UNDERSTANDING THE DRIVERS OF HOUSING DEMOLITION METHOD SELECTION – A WASTE MANAGEMENT PERSPECTIVE

(SCIENTIFIC PAPER)

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ABSTRACT

Construction and demolition waste are important issues affecting the sustainability of the built environment. Of note, the management of demolition waste has yet to be fully investigated as a research topic. Using a case study methodology, key drivers that influence the selection of demolition method and the effect these drivers have on waste recovery, were identified. A key external dimension to demolishers concerned the type of feedstock available for demolition. A more internally focused dimension concerned organisational drivers and these were broken down into supply chain entrepreneurship, systematic site safety, demolition productivity and economies of scale. Another internally focused dimension looked more specifically at the project level of decision making and was broken down into physical demolition costs, client environmental needs, cartage costs, development approval needs and contaminated material needs. Of note, physical demolition costs could be broken down still further into site based costs, cartage costs, the "pay or paid" scale of waste saleability and government cost interventions. A model reflecting the order and context of the findings is presented in the paper and provides a basis for systematically studying and improving waste recovery. An ongoing research agenda is suggested.

KEY WORDS: demolition; waste management; waste recovery

INTRODUCTION

The objective of this paper is to develop a principles based understanding of factors that influence the selection of construction demolition processes. This is done with a specific view to better understanding how such factors - good or bad - effect waste recovery from demolition projects. This level of detail is important in order to open up the possibility of manipulating such drivers in order to improve waste management outcomes.

LITERATURE REVIEW

As far back as the Bruntland report, the construction industry was targeted as a problematic area in terms of challenging natural resource usage and causing environmental damage (World Commission on Environment and Development 1987). Construction and Demolition (C&D) waste is often seen as the major contributor to the solid waste stream going to landfill, hence making it an area of focus for improvement (Kalin 1991; Alexander 1993; Helper 1994; Tam and Tam 2006). Demolition waste is by far the largest contributor to this waste stream, but while many waste management studies talk about C&D waste as a generic construct, a closer look reveals that much of the research in this area relates to waste management of new construction and not the specifics of demolition waste. Work that has generalisability to demolition includes studies by Poon (1997), Poon et al. (2001) and Pun et al. (2006). Work by the Building Research Establishment in the United Kingdom - specifically work by Hurley et al. (2001) - provides significant insight into the base principles and operational structure of the demolition industry. In many ways, this study is an extension to their work in terms of providing greater structure and detail in explaining the selection of demolition processes. A better understanding of such factors provides potential for an improved ability to identify and act on impediments to waste recovery.

This is particularly important because the nature of urban renewal and the consolidation of growing populations in cities means that a continuing supply of demolition feedstock exists. It is therefore a society-wide issue to make the best use of recoverable waste, especially given the depleting availability of natural resources and concerns over carbon emissions in transforming raw materials into new products (Moriguchi 1999; Muller 2006).

In rising to this challenge, the current study chooses to take a targeted approach to investigating demolition waste and subsequently focuses on housing demolition projects (i.e. low rise, detached and semi-detached projects). Building development of this nature makes up a significant proportion of demolition projects. For instance, planning decisions that foster population growth and urban consolidation often require the demolition of low density suburban development to make way for higher density urban development. Housing projects also make for an interesting area of study given the difficulties in cost effectively dealing with waste because of the small economies of scale involved in such projects. As such, these projects represent the focus of the empirical research and also create corresponding limits to the generalisability of the research findings.

RESEARCH METHOD

The research consisted of nine case studies undertaken in three major cities across Australia including Sydney, Melbourne and Brisbane. The focus on these State capitals aimed to capture the dynamics of what happens in large and competitive demolition and waste management markets.

In each case, the demolition contractor formed the central subject of each study, but in saying this, the primary focus of the information gleaned from them concerned a detailed understanding of how the waste stream operated within a demolition based system. In fully addressing this, the case studies not only investigated indivdual demolition contractors, but the rest of their operational framework as well, including their subcontractors and those involved in transporting, reprocessing, accepting and reselling waste. In depth face-to-face interviews represented the main means of gathering data and this was facilitated via a standard regime of questions. The questions focused on demolition processes, identifying impediments to waste recovery and general waste management issues. The questions were developed with the assistance of a project reference group and pilot testing of the questions. Ultimately, the mix involved semi-open and open questions, aimed at allowing participants to speak freely about how their mode of operations worked, rather than forcing them into preconceived notions of their operations.

