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Minimizing waste on construction project sites

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Abstract Waste minimization strategies and the relative significance of construction waste sources were examined using a survey of 24 construction firms operating in Australia. The results indicated that a sizeable proportion of respondent firms did not have specific policies for minimizing waste. Furthermore, while a majority of firms with specific waste minimization policies made efforts to minimize waste at source, i.e. to avoid generating waste in the first place, this minimization was limited to waste generated by site offices and amenities. Potential scope exists for improving the effectiveness of waste minimization at source by addressing the sources of all waste generated during the construction phase. The survey results indicated that the five most significant sources of construction waste were design changes, leftover material scraps, wastes from packaging and non-reclaimable consumables, design/detailing errors, and poor weather. Potential opportunities for minimizing the amount of waste generated on construction project sites are identified.

Keywords Australia, environmental impact assessment, construction waste, project management, sustainable development, waste minimization

INTRODUCTION

The construction industry has been found to be a major generator of waste. Craven *et al.* (1994) reported that construction activity is likely to generate ≈ 20–30% of all waste deposited in Australian landfills. According to Ferguson *et al.* (1995), more than 50% of the waste deposited in a typical landfill in the UK could be construction waste. Lanting (1993) found that construction waste constitutes 26% of the total amount of waste produced in the Netherlands. Rogoff & Williams (1994) reported that 29% of the solid-waste stream in the USA consisted of construction waste. Research studies have also reported that construction waste constitutes 19% of the total waste deposited in landfills in Germany (Brooks *et al.* 1994) and 13–15% of the total waste deposited in landfills in Helsinki, Finland (Heino 1994).

As more stringent controls are placed on landfill sites, the cost of disposing of construction waste is likely to rise, becoming a major cost in construction projects. Furthermore, the release of polluting emissions during the construction production process and the transportation of contaminated waste are potential hazards to the environment. The generation of construction waste also contributes to the depletion of raw materials used in the construction industry. Therefore, waste minimization is an important element of sustainable development since it will benefit both the environment (through the reduction of environmental pollution) and construction firms (by increasing their competitiveness through lower production costs).

Despite the significance of the construction waste problem, very little is known about the sources of construction waste. Practical waste minimization strategies require a detailed understanding of what causes construction waste. Effective methods for dealing with these wastes at their source can then be determined. The present paper reports the results of a preliminary survey of waste management practices on construction project sites conducted as part of a research study on the minimization of construction waste by the Faculty of Design, Architecture and Building at the University of Technology, Sydney, Australia. The objectives of the study were: (1) to identify waste minimization strategies employed by construction firms in New South Wales, Australia; and (2) to determine the relative significance of construction waste sources.

LITERATURE REVIEW

Waste minimization strategies

Three main waste minimization strategies used in construction projects were identified from the literature (Ferguson *et al.* 1995). These were: (1) avoiding waste; (2) re-using materials; and (3) recycling waste. Avoiding waste refers to any practice or process that avoids, eliminates or minimizes waste at source. Avoiding waste is also referred to as minimization of waste at source. Re-using and recycling waste refers to the re-using and recycling of waste materials, thereby reducing the volume of waste material to be disposed of and discharged into the environment.

Experienced practitioners in the waste and environmental pollution fields recommend that minimization of waste at source should be given the highest priority when developing strategies for waste minimization (Crittenden & Kolaczkowski 1995). This is because, conceptually, it makes more sense to avoid or minimize the generation of waste than to develop extensive schemes for treating waste. Re-using and recycling strategies allow waste materials to be put to beneficial use. However, re-using and recycling do not avoid the generation of waste (although these approaches serve to reduce the quantity of waste to be ultimately disposed of and treated).

Government initiative on waste minimization

The government of New South Wales, Australia, is proposing to achieve a 60% reduction in waste by the year 2000, and therefore, has proposed reforms to the existing Waste Disposal Act (Waste Reforms 1995). The existing Waste Disposal Act was enacted in 1970, and focuses on the storage, collection, treatment and disposal of wastes. The proposed reforms are based on a waste management hierarchy that prioritises waste management options into: (1) avoiding waste; (2) re-using waste; (3) recycling waste; and (4) disposing waste (where the first three options are not possible). Figure 1 illustrates the proposed waste management hierarchy.

