers, 4 general company managers, 2 project consultants, 1 site engineers, and 4 other professional (including portfolio manager, regional manager, environmental manager and design manager). Nearly half of them had over 10 years of experience in retrofit projects. The nature of work undertaken by the respondents covered a wide range of retrofit work areas. Interior finishes, mechanical systems, internal walls and doors, electrical systems and demolition are best represented.

4.3 Statistical data analysis

The survey data was input to SPSS 19 for statistical analysis. The mean values of both Frequency and Importance of each factor were first calculated with a t-test to identify the most critical factors for waste management in building retrofit projects. t-test is used to determine if the mean of a sample is similar to the mean of the population, or to examine if the means of two samples are significantly different. In this research, t-test was applied to the factors with the mean values of Frequency larger than the cut-off value or the mean values of Importance larger than the cut-off value. It was used to investigate whether these factors' Frequency values or Importance values were significantly larger than the cut-off value at 95% confidence level (p=0.05). If the p-value of the test of the mean rating by the respondents is lower than 0.05, the null hypothesis (the factor never or seldom occurred/ the factor was not at all important or slightly important) is rejected.

Based on the critical waste management factors, Kendall's W test was used to calculate the coefficient of concordance of the respondents' ratings for the factors' significance levels, in order to investigate if there is any association in the respondents' opinions on the criticality of the factors at 95% confidence level. If the p-value is larger than 0.05, the null hypothesis (the respondents had similar opinions on the criticality of the factors) is accepted. If the coefficient of concordance W is close to 1, it indicates that the respondents had similar ways of determining the critical waste management factors. If the coefficient of concordance W is close to 0, it shows that the respondents' had diverse ways of viewing the significance levels of the factors.

Based on the result from the Kendall's W test, it is important to consider the respondents' different professional responsibilities and natures of undertaken works to further assess if they were relevant to the respondents' different opinions. To this end, the Kruskal-Wallis H analysis was first applied to identify how the critical waste management factors were rated by stakeholders with different project roles. If the p-value is larger than 0.05, the null hypothesis (there was no significant difference in the respondents' ratings considering their professional responsibilities) is accepted. In addition, the Mann-Whitney U was tested to see if there was any significant difference in the respondents' ratings on the factors considering their different work backgrounds. 95% confidence level was applied. If the p-value is lower than 0.05, the null hypothesis (there was no significant difference in the respondents' ratings considering their work natures) is rejected.

5 Data Analysis and Findings

Internal data reliability was checked to ensure the consistency of each variable in measuring the factors. Split-half reliability and Cronbach's alpha are both possible alternatives. Compared to split-half reliability, Cronbach's alpha is more widely used because it calculates the average of all the possible split-half reliability coefficients (Bryman and Cramer, 2009). Therefore Cronbach's alpha was tested in this research. The value is 0.945 which is well above the required 0.8 to mark the survey data as internally reliable.

5.1 Identification and ranking of the critical waste management factors

The ranking of the waste management factors was carried out based on their mean values of both Frequency and Importance. The cut-off mean value was set at 3, which represents “occasionally” for Frequency and “some importance” for Importance. Out of the 39 waste management factors, those which were perceived by the respondents as “occasionally, often or always” happening (mean value>=3) or rated by the respondents as “with some importance, important or very important” (mean value>=3), were identified. T-tests were applied to both sets of factors to further assess whether or not their Frequency or Importance values were larger than the cut-off value. 20 factors which appear in both of the final factor lists were selected as the critical waste management factors for office building retrofit projects. Table 2 summarises the descriptive and inferential statistics for these critical factors. They are ranked according to their mean values of Importance, representing their influence on effective waste management in office building retrofit projects. “Lack of motivation to minimise waste” is the most significant factor of waste management in building retrofit projects. It is believed that any enterprise or individual needs motivation to react to anything. Economic benefits and beliefs usually become their motivation for undertaking environmental activities (Zorpas, 2010).

{insert Table 2 here}

5.2 Agreements on the critical waste management factors

In order to examine whether the questionnaire respondents ranked the 20 critical waste management factors in a similar order, Kendall’s W test was performed to calculate the coefficient of concordance. The result of the analysis shows that the coefficient value is 0.085 and the p value is 0.000, indicating that the respondents had different opinions on the importance of the critical factors for waste management, and they held different and even conflicting preferences and evaluation systems in determining the most important factors (Table 3).