Questions were directed at the directors or senior managers of the firms involved. In addition, active demolition sites were visited as were resource recovery and recycling facilities used by the demolition contractors involved. A catalogue of photographs was also taken of such processes, plus first-hand observations of how waste was received, processed, on-handled and/or sent to end user markets. Further to this short discussions about processes were conducted with management personnel onsite.

In broad terms the above approach was guided by Yin's (1994) account of executing case study research and was merged with Boyatzis's (1998) method of coding raw data using thematic analysis. Here, thematic analysis is akin to content analysis, and acts as a means of inductively coding unstructured data into a structured framework. Importantly, it differs from content analysis in so far as the focus being on theme frequency rather than word frequency. Themes are patterns in communicated messages or observations and serve to make greater sense of raw or unstructured data (Boyatzis 1998). For instance themes are used to make inferences based on the relationships between events and symbolic content and these inferences are underpinned by an objective method of identifying and coding themes (Boyatzis 1998).

OVERVIEW OF FINDINGS

A number of key themes (referred to henceforth as drivers) were identified by the research as influencing the method of demolition selected by contractors including:

- External drivers as defined by the type of demolition feed stock
- Organisational drivers including:
  - Supply chain entrepreneurship in reuse/recycling markets
  - Systematic site safety
  - Demolition productivity and economies of scale
- Project specific drivers including:
  - Typical physical demolition costs (site based costs, cartage costs, the "pay or paid" scale of waste saleability, government cost interventions)
  - Client environmental needs
  - Development approval needs
  - Contaminated materials needs

Each is elaborated upon further below

EXTERNAL DRIVERS AS DEFINED BY THE TYPE OF DEMOLITION FEED STOCK

The existing building stock determines what will be demolished and what type of waste will be generated. This is henceforth referred to in this paper as "demolition feed stock". As identified by Muller (2005) and Moriguchi (1999), demolition typically occurs because existing buildings have reached the end of their economically useful life. This research was able to categorise these circumstances in greater detail as relevant to housing demolition projects. For instance there were two sub-variables that influenced the buildings to be demolished, as follows:

- Building redundancy i.e. houses that are dilapidated or redundant in meeting the owner/occupier's needs, hence bringing about the need to demolish
- Land opportunity cost i.e. land that the house is sited upon having a higher and better use than its current use - as brought about by market forces or rezoning of land usage - hence bringing about the need to demolish in order to make way for new development.

The main reason for identifying the difference is because the two separately influence the quantity and predictability of up and coming *demolition feed stock*, thus affecting the quantity and type of waste that will be generated. For instance, local government plans for re-zoning and redevelopment could be used to generate data for estimating the number and type of housing units that will be demolished over a given period of time. As a result, predictions can also be made about the amount of waste that will be created and potentially recovered for reuse and recycling.

To make optimum use of such data there is the need to know what type of waste material will arise from the *demolition feed stock*. The research not surprisingly found that such issues are a function of the type of construction involved, as defined by the time period in which the *demolition feed stock* was built and the associated regional differences in construction style that existed at that point in time. For instance, a significant number of houses being demolished in Brisbane were built prior to the late 1960s and were constructed predominantly out of timber construction. In contrast, Melbourne houses of similar age had a much greater proportion of brick usage but often involved suspended timber floors. In Sydney, there was similar usage of brick construction plus a greater proportion of concrete slab on ground construction. As a result, timber waste was more prominent in the Brisbane feedstock, than the Melbourne and Sydney feedstock. Because of this, it was observed that demolishers developed standard modes of operation geared to suit timber, and its recovery.

ORGANISATIONAL DRIVERS

It was found from the data that the approach utilised for demolition was made at an organisational-wide level first and at a project specific level second. The organisational level involved standardising and systematising operations to improve managerial and operational efficiency. Three linked but separate factors that were prominent in the data are discussed further below.

Systematic Site Safety of Workers

Demolition safety requirements were found to differ in each city according to State based legislation and this was in turn found to impact on the method of demolition chosen by contractors. For instance, hand demolition whilst common in Brisbane, was less the case in Melbourne. Issues affecting the Melbourne cases concerned the high safety risks perceived with the hand demolition. Here, perceptions were clearly influenced by the way contractors interpreted their duty of care relative to State legislative requirements. To mitigate such perceived risks, they had to allocate much greater care, attention and supervision to site safety procedures. They also incurred significant cost in terms of providing safety infrastructure such as rails, scaffolding, toe boards and similar treatments. As a result, there was a bias towards the use of excavation machinery instead of labour usage in the demolition process, hence providing a means of effectively mitigating project safety risks, but implemented at an organisational level.

