Date: September 1999

BRANZ
THE RESOURCE CENTRE FOR BUILDING EXCELLENCE

STUDY REPORT

No. 88 (1999)

Construction Site Waste Generation – The Influence of Design and Procurement in Auckland

Roman Jaques

The work reported here was funded by the Public Good Science Fund of the Foundation for Research, Science and Technology and the Building Research Levy.

ISSN:0113-3675

PREFACE

This report discusses what influences there are on the generation of construction site waste. The research involved is part of a long-term effort to reduce the amount of material waste from building and demolition sites that is destined for the landfill.

ACKNOWLEDGMENTS

The Auckland construction waste survey relied heavily on the good will of 84 architects, quantity surveyors and contractors, who donated their time by completing the questionnaires. The author would especially like to thank the six designers - Adam Mercer, Geoff Still, Reinhard Kanuka-Fuchs, Joanne Kelly, and Trevor Pyle who also participated in telephone interviews. The assistance of Mark Smithers of Deakin University, Geelong, Australia, is gratefully acknowledged for providing material on which to base the BRANZ questionnaire. Technical comment on the final draft by Auckland Regional Council's Peter Mittermuller is also appreciated, as is the statistical input from BRANZ's Andrew Pollard.

Funding from the Public Good Science Fund of the Foundation for Research, Science and Technology and the Building Research Levy is acknowledged.

READERSHIP

This report is intended for designers, waste researchers and environmentalists.

CONSTRUCTION SITE WASTE GENERATION – THE INFLUENCE OF DESIGN AND PROCUREMENT IN AUCKLAND

BRANZ Study Report No. 88 **Roman Jaques**

REFERENCE

Jaques, R. 1999. "Construction Site Waste Generation - The Influence of Design and Procurement in Auckland". BRANZ, SR 88. Judgeford.

KEYWORDS

Construction Waste; Material Waste; Design; Procurement; Construction Site Waste Generation.

ABSTRACT

This research is part of a long-term effort to reduce the amount of material waste from building and demolition sites destined for the landfill. Specifically, it was to "*define at least two critical influences that can lead to more resource efficient construction (reduced generation of waste material) and that are of practical use to New Zealand builders*". To find these critical influences, a survey was carried out based on a survey conducted in a similar construction environment (Australia). Architects, quantity surveyors and contractors, all from the Auckland region, were surveyed. From the results, the following critical influences were identified:

- There is very little importance placed by architects on waste minimisation. In association with this there is a lack of operational material waste minimisation plans and strategies.
- Architects and quantity surveyors think that creating a buildable design that allows for a logical sequence in construction and avoids variations on site minimises the amount of waste material generated.
- Architects believe that accurate and integrated project information and making waste reduction efforts financially beneficial to the client, help mitigate waste production.
- CADD is seen by architects as a waste generator rather than a waste reducer, both in terms of materials (paper generated) and time (for all but repetitive design).
- Contractors cite the use of standardised forms (both in the room and material sizes), so that cutting sheet materials to fit can be reduced, as the most important factor in reducing waste.

The results of this work will now be used to feed into Regional and Local Authority waste management plans, and to support waste reduction programs being implemented by building companies and those associated with the construction industry.

CONTENTS

Page No.