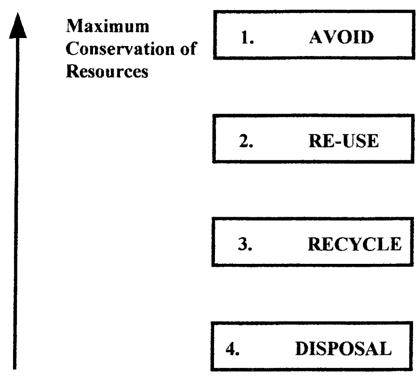

Figure 1 Waste management hierarchy: (1) avoiding waste; (2) re-using materials; (3) recycling and reprocessing materials; and (4) waste disposal (if the first three options are not possible).

Construction waste

In the UK, the Building Research Establishment conducted a series of studies in the 1970s (Skoyles 1974, 1976; Skoyles & Hussey 1974) to determine the incidence of waste on building construction sites. These studies found that waste levels were not necessarily related to the type of construction or the building company, but to the site and the people engaged on it. The studies showed that all those involved in the building process contributed to waste: those who design materials, plant and buildings; those who specify and communicate (e.g. the quantity surveyor and head-quarters staff); and particularly, the site manager and site operative.

Spivey (1974) was one of the earliest construction engineers to propose a specific construction waste management system based on the collection, transportation and disposal (by incineration, landfilling and recycling) of construction waste. Spivey also classified the components of construction waste as follows: (1) demolition materials (e.g. concrete, brick, wallboard, plaster and used timber); (2) packaging materials (e.g. paper, cardboard and plastic); (3) wood (including trees and scrap timber); (4) waste concrete and asphalt; (5) garbage and sanitary waste; (6) scrap metal products; (7) rubber, plastic and glass; and (8) pesticides and pesticide containers. Nevertheless, Spivey's (1974) work did not address the issue of minimizing construction waste at source.

Gavilan & Bernold (1994) categorized and evaluated construction waste according to the following sources: (1) design (e.g. blueprint error, detail error and design changes); (2) procurement (e.g. shipping error and ordering error); (3) materials handling (e.g. improper storage/deterioration and improper handling); (4) operation (e.g. human error, equipment malfunctions, acts of God or catastrophes, accidents, and weather); (5) residual (e.g. leftover scrap and unreclaimable non-consumables); and (6) others. The Gavilan & Bernold (1994) study found that most of the construction waste came from residual material, i.e. leftovers from cutting stock material to fit and non-re-usable non-consumables. Data from the study showed that this source accounted for 80–85% of brick and block wastes, 85–90% of dimensional timber wastes, and 90% of sheet-rock wastes. Bossink & Brouwers (1996) classified and evaluated construction waste sources in accordance with the following applications of construction materials: stone tablets, piles, concrete, sand-lime elements, roof-tiles, mortar, packing, sand-lime bricks and others (mainly small fractions of metal and wood). The Bossink & Brouwers (1996) study found that the largest source of construction waste was the use of stone tablets (29% by weight of total construction waste). The use of piles (17%), concrete (13%), sand-lime elements (11%) and roof-tiles (10%) also contributed greatly to the total amount of construction waste in the construction projects studied. All together, stone tablets, piles, concretes, sand-lime elements and roof tiles account for 80% of the total amount of waste in the construction projects studied.

The studies referred to above categorized and evaluated construction waste using different source identification models. Nevertheless, these studies have been fragmented and have focused on isolated aspects of the problem. The studies have evaluated the sources of construction waste for specific types of construction and specific construction materials. The study for which this paper presents preliminary results aims to ultimately develop an overall strategy for minimizing waste on construction project sites. Therefore, the present paper approaches the construction waste problem from a holistic perspective and attempts to identify waste minimization strategies generally used on construction sites and provide a generic comparison of the significance of construction waste sources.

METHOD

Data for the study were collected using a questionnaire containing questions relating to construction waste minimization strategies and sources of waste on construction project sites. The waste minimization strategies and construction waste sources outlined in the questionnaire were identified from a review of relevant literature.

Respondents were asked to indicate if their firm had a specific policy for minimizing construction waste, and if they did, respondents were asked to indicate which of the strategies were employed by their firm to reduce waste generated on construction project sites. In addition, respondents were asked to indicate if they employed a combination of the listed strategies or any other strategy not identified.

