

WASTE MANAGEMENT IN THE AUSTRALIAN CONSTRUCTION INDUSTRY: A HUMAN FACTORS APPROACH

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Research has shown that construction and demolition waste forms a significant proportion of waste going to landfill (Graham & Smithers 1996). Australian construction industry participants have demonstrated a commitment to reduce C&D waste going to landfill by signing a Wastewise Construction Agreement with the federal government. Despite the willingness of construction firms to commit to reduction targets, the development of company-wide waste management strategies is still in its early stages. Although it has been demonstrated that a large proportion of construction waste is generated through a failure to manage waste within the management of a construction project itself (Bossink et al 1996), the majority of research in this field has focused heavily on factors external to the management of the construction process. This paper describes the application of a methodology to identify social and psychological factors which may determine behaviour in waste management within one of Australia's largest construction firms. The application of a behavioural approach to improving waste management performance is discussed.

Keywords: Behaviour, construction and demolition waste, minimisation, recycling, waste management.

INTRODUCTION

Owing to its bulk and weight, solid waste generated during the construction process represents a significant proportion of industrial solid waste. This waste is typically disposed of in landfill. In the Australian state of Victoria, construction and demolition (C&D) waste makes up 44 per cent of landfill, by mass (McDonald, 1996). The growing use of organic polymers and chemical additives in construction renders this waste increasingly liable to contamination by hazardous substances (Lahner and Brunner 1994). It is now understood that much construction waste, which was previously regarded as inert, generates harmful leachate (Apotheker 1992). In the UK, toxins arising from the burning of treated waste wood, appear to be accumulating in the food chain (CIRIA 1993).

Rapidly decreasing landfill space and public opposition to the creation of new landfill sites (BIE 1993) has led to escalating landfill & tipping fees. These fees now represent a significant cost to construction contractors. These costs will be passed on to construction clients and, ultimately, will be borne by society as a whole. The reduction of construction waste not only yields significant benefit to the environment but it has been reported that one Australian construction firm has been able to reduce landfill space used by 43%, enjoy a 55% cost saving and recycle 35% of waste generated (Graham and Smithers 1996).

The extent of the problem has been recognised by the construction industry and some of the larger participants have demonstrated their commitment to waste management by signing an Australia-wide Wastewise Construction Agreement. Despite setting the ambitious goal of achieving a 50% reduction in waste going to landfill by the year 2000, the waste management systems of the signatory companies are still in their infancy.

The environmental benefits of waste management include prolonging the life of landfill sites and reducing primary resource requirements (CIRIA 1993). In addition, waste management would serve to reduce transport needs and their associated impact on the environment (CIRIA, 1993). Social benefits include the avoidance of creating new and undesirable landfill sites, stemming potential environmental health risks associated with waste and its disposal and reducing the cost of construction.

Waste management in construction is increasingly recognised as an important and challenging issue. The problem of how to effectively manage construction waste is currently under investigation in the Australian construction industry.

DETERMINANTS OF C&D WASTE

Donovan (1991) lists factors which determine the quantity of C&D waste generated. These include economic development, the occurrence of natural disasters such as hurricanes, availability and cost of hauling and disposal options, regulations, availability of recycling facilities and the extent of end use markets. All of these factors may be regarded as "macro" factors, external to construction firms generating the waste. Schlauder and Brickner (1993) suggest that the unpredictable nature of determinants of C&D waste prohibits investment in C&D waste processing infrastructure. Typically, construction industry participants are not able to directly change these external factors.

Graham and Smithers (1996) tabulated causes of waste arising from actions taken by parties involved directly in a construction project. These causes are reproduced in Table 1. Causes identified by Graham and Smithers are "micro" causes, internal to the management of a construction project. As such, construction industry participants can directly determine and manage these factors.

Table 1: Causes of construction waste (Graham and Smithers, 1996)

Project phase	Design	Procurement	Materials handling	Operation	Residual	Other
Causes of waste	Plan errors	Shipping errors	Improper storage	Human error	Leftover scrap	Theft
	Detail errors	Ordering errors	Deterioration	Tradesperson - other labour	Unreclaimable non-consumables	Vandals
	Design changes		Improper handling: - on site - off site	Equipment error: Acts of God: - catastrophe; - accidents; - weather.		Client actions

MANAGEMENT OF C&D WASTE

Peng *et al* (1997) identify a six step hierarchy of materials waste disposal options applicable to C&D waste. These options are arranged in order by which they have an

impact upon the environment. Waste reduction at source, has the least impact on the environment followed by reuse, recycling, composting, and incineration of waste. Disposal of waste in landfill has the largest environmental impact and is the least preferable option.