{insert Table 3 here}

5.2.1 Agreements across professions

In order to further investigate if there were major differences in different project participants' ranking of the factors' significance levels, the Kruskal-Wallis H analysis was used. Agreement across project participants with different professional responsibilities was first tested as shown in Table 4. As all the p values are larger than 0.05, there was no significant difference in the opinions of various stakeholders for the critical waste management factors, which indicated that there was generally a consensus regarding the respondents' perceptions and expectations in waste management in office building retrofit projects.

{insert Table 4 here}

A closer look at the mean ranks identified from the Kruskal-Wallis H analysis reveals that the six groups of respondents held varied opinions on the most significant factor regarding waste management in office building retrofit projects. In terms of their roles, the six groups can be categorised into two major types of respondents: the top-level decision-makers (G2, G5 and G6) and the site practitioners (G1, G3 and G4). The top-level decision-makers believed that strategic factors related to the work delivery and waste management processes, such as lack of knowledge and training of waste minimisation, small packages of work undertaken by subcontractors and problems discovered during work process, were the most important factors for waste management in office building retrofit projects. However, the site practitioners paid more attention to stakeholders' actual motivation and wills to waste management, and rated "last minute client requirement changes" and "incomplete or error in contract document" as the most significant to waste management. Existing studies have also confirmed that efforts should be made at all levels to minimise waste generation and manage the generated waste in an environmentally sound manner (Wilson and Tormin, 1998). In this process, different stakeholders will have different roles to play to support their priorities. Identification and coordination of their different interests and involvement in various waste management activities is therefore very important (Joseph, 2006).

5.2.2 Agreements across work natures

In addition to the differences of opinions by different project roles, it is also worth exploring the influences of respondents' different work natures on their ratings of the critical waste management factors. It will provide a better understanding of different waste management situations and requirements in different types of retrofitting works. The Mann-Whitney U test is a non-parametric test which explores differences between two independent samples. The questionnaire respondents were categorised by each work nature and the scores on the importance of the critical factors were evaluated whether they differ significantly. The factors identified with significant difference in the importance across certain work natures are summarised in Table 5 for ranks comparison.

It reveals that respondents from the building structure work background might not rate "lack of knowledge and training of waste minimisation" as important as other respondents did. Similarly, people with background in lifts and elevators related works tended to raise less significance levels for "lack of motivation to minimise waste", "lack of knowledge and training of waste minimisation" and "low level of recognition of importance of waste minimisation" compared to people without experience in this area. This may be because building structure and lifts and elevators are the types of works which don't have as much potential for waste minimisation as other works do. It can be noted that respondents who worked with internal walls and doors have rated the factor "work undertaken when part of the building remains occupied" as more important than other respondents' opinions. The partially occupied building space is a usual characteristic in building retrofit projects according to existing studies. It will influence the progress of retrofitting work and waste management activities because of the space and time conflicts and possible risks to the environment, health and safety. For the factor of "incomplete or error in contract documents", it appeared to significantly affect waste management in building retrofit projects in relation to demolition works. Demolition is more one-off work in building retrofit projects according to some industry practitioners, so contract terms are important in specifying jobs needed to be completed. However, it seemed not to be the same case for drainage works.

{insert Table 5 here}

6 Discussions and Recommendations

The critical factors of waste management in building retrofit projects stem from factors influencing waste management in both general C&D and retrofit project context. 11 of the critical factors are the common ones shared by all building and construction projects, and nine factors reflect characteristics of retrofit project situations. These factors can be grouped and summarised in Figure 1 with five dimensions: (1) industry culture; (2) organisational support and incentive; (3) existing building information; (4) design; and (5) project delivery process. They represent issues of waste management at the levels of industry, organisation and project respectively.

{insert Figure 1 here}

Industry culture

It is worth noting that the three factors concerned with industry culture are ranked in the top five and regarded by industry stakeholders as highly critical for waste management in office building retrofit projects. The prevailing industry culture of viewing waste as inevitable by-product of construction activities and regarding waste management as a low project priority has resulted in a lack of commitment of practitioners in minimising and managing waste (Teo and Loosemore, 2001). The culture of the industry has a direct impact on organisations' behaviour. Their attitudes and performance on waste management vary depending on size, waste management policy, training programs in place, etc. (Begum et al. , 2009). Therefore, the transformation of industry culture and development of industry norm and performance standard are the ultimate ways of improving waste management practice in building retrofit projects.