A construction waste source identification model was developed on the basis of the studies of Spivey (1974) and Gavilan & Bernold (1994). Construction waste was classified into the following sources: (1) design and detailing errors; (2) design changes; (3) procurement errors (e.g. over-ordering, under-ordering and supplier error); (4) improper materials handling (during fabrication, packaging, loading or delivery); (5) improper materials storage; (6) poor workmanship; (7) poor weather; (8) site accidents; (9) leftover material scraps from cutting stock-length material into shorter pieces to fit the design; (10) waste resulting from packaging, pallets and unreclaimable non-consumables (e.g. sheet piles that can not be recovered); (11) criminal waste caused by damage or theft; and (12) lack of on-site materials control and a waste management plan (e.g. re-ordering construction materials because the original order cannot be found: when original order arrives it ends up as waste).

Respondents were asked to indicate the relative significance of the construction waste sources by indicating if the source was 'very significant', 'significant', 'of minor significance' or 'not significant'. For each construction source, a severity index was determined by calculating the total percentage of respondents giving the response 'very significant'.

Copies of the questionnaire were sent to 52 construction firms randomly selected from lists of the Master Builders Association of New South Wales and the (defunct) Australian Federation of Construction Contractors. Twenty-four of the firms responded, giving a 46% response rate. Figures 2–4 illustrate the profile of the sample. The figures show that a high proportion of the respondent firms were large and relatively experienced in the provision of construction services. Figure 2 shows that nearly half of the respondent firms (47.6%)

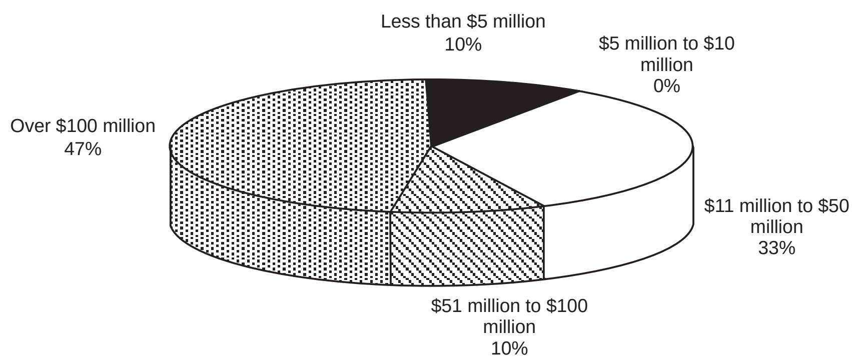

Figure 2 Average annual volume of work handled by respondent firms.

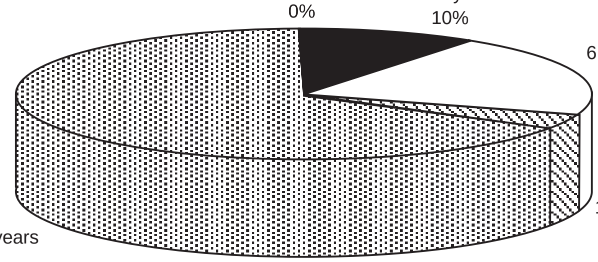

Figure 3 Number of years respondent firms have been offering construction services.

handled an average annual volume of construction work worth over $100 million. Similarly, over half of the respondent firms had been offering construction services for over 15 years (66.7%) and had completed over 40 construction contracts in the past 5 years (57.1%).

RESULTS

The results of the present study indicate that a sizeable proportion of construction firms do not have a specific policy for minimizing construction waste. Table 1 shows that 57.1% of the respondents had specific policies for minimizing waste on construction project sites, while 42.9% did not have a specific policy for minimizing construction waste.

Table 2 shows the distribution of the waste minimization strategies adopted by respondents who had specific policies for minimizing construction waste. Some 23.1% of respondents in this category limited their waste minimization strategy to recycling waste only. However, 61.6% of respondents in the category were involved in waste recycling either as the sole waste minimization strategy or in combination with other waste minimization strategies. It is interesting to note that none of the respondents limited their waste minimization strategies to re-using waste only. Similarly, only 7.7% of respondents with specific waste minimization policies limited their waste minimization strategies to minimizing waste at the source of origin. Nevertheless, 53.9% of respondents with specific waste minimization policies were involved in re-using waste in combination with other waste minimization strategies. Similarly, a total of 77% of respondents with specific waste minimization policies were involved in minimizing waste at source either as the sole waste minimization strategy or in combination with other waste minimization strategies.