1. SURVEY METHODOLOGY 1

1.1 Background 1

1.2 Fine Tuning of Questionnaire 1

1.3 Survey Approach 2

1.4 Response Population for the Questionnaire 3

2. QUESTIONNAIRE RESPONSES 4

2.1 Architectural Practices: Set-up and Attitudes to Material Waste 4

2.2 Quantity Surveying Practices: Set-up 4

2.3 Contractors' Practices: Set up and Attitudes to Material Waste 5

2.4 Graphical Interpretation 6

2.4.1 Building professionals' responses 6

2.4.2 Architects' responses 8

2.4.3 Quantity surveyors' responses 8

2.5 Written Answer Feedback from Architects and Quantity Surveyors 9

2.6 Descriptive Feedback from Contractors 12

3. ONE-ON-ONE FOLLOW-UP INTERVIEWS 14

3.1 Background to the Interviews 14

3.2 The Two Issues 14

3.2.1 Issue #1: CADD usage 14

3.2.2 Issue #2: prefabrication 16

3.3 The One-on-one Interview Questions 16

3.4 Results 17

4. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS 19

4.1 Discussion 19

4.2 Conclusions 20

4.3 Recommendations 21

APPENDIX A: SIXTEEN COMMON QUESTIONS 22

APPENDIX B: FORM LETTER SENT TO BUILDING PROFESSIONALS 23

APPENDIX C: SAMPLE QUESTIONNAIRE (ARCHITECTS) 24

APPENDIX D: ABBREVIATED TRANSCRIPT OF ONE-ON-ONE INTERVIEWS WITH ARCHITECTS 27

REFERENCES 29

List of Tables

Table 1: Project type - architectural practices (question A2) 4
Table 2: Procurement distribution - quantity surveying practices (question C1) 5
Table 3: Methods of waste minimisation (question B5) 5
Table 4: Principal causes of waste among trades (question B3) 6
Table 5: Architects' design stage measures to reduce waste (question D1) 10
Table 6: Quantity surveyors' measures to reduce material waste 11
Table 7: Estimated New Zealand waste percentages compared with overseas surveys 12

List of Figures

Figure 1: Correspondence analysis of Auckland building professionals 7
Figure 2: Correspondence analysis of survey responses from architects 8
Figure 3: Correspondence analysis of survey results from quantity surveyors 8

1. SURVEY METHODOLOGY

1.1 Background

The research reported here is part of a BRANZ long-term examination of waste issues, the ultimate goal of which is to reduce the amount of material waste from building and demolition sites destined for landfill. Towards this goal, various initiatives are being developed and implemented. Initiatives range from reusing and recycling building materials through to the trail of on-site waste reduction demonstration programmes.

The overall objective of this research was gain some understanding of the role that various processes have on the generation of material waste on building sites. Specifically, it was to "*define at least two critical influences that can lead to more resource efficient construction and that are of practical use to New Zealand builders*".

In some countries the construction and demolition industries' significant impact on the environment is being recognised[1,2,3] and there is recognition that there is huge potential for the negative aspects (for example site waste) of this impact to be reduced. A few governments are even taking an active role in targeting the construction sector's tendering system, to reduce the amount of waste material and its effects[2,3]. An example of this is the recent Swedish initiative[3], which is addressing construction waste through the procurement process (as well as differentiated taxes on disposal fees). The Swedish Environmental Protection Agency (EPA) has given public clients a list of parameters which should be considered in tender evaluation, in addition to those usually put forward. This list includes items such as 'cost', 'quality', 'environment', and 'operation and maintenance'. Along with each of these items, the EPA has defined their importance (by attaching a weighting) to aid bid evaluation. At present, 'environment' is on an equal footing with operation and maintenance.

To gain a better understanding of the New Zealand situation regarding influences on construction resource efficiency and waste, a pilot study[4] was conducted in early 1998. The pilot study targeted a variety of building professionals – architects, quantity surveyors and subcontractors – in the Wellington region. The pilot survey was based on a survey[5] performed in a comparable construction environment (Australia). The pilot study and the survey reported here share the same terms, definitions and study background, so these are not repeated here.

It is recommended that the pilot survey is read prior to or in conjunction with this study report.

1.2 Fine Tuning of Questionnaire

As a result of the pilot survey carried out in 1998[4], some fine-tuning of the questionnaires was performed. Of the three types of professionals surveyed, only architects suggested improvement to the pilot survey. Some of the architects thought some questions were ambiguous (see Section 4.3 in the pilot survey), which could lead to misinterpretation.