Organisational support and incentive

Three critical factors can be grouped together as organisational support and incentive. It indicates that the attitudes and financial and technical abilities of industry stakeholders affect waste minimisation and management in office building retrofit projects. This is consistent with Begum et al.(2009) and Barr (2007), who identified positive relationship between environmental values and environmentally responsible behaviours. This study shows that the positive organisational attitudes and values of waste minimisation can lead to effective waste management performance in office building retrofit projects through inter-organisational and intra-organisational measures such as stakeholder collaboration, investment in technique and equipment, and incentive for waste management activities.

According to additional comments provided by the questionnaire respondents, currently most office building retrofit project teams would rely on waste management contractors to collect and deal with waste generated from the project process. There is a lack of waste auditing and planning by the project teams in the early project stages for potential material reuse and no integrated planning and coordination for both waste handling and retrofit work delivery. This can lead to unnecessary waste disposal and increased project cost. Most waste taken away by waste management contractors will still end up in general waste landfill. Therefore, collaborations between various stakeholders in the project teams need to be strengthened in pre-project waste evaluation, auditing and planning. This should start with improved support from the organisational level to work with waste management contractors to increase waste recovery and management quality.

Existing building information

The three factors grouped as existing building information are unique for retrofit projects, because general new building and demolition projects are more straightforward in planning and delivery with expectable waste information. “Lack of as-built drawings” and “insufficient information about the existing building” are two factors highly ranked for their criticality in this group. They make it difficult to identify existing building conditions and analyse building materials and components to be removed during retrofitting especially hazardous materials used in old buildings. “Cost uncertainty” is also a critical factor in this group but ranked relatively lower than other factors. Cost effectiveness is an important issue considered for waste prevention, management and disposal in general C&D projects (Marzouk and Azab, 2014, Yuan et al. , 2011). In office building retrofit projects, waste is usually dealt with by waste management contractors that provide affordable, specialised and quality waste management service packages for the particular project needs. This allows the project team to have a tangible cost indication for waste handling and therefore reduce the impact of cost issue on waste management.

New technologies such as 3D laser scanning and Scan-to-BIM have been developed for the Australian building market to perform existing building surveys, produce accurate as-built drawings and construct 3D BIM models. These technologies need to be further developed to not only assist architects and designers with retrofit design strategies, but also enable stakeholders to analyse, evaluate and plan for material dismantling and waste handling before work start. Waste management contractors need to work together with the project team on this technology platform to identify potential opportunities of material recovery and ensure waste handling activities can be scheduled and coordinated with the overall project plans and timelines for integrated project and waste management.

Design

Two factors of the design group are ranked in the top five of the critical waste management factors. Design modification is an important reason for waste generation (Wang et al. , 2014). Because of the last minute client requirement changes, lack of communication and complications in design, few attempts are undertaken to minimise waste at the design stage (Osmani et al. , 2006, 2008). This situation is intensified in retrofit projects with limited existing building information, risky work nature and frequent replacement of internal fit-out depending on varied requirements of building tenants. In addition, a lot of office building retrofit projects in Australia are motivated by sustainable building rating schemes, which often encourage clients to recycle materials to achieve the green building objective (Fowler and Rauch, 2006). This drives stakeholders to solely focus on the waste recycling rate rather than waste minimisation.

It also leads to the lack of motivation by the designers to reduce waste through optimised design strategies.

Flexibility needs to be taken into account in design to meet the short life nature of office fitout due to high churn rates of building tenants. New fitout design strategies are expected to be carried out such as re-adaptable and reusable design. Communication and collaboration in early project stages between different project stakeholders including building operational management and waste management contractors need to be enhanced. This will strengthen the building information available for design, reduce material consumption, improve waste planning and minimisation, and save cost, space and time for waste handling and recovery in the later stage of project delivery.