Strategic Productivity and Economies of Scale

Similar to the above, strategic productivity revolved around the use of machine versus labour based demolition. It was apparent that some companies had committed themselves at an organisational level to optimising excavation machine usage and subsequently minimising labour usage. The reverse was true in other companies who had committed to a hand demolition approach. Clearly, machine usage had the potential for higher productivity and safety, but this was potentially offset by other factors favouring hand demolition, such as the ability to site separate certain materials (such as timber) for re-sale. For instance the machine intensive approach had limited ability to do this, but in contrast, the labour focused approach showed far greater dexterity in undertaking such tasks. It was evident that contractors showed preference for one or the other method depending on the extent and type of materials they intended to recover and the financial return they expected from such materials.

In making such decisions, it was evident that economies of scale played an important role. For instance, if the demolition feed stock in a given region contained large and regular amounts of a specific material, then demolishers would adopt a standardised approach suited to recovery of such materials. In Sydney and to some extent Melbourne, demolishers often standardised towards the excavator driven approach because it allowed them to recover bricks and concrete whilst the remaining lesser materials were sent to landfill. In contrast, the timber intensive houses in Brisbane caused greater usage of hand demolition in order to facilitate timber recovery.

Supply Chain Entrepreneurship

It was found that demolishers who were highly involved in demolishing a specific type of construction, often exhibited supply chain entrepreneurship as a value-add to specific types of waste materials that they regularly encountered. This adds to work by authors such as (Dainty and Brooke 2004). In short, it was found that "materials trading" had become part of their repertoire and in many ways this was a step beyond the basic act of physically demolishing buildings. The nature of supply chain entrepreneurship included attention to storage of materials, reprocessing or materials and finding markets for material sales. A common theme in undertaking these activities was the need for various forms of organisational integration, and so the following variants on supply chain entrepreneurship were identified around this theme:

- Vertical integration – Organisations involved in this category undertook demolition with a view to maximising recovery of targeted materials which were sent directly to their own salvage yards for recycling operations. Such materials were re-processed to varying extents and offered for sale in product display yards and industrial wholesale settings.

- Symbiotic integration – This occurred where certain demolishers integrated effectively with specialist re-use and recycling operators. Here, demolishers still undertook the main physical processes onsite, but created sub-arrangements with specialist operators to come onsite and salvage targeted materials including things like large structural timbers, decorative timber floor boards and certain fixtures and fittings. Under another version of this relationship, the specialist operators would only arrange to pick up the materials direct from site, thus being less involved, but still saving the demolisher from cartage and tipping processes. Under either scenario, the specialist operators were involved in the project at tendering stage. For instance the two parties would agree on the value of the yet to be salvaged materials, and this would be subsequently factored into the demolisher's profit and cost structure for the project. This symbiotic relationship created an efficient and stable supply chain in terms of not only improving the cost and efficiency for waste management and recovery, but the agreed logistics of onsite preparation, packaging of waste, pick-up and eventual processing of it. This facilitated a more competitive tender price than would have been otherwise possible. It also clearly helped create a more efficient, standardised, transparent, simple and predictable market for demolishers. This mutually beneficial arrangement also resulted in a cheaper price to the demolisher's client.

- Site-time dependant integration – this represents a more basic supply chain than the previous options because under these circumstances, the demolisher was found to sell recovered materials direct from site. In such instances, the site acts as a temporary storage facility and shop front for selling materials. It tended to occur where demolishers did not have appropriate offsite storage facilities or where the materials were not worth the cost of offsite cartage, storage and selling. Little infrastructure was required for this approach, hence favouring small demolishers. Even so, the feasibility of this approach was highly dependent on the site characteristics and the availability of time on the site, to store and sell materials. For instance, there is usually a very short window of opportunity in which to find a client, sell the recovered materials and have them taken away from site, before the situation becomes an impediment to site progress. Demolishers spoke of this as often being infeasible, especially where their client incurred time based holding costs on the site, or where time based cost penalties were written into the contract.

PROJECT SPECIFIC DRIVERS

While the above factors created an overall organisational framework for demolition contractors to work within, this was then processed down to decision making at a project specific level. Relevant drivers of project decision making that were observed in the data, are detailed below.