Waste reduction at source, the best option in the waste management hierarchy, can be achieved through attention to good practice on site. Operational changes may be implemented at site level, to achieve improvements in a relatively short space of time. These may include:

the provision of a clear specification of good housekeeping and materials handling procedure;

- implementation of quality assurance techniques;
- regular auditing of materials purchased against materials used;
- prevention of over-ordering;
- preventive maintenance;
- improved segregation of waste streams to prevent contamination; and
- improvement in storage conditions.

Technological change, input material change and product change are other methods by which C&D waste may be reduced at source (Crittenden & Kolaczowski 1995). Developers, designers and clients tend to be over-cautious in specifying building materials and plant and in some instances may over-specify leading to unnecessary use of materials. A similar problem arises with over-designing in opting for generous margins of safety, leading to excessive use of materials (CIRIA, 1993). Waste may arise from materials producers' failure to provide materials in coordinated sizes. In order for changes in product, material input or technological processes to be implemented in the construction industry, clients, designers and materials suppliers must also be aware of and involved in the process of managing C&D waste.

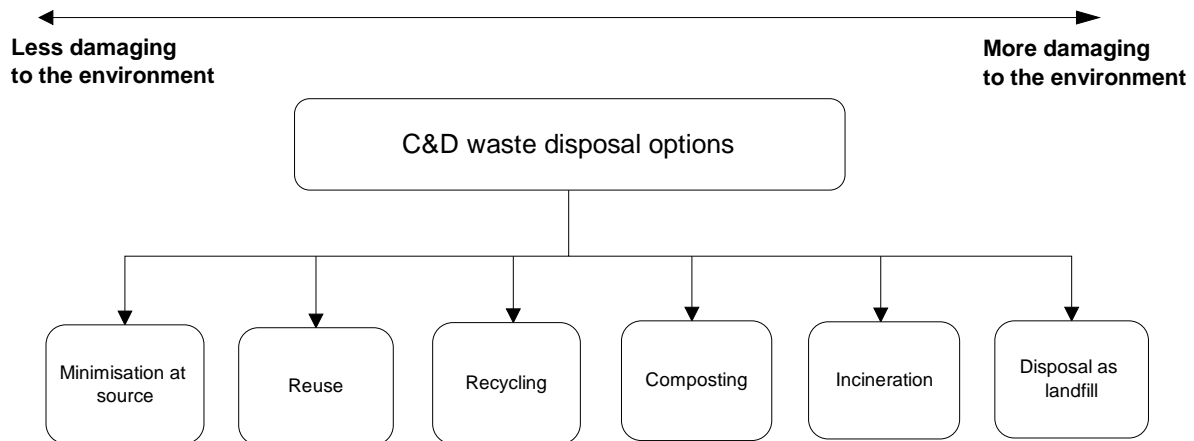
C&D waste has a high potential for recovery and reuse (Schlauder and Brickner 1993). Reuse involves moving materials from one application to another without the need to re-process those materials. Cosper *et al* (1993) identify Preservation and Conservation Association, a non-profit-making organisation in the United States, which specialises in salvaging building materials for reuse.

Recycling differs from reuse in that it involves re-processing materials rather than reusing them in their original form. Recycling options for C&D waste are increasing (von Stein & Savage 1994; Merry 1990) and, as is discussed below, much research into C&D waste management has focused on the development of recycling equipment and the development of products made from recycled C&D waste.

Land clearing debris such as tree stumps and vegetation can be processed through composting. Where landfill space is in short supply, incineration of waste may be considered but the environmental consequences of incineration are as yet unknown (Peng *et al* 1997). Finally, the least desirable option for waste disposal is landfill.

Figure 1 represents a framework of C&D waste disposal options which reflect the hierarchy described above.

Figure 1: C&D waste disposal options in order of preference



PREVIOUS RESEARCH

Much of the C&D waste literature explores the extent to which infrastructure is in place to enable cost-effective recycling of C&D waste and identifies technology available for processing such waste. For example, much attention has been devoted to the use of recycled materials such as rubber in the manufacture of asphalt road surfaces (Flynn 1995; Blumenthal 1995), or crushed demolition concrete as secondary aggregate for fill & hardcore in road construction (McCormack 1994, Anon. 1991). Recycling equipment has also been a popular topic for research (Filtz *et al*, 1993). Researchers have largely focused on factors external to construction firms and identified waste management in terms of the existence and improvement of external facilities for waste collection and processing.