Project delivery process

The factors grouped as project delivery process can be similarly identified from general building construction projects. But they are much intensified in office building retrofit projects due to the constrained work space shared with building tenants. This involves issues of waste handling, storage and transportation around the building that can cause health and safety concerns for the building tenants. Various subcontractors can have different views and diversified recognitions on waste management because of different specialists. Their coordination in dealing with waste issues is important for effective waste management during the project process.

Waste auditing, assessment and planning needs to be enforced by government regulations as a compulsory requirement in the planning stage of office building retrofit projects. It should be carried out through the collaboration of architects, designers, constructors and waste management contractors to ensure waste is either minimised or properly handled as planned without affecting building occupants. Existing waste management facilities during building operation can be effectively utilised for waste collection and temporary storage to avoid extra space taken up by additional waste management equipments. Traditional procurement approach needs to be changed to allow early and more active engagement of contractors and even subcontractors to have input to minimise waste and solve complex problems during work delivery. A better understanding of interactions between retrofit work nature and waste issues as well as waste handling procedure specific to building retrofit projects is expected for project participants by putting relevant resources and training programs in place by the government or industry associations. Because the disparate types of specialised works involved in office building retrofit projects are highly variable in site situations, work procedures and client's requirement and specification, specific measures of waste management are expected to be developed for different specialists. Waste issues arisen in different parts of retrofitting works need to be planned on an overall basis and addressed through coordination of participants to reduce impacts on each other.

7 Conclusions

This research identified critical factors of waste management in office building retrofit projects by exploring the characteristics and processes of work delivery and waste management specific to this type of project. The final list of factors consists of issues both common to general C&D projects and those specific to building retrofit projects. They are grouped into five dimensions: (1) industry culture; (2) organisational support and incentive; (3) existing building information; (4) design; and (5) project delivery process. The critical waste management factors for office building retrofit projects differ from those in general C&D projects because of issues such as partial operation of buildings, constrained site spaces and limited access to as-build information. These issues intensify the severity of some factors and can cause additional implications. .

The critical factors show that the planning, auditing and assessment of waste during the design and planning stage of office building retrofit projects is essential to effective waste management. The design for office building fitout can adopt more innovative ideas such as re-locatable and reconfigurable office partitions and re-adaptable design to help minimise waste as well as health concerns during retrofit. Waste management contractors should be involved at early stages of the project to gather information for waste minimisation, handling and recovery. Instead of limiting building surveying efforts to condition reporting, they can be combined with BIM technologies for waste analysis, that will help identify types of waste therefore processing needs, peak generation time and volumes, and inform project planning and execution processes. The effective coordination of different specialist subcontractors will ensure waste from different parts of the retrofitting work is treated without impact on other parts.

The research results will facilitate a better understanding of waste management issues in building retrofit projects and provide useful reference for decision-makers to develop relevant measures. Future research will be undertaken to further explore the interactions between stakeholder, work process and waste management and develop detailed strategies to respond to the critical factors identified to date.

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Annex: Sample of questionnaire

Section 1: Demographic Details

The following items will be used for statistic purpose only. Your responses will be treated **CONFIDENTIALLY** and will **NOT** be used to identify specific individuals.

Q1.1 Which of the following best describes your daily job?

O Project manager

O Site manager

O General company manager

O Site engineer

O Contract manager

O Project consultant

O Other, please specify

Q1.2 What length of experience do you have in retrofit projects?

O Less than 5 years O 5-10 years O 11-15 years O 16-20 years O More than 20 years

Q 1.3 What is the location of office building retrofit projects mainly undertaken by your company?

O Melbourne O Sydney O Brisbane O Adelaide O Perth O Canberra O Other, please specify

Q1.4 What is the nature of work undertaken by your company on office building retrofit projects? (multiple answers are permitted)

- Building structure (formwork, reinforcement, concrete, brickwork, masonry)
- Building envelope (roof, façade, windows)
- Mechanical systems (air conditioning, heating, ventilation)
- Electrical systems
- Internal walls and doors
- Interior finishes (carpentry, joinery, partitions, plastering, suspended ceilings, pavior and terrazzo, tiling, glazing, painting, carpeting)
- Fire and life safety
- Lifts and elevators
- External works (walkways, roadways, landscaping)
- Excavation
- Demolition
- Drainage
- Other, please specify

Q1.5 Would you like a summary of the findings from this questionnaire?