Typical physical demolition costs

The differences between competing approaches to demolition were found to be identifiable according to four cost related sub-variables discussed below. Some of these are already defined in the extant literature including content from papers by Mills and Showalter (1999), Pun et al. (2006), Begum et al. (2006), and Treloar et al. (2003). Even so, costs are reiterated and redefined here, in order to elaborate on context and to provide a holistic framework of the drivers identified in the data. This framework is considered important where identifying variables that could be manipulated in order to improve waste management outcomes.

- Site based costs - Site costs were conceptualised to include the act of pulling the building down, separation of materials, moving the materials to a cartage point, preparing the materials for cartage (e.g. de-nailing, strapping, loading and placing materials in bins or trucks). Here it was apparent that labour intensive approaches suffered more than excavation machine intensive approaches. This study found that in terms of site costs, the machine driven approach was cheaper than the labour driven approach but such costs may be offset by other factors such as the re-saleability of demolition waste for reuse and recycling purposes (as discussed later in this paper).

- Cartage costs – these costs were conceptualised to include all road and trucking costs involved in taking waste from the demolition site to a designated drop-off location (e.g. a transfer station, a recycling depot, a landfill site). A reason for identifying cartage costs as separate to site costs was the potential for this activity to be influenced separately to site costs. For instance it was found that inner city demolition projects typically made use of close proximity transfer stations, especially where truck shuttle times were crucial to the optimisation of site demolition processes. Where travel times were less crucial, out-lying landfill depots or waste recovery stations may be the preferred option. In still other observed instances, vertically integrated demolition contractors had their own recycling and reuse facilities, thus influencing the distance they were prepared to travel to reach the required drop-off points. Alternatively, other demolition contractors avoided cartage costs altogether by utilising specialist operators (as referred to previously). Another option was to re-utilise the waste materials onsite, though this was seldom observed, probably due to the relatively small economies of scale provided by housing demolition.

- The "Pay or Paid" Scale of Waste Saleability - Decisions on the two previous cost issues were found to be strongly influenced by whether or not the demolisher would get paid for saleable waste; would be able to off load the waste for free; or would have to pay to off load it. Specific instances and examples from the research are elaborated upon below:

    - Get paid for high value waste – this option was most apparent in Brisbane based houses constructed predominantly out of hardwood. Timber recyclers paid demolishers well for such timber and even provided salvage crews to recover such materials from site and/or cart it from site. A key reason was the limited supply of new hardwood – especially in large section sizes. As a result, a hand demolition approach was used because of its central role in recovering such high value materials.

    - Free drop-off for neutral value waste – this option was most apparent where timber waste was utilised as bio-fuel for power generation. The bio-fuel furnace was equipped to deal with a variety of minor impurities in the timber, thus negating the need for nail and metal removal from the timber and keeping the need for onsite processing of the timber to a minimum.

    - Pay to off load negative value waste - the main example of this concerned was where there was no realisable market for selling or getting rid of the waste for free. Taking waste materials to landfill was the most obvious instance of this. Cartage costs also played a role in deciding upon this option over others. In some instances, the amount of payment was mediated by lesser versions of the "free drop-off" option above – such as dropping off concrete and brick waste for a lower price than the landfill price.

- Government cost interventions - as is common in many waste management markets around the world (Skumatz 1993; Morris, Phillips et al. 2002; Duran, Lenihan et al. 2006; Skumatz 2008) government cost intervention were evident in the Sydney and Melbourne case studies in the form of landfill levies. The intervention served to increase the cost of each tonne of waste brought to landfill. Of note, the increased landfill cost had the effect of reducing the relative cost of competing reuse and recycling options.

Client Environmental Needs

Government clients, institutional clients and corporate clients were constantly cited by demolishers as having a core commitment to sustainable building development and this included the responsible treatment of waste. As a result, such clients included the responsible treatment of waste, as a performance condition of their tender and work specification documentation. As a result, demolishers were required to submit a waste management plan as part of the tender process, including details on how they intended to recover and treat materials.

Development Approval Needs
For sometime now, local governments in various parts of Australia require a waste management plan to be submitted as part of the building development application and approval process. As a result, demolishers who are involved in demolishing an existing building on such developments are often involved in preparing such plans and then executing them.

Contaminated Materials
The impact of contaminated materials to demolition and waste recovery is not new to the literature as is apparent from work by authors such as Smith and Bishop (2005), Shibata et al. (2006), and Xing and Hendriks (2006). In terms of this study, the main insights revolve around three specific types of contaminated materials that were regularly mentioned by demolishers as affecting their approach to demolition, including lead paint, asbestos cement, and certain types of treated timber. The handling of such materials required specific treatment in accordance with regulatory compliance. As a result, such materials typically required selection of a specific approach to demolition and in this context hand demolition was often strategically used to selectively manage the segregation and removal of such materials. This was to manage the safety of both workers and the public. It was also to prevent such materials from inadvertently contaminating other site waste which could be recovered for recycling.