Table 3 shows the severity index and the ranking for each source of construction waste. The results indicate that design changes, leftover material scraps (from cutting stock length material into shorter pieces to fit the design), waste from packaging, pallets and unreclaimable non-consumables, design/detailing errors, and poor weather (in that order) rank as the five most significant

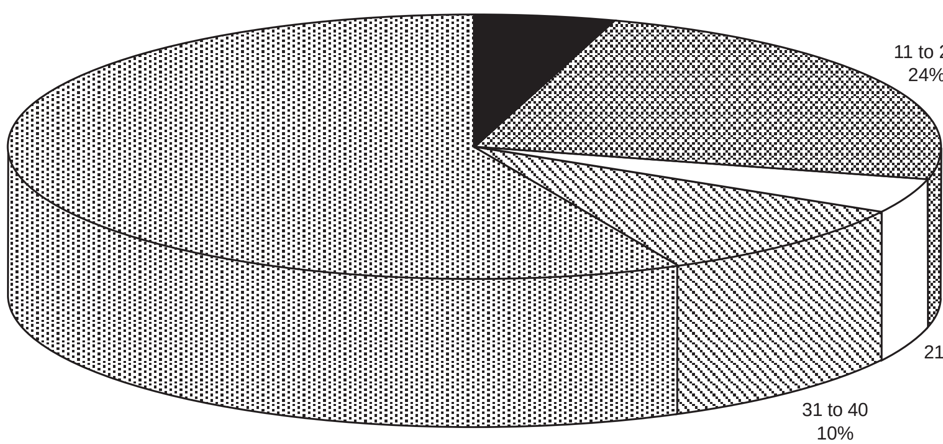

Figure 4 Number of construction contracts completed by respondent firms in the last 5 years.

Table 1 Proportion of respondents with a specific policy for reducing construction waste

Specific policy (Y/N)	Proportion of respondents
Yes	57.1%
No	42.9%

sources of construction waste. Similarly, criminal waste caused by damage/theft ranked as the least significant source of construction waste.

DISCUSSION

The present results indicate that minimization at source is widely practised as a waste minimization strategy by construction firms with specific waste minimization policies. However, unlike recycling, it is perceived to be more effective only when undertaken in combination with other waste reduction strategies. This can be attributed to the fact that it is practically impossible to minimize waste at source to the point where waste generation is completely eliminated. Therefore, any waste that is generated after minimization at source would need to be reduced using another waste minimization strategy (e.g. recycling or re-using). Nevertheless, comments passed by respondents suggest that the focus of waste minimization at source is on waste generated by site offices and amenities. Examples of waste minimization practices given by respondents include: computer transfer of drawings and information; using both sides of papers for photocopying; and using ceramic mugs and metal spoons in place of disposables. Sources of waste generated during the actual construction process are not addressed during waste minimization. Rather, waste generated during the construction process (e.g. concrete, metals, wood and glass) is recycled or re-used where possible, or are disposed of. Therefore, there is a lot of scope for improving the effectiveness of waste minimization at source by addressing the sources of waste generation during the construction process.

Effective waste minimization strategies can be developed for construction project sites by: developing an inventory of all waste streams on construction sites; identifying the sources of the waste streams; and determining the quantities and compositions of the waste streams. The sources of waste can then be ranked by size, economic value, and costs of storage, disposal, treatment and pollution control. A comprehensive set of waste minimization strategies can then be developed which focuses on eliminating the waste at source. However, since the complete elimination of waste at source is unlikely to be a realistic goal, options for reducing waste at source should be examined, and where

Table 2 Distribution of waste reduction strategies employed by respondents with specific waste reduction policies

Waste reduction strategy	Proportion of respondents
Re-using waste only	0%
Recycling waste only	23.1%
Minimizing waste at the source of origin only	7.7%
Combination of re-using waste and minimizing waste at the source of origin	30.8%
Combination of re-using waste, recycling waste and minimizing waste at the source of origin	23.1%
Combination of recycling waste and minimizing waste at the source of origin	15.4%

Table 3 Severity index and ranking for construction waste sources

Source of construction waste	Severity index	Ranking
Design changes	52.4	1
Leftover material scraps	42.9	2
Non-consumables	38.1	3
Design/detailing errors	28.6	1
Poor weather	23.8	5
Inadequate materials handling	14.3	6
Inadequate materials control plan	14.3	6
Procurement errors	9.5	8
Materials storage	9.5	8
Site accidents	9.5	8
Poor workmanship	4.8	11
Criminal damage/theft	0	12

this is not possible, opportunities for re-using and recycling waste materials should be identified.