O Yes O No

Q1.6 Please provide your contact information. The information will be kept strictly confidential.

Name:

Email address:

Contact number:

Company name:

Q1.7 Would you be prepared to be contacted for an in-depth interview based on the findings from this questionnaire?

O Yes O No

Section 2: General factors

There are common factors which are related to waste management in all construction and demolition projects. This section seeks to identify performance of these factors in affecting waste management in office building retrofit projects.

Frequency: Probability of occurrence of the given factor in office building retrofit projects.

Importance: Influence of the given factor on waste management in office building retrofit projects.

Seven categories of factors are provided in this section. Please specify both frequency and importance of the factors.

Design

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Incomplete or error in contract documents	O	O	O	O	O	O	O	O	O	O
Poor design and specification	O	O	O	O	O	O	O	O	O	O
Lack of design information	O	O	O	O	O	O	O	O	O	O
Last minute client requirement changes	O	O	O	O	O	O	O	O	O	O
Design changes	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors.

Site planning

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Inappropriate construction methods	O	O	O	O	O	O	O	O	O	O
Poor arrangement of working space	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors.

Materials handling and management

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Inappropriate material storage	O	O	O	O	O	O	O	O	O	O
Excessive or unnecessary inventories	O	O	O	O	O	O	O	O	O	O
Material damaged during transportation	O	O	O	O	O	O	O	O	O	O
Residual from material cutting and package	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors.

Project management

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Delay in making decisions	O	O	O	O	O	O	O	O	O	O
Unnecessary or inefficient work arrangements	O	O	O	O	O	O	O	O	O	O
Lack of supervision and control	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors.

Work process

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Error by tradesperson or labourer	O	O	O	O	O	O	O	O	O	O
Poor workmanship	O	O	O	O	O	O	O	O	O	O
Rework of defective items	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Teamwork

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Lack of experience and professional quality	O	O	O	O	O	O	O	O	O	O

	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Lack of coordination and communication	O	O	O	O	O	O	O	O	O	O
Lack of motivation to minimise waste	O	O	O	O	O	O	O	O	O	O
Lack of knowledge and training of waste minimisation	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Organisation

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Low level of recognition of importance of waste minimisation	O	O	O	O	O	O	O	O	O	O
No company rewards for effective waste management and minimisation	O	O	O	O	O	O	O	O	O	O
Failure to conform with building code of conduct and regulations	O	O	O	O	O	O	O	O	O	O
Not enough collaboration between main contractors and subcontractors for waste minimisation	O	O	O	O	O	O	O	O	O	O
Lack of capital, resources and technique for waste monitor and minimisation	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Section 3: Characteristic factors specific to office building retrofit projects

These factors reflect the specific characteristics of office building retrofit project delivery. This section seeks to identify the influence of these factors on waste management.

Frequency: Probability of occurrence of the given factor in office building retrofit projects.

Importance: Influence of the given factor on waste management in office building retrofit projects.

Please specify both frequency and importance of the factors.

Information

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Insufficient information	O	O	O	O	O	O	O	O	O	O

	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
about the existing building										
Lack of "as-built" drawings	O	O	O	O	O	O	O	O	O	O
Cost uncertainty	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Space

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Work undertaken when part of the building remains occupied	O	O	O	O	O	O	O	O	O	O
Physical site constraints	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Process

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Poor specification of the delivered service	O	O	O	O	O	O	O	O	O	O
Problems discovered during work process	O	O	O	O	O	O	O	O	O	O
Small packages of work undertaken by subcontractors	O	O	O	O	O	O	O	O	O	O
Highly labour-intensive work progress	O	O	O	O	O	O	O	O	O	O
Constrained time schedule for work progress	O	O	O	O	O	O	O	O	O	O
Dangerous working nature with hazardous or toxic materials, noise and vibration	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Management

	Frequency					Importance				
	Never	Seldom	Occasionally	Often	Always	Not at all important	Slightly important	Some importance	Important	Very important
Complex process which needs greater coordination	O	O	O	O	O	O	O	O	O	O

Less well planned process which is difficult to control	O	O	O	O	O	O	O	O	O	O

Please specify other factors in this category (if any). Please indicate both frequency and importance of the factors

Section 4: Additional comments

Please provide comments relevant with waste management in office building retrofit projects (if any).