The selection of appropriate processing technologies depends upon the form in which waste is received. For example, mixed waste must be processed differently to homogeneous waste and waste contaminated with chemicals requires different treatment to uncontaminated waste. It is therefore important to investigate methods by which materials are collected and removed from construction sites and factors which affect the collection and removal of waste at site level. For example, Cospers *et al* (1993) describe a system of separating residential construction waste on site, implemented by Cornerstone Material Recovery in the United States. By placing a combination of individual containers by each house under construction, the distance workers must travel to deposit waste is minimised. Containers are emptied every week, or more frequently if required and thus source separation occurs automatically over time.

Bossink *et al* (1996) quantified the costs of construction waste generated in the Dutch building industry. They measured purchase losses, collection costs, transportation costs, recycling costs and dumping costs. Purchase losses, or the costs of materials that leave the site as waste, amounted to two thirds of total costs. This suggests that, while infrastructure and recycling technology are valuable research areas, greater attention should also be placed on factors determining the efficacy of waste management within construction firms themselves.

Human factors as well as technology factors are critical to the successful attainment of desired environmental outcomes (Baetz *et al.* 1991; Beaumont *et al.* 1993). The current research aims to identify psychological and social factors which form the basis of construction industry participants' responses to waste management. Through understanding the value trade-offs which motivate these responses, an intervention to elicit desired behaviour change will be planned and implemented in one large contracting organisation in Australia.

HUMAN FACTORS

The construction industry's culture and its resistance to change have been identified as barriers to achieving effective waste management (Federle 1993). The effectiveness of a construction waste management programme depends upon the extent to which individuals involved in the construction process, change their behaviour in relation to the minimisation of waste generation and the separating of waste for recycling purposes.

Procedures and policies relating to waste management must be translated into behaviour changes at site level. The construction industry environment is one in which participants face conflicting goals. The emphasis on productivity goals and speed of construction may detract from the perceived importance of a company's stated waste management goals. For example, pressures to complete work quickly lead tradesmen to cut components from new material rather than using previously cut pieces (Federle 1993). In many instances, it is possible that site failure to implement waste management procedures effectively may be a reasonable response to prevailing environmental conditions on site or within the company as a whole.

WASTE MANAGEMENT CLIMATE

Researchers examining behaviour in organisations suggest that employees' perceptions of the work environment act as a frame of reference by which the appropriateness of behaviour is gauged (Schneider 1975). Through this process of evaluating the expected outcomes associated with certain behaviours, employees' future behavioural patterns are shaped. Research into the existence and effect of a safety climate has indicated that employees' perceptions relating to factors such as management commitment to safety, the extent to which safe employees are rewarded with promotion and the extent to which employees have control over safety aspects of their job have been components of a measurable safety climate (Cooper *et al.* 1993; Dedobbeleer & Beland 1991; Coyle *et al.* 1995). Employees' perceptions of the work environment may just as easily relate to their behaviour in waste management. Thus, if management commitment to waste management is perceived to be weak and employees believe that they have little control over waste management performance, or that their contribution will not be valued, behaviour will reflect these beliefs. The identification of significant waste management climate factors and the measurement of these factors could therefore be a useful starting point from which to develop a strategy for behaviour change.

GOAL SETTING

The setting of performance goals in waste management is recommended by Crittenden & Kolaczowski (1995) & Fishbein *et al.* (1994). To date, the extent of goal setting in waste management has been restricted to broad objectives of waste reduction,

expressed in percentage terms, being set at company level. These objectives are not site specific and site personnel may perceive them to be of little relevance. Despite the fact that it is acknowledged that waste management should be dealt with on a site-specific basis (Mincks 1994; McDonald 1996) no applied research to implement goal setting in waste management at a site level, has ever been undertaken.

The goal setting theory of motivation was developed by Locke (1968). Locke's theory holds that the primary factors in motivation are goals which an individual consciously decides to pursue. A goal or intention is the most immediate determinant of effort. The results of laboratory experiments and applied research in organisations, suggest that goal setting is an effective motivational tool. The results also indicate that specific, hard goals yield better performance than easy, "do your best" type goals (Latham and Baldes 1975; Locke *et al.* 1981). The value associated with setting specific performance goals suggests that setting broad objectives at company or even industry level, will have little motivational impact at site level. Site-specific goal setting should be trialled.

Communication and performance feedback are also recognised to be necessary elements of the goal setting process (Locke *et al.* 1981). A combined goal setting and feedback intervention has previously been found to be effective in bringing about improved safety performance in the construction industry (Lingard 1995; Duff *et al.* 1994; Matilla & Hyodynmaaa 1988). The extent to which this approach can yield improvements in other performance criteria, such as waste management, should be investigated.