CONCLUSION

The research provides a new framework that generalises the underlying drivers of demolition method selection, as posited from a waste recovery point of view and as relevant to housing demolition. This is presented in the form of a model that summarises and orders the previous discussion, as presented in Figure 1. The generalisability of the model is limited by the context of the research method applied, but is presented in a way that makes it testable well beyond these limits including application to other building typologies. For instance it would be interesting to see if the same factors influenced the demolition of commercial buildings. Such construction offers significantly different economies of scale and different material profiles and so some drivers may be more or less active than in this study.

In providing insight into the model, a key issue is the perceived quality of the materials being recovered from site and the ability to convert these materials into saleable materials that can be sent back to market. Here, not all forms of waste were found to be of equal value. This was reflected in the research by whether demolishers would get paid for their waste (e.g. hardwood), were forced to give their waste away for low value or for free (e.g. bio-fuel), or had to pay to get rid of their waste (e.g. landfill tipping fees).

The framework provided in this paper provides a basis for looking at such issues in a systematic way. Future research should aim to confirm the validity of this framework across a broader range of demolition projects. In addition, the model should be used to profile and identify the location of impediments to the recovery of specific materials in the demolition waste stream, hence making it more possible to undertake a targeted approach to improved recovery.

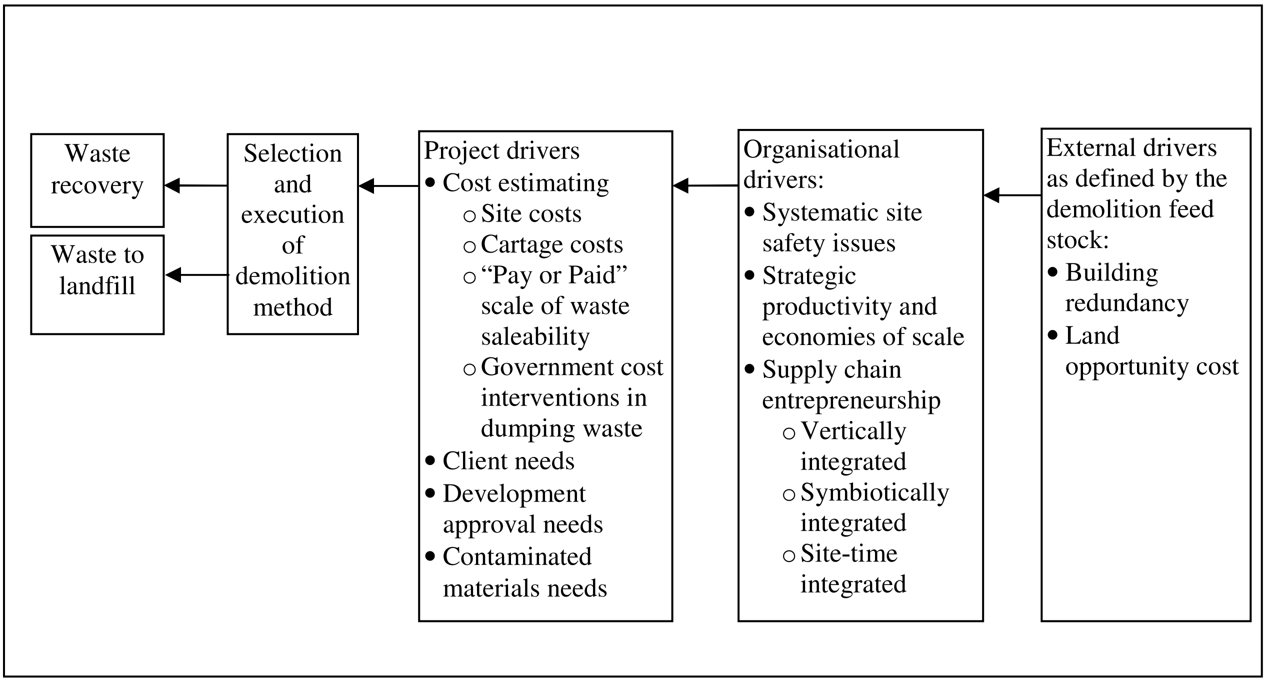

Figure 1: Model presenting the underlying drivers influencing demolition method and waste recovery potential

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