In the present study, design changes were found to be the most significant source of construction waste. Changes to the original design can result in waste in two ways. Firstly, if the construction materials have already been purchased on the basis of the original design, waste could result if the materials cannot be resold or returned to the supplier, and the only option is to dispose of the materials. Similarly, if a structure has already been constructed, a change in the design may result in part of the structure being taken apart. In such a situation, waste results if the materials cannot be salvaged. Timely communication of design changes to all parties concerned is one way of reducing construction waste arising from this source.

The second and third most significant sources of construction waste were leftover material scraps, and packaging, pallets and unreclaimable non-consumables. To a large extent, residual waste resulting from leftover material scraps from cutting stock-length material into shorter pieces to fit the design, or pallets, packaging and unreclaimable non-consumables is inevitable. However, waste from leftover material scraps from cutting stock-length material into shorter pieces to fit the design can be minimized by careful dimensioning of materials and components during design to avoid cutting-to-fit. In a previous study undertaken by Formoso *et al.* (1993), the wastage of steel bars was reduced by the way steel cutting was defined in the structural design.

The fourth most significant source of construction waste was design and detailing errors. Waste arising from design and detailing errors is similar to waste arising from design changes. Construction materials purchased on the basis of wrong specifications could result in waste if these cannot be sold or returned to the supplier. Similarly, if material has already been used for part of a structure constructed on the basis of wrong specifications, the flawed part of the structure may have to be taken apart, resulting in waste if the materials cannot be salvaged. Clear specification of project goals by the owner, careful attention to detail at the design and planning stages, and a thorough review of the project specifications by the contractor at the construction stage can help to reduce wastes resulting from design and detailing errors.

Poor weather was the fifth most significant source of construction waste. Disruptions to construction activity caused by poor weather could result in waste if the work done before the disruption has to be discarded and the activity has to be started all over again. Materials already used are wasted if these cannot be salvaged. Waste arising from poor weather could also be caused by improper storage without proper protection. Improper storage ranked low in significance in the present study as a source of construction waste. However, respondents could have perceived improper storage to mean lack of protection against deterioration and biodegradation over a period of time. Wastes could also result if materials are left exposed to rainfall and extreme conditions of hot or cold weather. Detailed planning of construction process requirements and material storage facilities which takes into consideration poor weather conditions would reduce waste caused by poor weather.

CONCLUSION

The present paper has presented results from a preliminary survey on waste minimization strategies employed by construction firms and the relative significance of construction waste sources. The results of the survey indicate that a sizeable proportion of construction firms do not have specific policies for minimizing waste generated on construction project sites. Amongst the firms which do have a specific waste minimization policy, minimization at source (either alone or in combination with other waste minimization strategies) was the most widely practised waste minimization strategy. However, this strategy appears to focus on waste generated by site offices and amenities. Sources of waste generated during the actual construction process are not addressed. Therefore, potential scope exists for improving the effectiveness of waste minimization at source by addressing all sources of waste generated during the construction phase.

The results also indicated that design changes, leftover material scraps, waste from packaging and unreclaimable non-consumables, design/detailing errors, and poor weather are the five most significant sources of construction waste during the construction process. These results reveal several opportunities for minimizing the amount of waste generated on construction project sites. These include:

- timely and effective communication of design changes to all parties concerned;
- careful dimensioning of materials and components during design to avoid cutting-to-fit;
- clear specification of project goals by the owner to avoid ambiguity which could lead to flawed design and planning decisions;
- careful attention to detail at the design and planning stages to avoid design and planning errors;
- a thorough review of the project specifications by the contractor at the construction stage to detect design, detailing or other errors; and

- detailed planning of construction process requirements and material storage facilities, taking into consideration poor weather conditions, to reduce waste caused by poor weather.

A limitation of the present study is that the data is based on respondents' perceptions rather than factual records. Nevertheless, the results have significant implications and suggest possible directions for future research. Further research is being undertaken to develop implementation models for minimizing waste at source on construction project sites. These research studies are addressing the following issues: (1) How is the site production process related to the character and quantity of waste generated on construction project sites? and (2) What is the economic benefit to construction companies, construction clients and the general community of implementing waste minimization plans on construction sites? Results from such studies would assist in determining the facilitative management practices and construction methods required to avoid, eliminate or reduce waste at source on construction project sites.

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