RESEARCH METHODOLOGY

The research is broken into two phases. Phase one involves the assessment of the waste management climate within the construction organisation. Key personnel from top management to site foremen and operatives, in Queensland, New South Wales and Victoria, have been identified for interview. A structured interview has been developed to gather qualitative and quantitative data regarding the extent to which these individuals:

- understand the issues associated with waste management;
- believe that the management of construction waste is important to themselves, to their company and to the construction industry as a whole;
- believe that they have the ability to manage waste; and
- are committed to managing construction waste alongside other company objectives.

The results of phase one will be analysed to determine factors which impede and facilitate waste management in the participating firm. Differences in attitudes between individuals at different levels in the company hierarchy and regional differences between Australian States will be considered in this analysis.

Phase two of the work will involve a field experiment on ten construction or renovation projects throughout Australia. One of Australia's largest construction firms, Civil and Civic, has committed to participating in the research. The flagship experimental site will be the Sydney 2000 Olympic Village. The pre-requisites for a project's involvement are that it must be of a sufficiently long duration and it must be characterised by cycles of activity that are repeated over time eg repeated floors of a

multi-storey building or units of a residential housing project. This latter feature will allow waste data to be normalised on the basis of the number of cycles represented (Crittenden & Kolaczowski 1995).

MEASUREMENT OF WASTE

A waste characterisation audit will be carried out on each site prior to the commencement of the experiment (EPA Vic, 1994). This assessment will be carried out by mapping material flows as suggested by Gavilan and Bernold (1994) and will identify waste streams arising from the construction process. Waste generation will vary according to the nature of the project, the region and other factors (Yost & Halstead 1994). Key materials, eg timber, steel, concrete and plasterboard, will be identified for each project.

Once key materials have been identified, the waste measurement methodology will be devised for each project. This methodology will utilise desktop calculations, comparing QS certified quantities of key elements with ordered quantities. Comparisons will be made between delivery dockets for key elements and quantities specified in the bill of quantities. Hong Kong Polytechnic have previously used this method to quantify construction waste (Hong Kong Polytechnic, 1993). The difference between these two figures was deemed to represent material wastage. Waste contractors records are also expected to be a useful source of information for desktop measurements. This process by further cross referencing with each project's waste contractor's records.

In addition to desktop calculations, construction waste, for each key material, will also be measured by weight and/or volume. This measurement will be carried out at intervals determined by material flows and construction schedules. This data is already routinely recorded on Civil & Civic's site records which document information on a proforma required by the company's waste minimisation strategy (Civil and Civic, 1995). The physical measurement of waste will enable the reliability and accuracy of the desktop assessment to be gauged.

EXPERIMENT DESIGN

The traditional control group versus experimental group research design relies upon random assignment of participants into these groups. This is not usually possible in applied research in industrial settings (Komaki & Jensen 1986) and therefore an alternative to this design has been selected. A multiple baseline, across waste stream, experiment design will be used (Barlow & Hersen 1985). This methodology has been utilised in previous, successful behaviour-based interventions in the construction industry (Duff *et al.* 1994, Lingard 1995). Sites will be selected on the basis the extent to which the construction work involves repetitive cycles such as the floors of a multi-storey building or the construction of identical home units. This will enable performance to be standardised and comparisons to be made between periods representing comparable cycles. Subject to the successful attainment of funding, a minimum of ten sites will be involved in the experiment.

EXPECTED OUTCOMES

The waste management climate within one large construction firm will be identified and measured. Human factors associated with the motivation to manage waste will be identified within the context of the construction firm. An intervention strategy aimed

at changing behaviour to facilitate improved waste management performance will be developed. This intervention will involve setting material specific performance goals at site level. Performance measurement and feedback will also be components of the intervention strategy. The intervention will be implemented and assessed using an action research approach. The potential usefulness of focusing on human factors and implementing a behavioural approach to waste management will be determined.

CONCLUSIONS

Previous research in construction solid waste management has focused on factors external to the management of the construction project. The existence of waste processing infrastructure and the development of new technology for recycling construction waste have been the focus of most research to date. The underlying assumption that inadequate waste processing facilities and external factors, such as the market for recycled products, are the only factors hindering more effective management of construction waste has been implicit in much of this work. Some recent literature suggests that a large portion of construction waste arises, because of mismanagement of the construction process itself. Reduction of this waste at source is recognised to be a better solution than recycling waste once it is generated. While it is important to continue the development of waste processing technology and to invest in waste processing infrastructure, researchers should also consider human factors, within construction firms that may determine the effectiveness of waste management at site level. With this in mind, research is currently under way to identify human factors which currently hinder the attainment of waste management goals in construction. An intervention strategy aimed to change behaviour of construction site personnel will be developed, implemented and evaluated during the course of the research.

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