Four architects were interviewed to see how the questionnaire could be improved. Their suggestions included (refer to Appendix 2 for the appropriate questionnaire):

- the inclusion of definitions for the different types of waste

- clarifying the wording of question A4 (the number of architects in the practice), the last question in B6 (on the effectiveness of waste reduction strategies), and question C1 (the types of procurement system used)

- improving the layout of the questionnaire - to improve consistency between the questions, making them easier and faster to read.

These changes were made prior to the questionnaire being sent out for this follow-up study.

1.3 Survey Approach

The survey approach for the Auckland region was similar to the pilot study[4]. As previously, business names/numbers were randomly chosen from the Yellow Pages for the questionnaires. Each professional/practice was called and a summary of the project given, before requesting their participation.

In addition to the questionnaires, six one-on-one interviews were held, so that some issues could be explored in more detail. The one-on-one interviews were based around two themes:

(1) What are the barriers to computer aided design and draughting, and does it have greater application in larger practices/projects?

(2) Why is prefabrication of building elements not seen as beneficial in terms of resource efficiency?

A recommendation within the pilot study was that the survey be extended nation-wide, covering the three main city centres – Auckland, Wellington and Christchurch. This was suggested because it was felt that the New Zealand building industry as a whole was not well represented otherwise. On closer examination of the three main city centres, it was found that Auckland city is unique. Of all the centres, Auckland city is the most progressive in construction-related waste mitigation techniques. For example, it has targeted measures, such as having Territorial and Local Authorities involved in support and promotion of construction-specific initiatives (such as the *Resource Efficiency in the Building and Related Industries*[6] programme), as well as more broad-brush initiatives (such as the *Resource Exchange Network for Eliminating Waste*[#] for materials exchange between industries). These initiatives are largely due to the fact that of all the major cities in New Zealand, Auckland has the highest environmental stresses placed on landfill, and as a result, also has many private waste operators and high landfill tipping fees. Overseas indications suggest that it is most likely that other major New Zealand cities will follow Auckland's lead, in the near future, due to increasing environmental pressure (through legislation, the depletion of natural resources, and a more educated public). In short, Auckland city today makes it a particularly good candidate for study now, as a guide to what the other major cities in New Zealand may be like in the near future.

[#] This is a product of the Councils in the Auckland Region. Contact RENEW Wasteline (09) 366 2070

The Auckland survey was conducted in October-December 1998. The one-on-one interviews were held in January 1999.

1.4 Response Population for the Questionnaire

It soon became obvious when analysing the pilot study questionnaire replies, that the limited number of respondents constrained the type of analysis. As a result, one of the recommendations from the pilot study, was that *"…for the next survey, more than 30 representatives from each profession are obtained…"* [The number 30 was chosen as it is recognised as a useful minimum sample size for smaller populations, which are assumed to follow standardised normal distribution. A sample size of 30 results in only about a 4% error in the prediction of the confidence interval. To achieve a significantly lesser error, a much larger sample size is necessary.]

Achieving a response from at least 30 architects and subcontractors in the Auckland region was not difficult. However, it proved to be problematic for the quantity surveyors group, where only 38 companies are listed in the Auckland Yellow Pages. A reply rate of nearly 80% would be necessary, which in questionnaires such as these is unlikely. Thus, a different approach was necessary for statistical analysis of responses from this group.

For the Auckland quantity surveyors, the question that needed to be addressed was 'What is the minimum response population needed, to get a statistically relevant answer (that is, a 'good indication' of what a much larger return rate might give), given that the population size is only 38?' To answer this, two assumptions were made:

i) there are five possible answers to each question (as they are 5-point graded), and
ii) there is no agreement within the industry.

It can be shown statistically that if at least 11 people are sampled, there is only a 5% chance that all of them will give the 'wrong' answer. It was felt that this suffices the 'good indication' requirement. This minimum population size was exceeded, with fourteen replies in total from Auckland-based quantity surveyors.

The response rate (ie the number of actual posted replies as a proportion of those who responded positively over the phone) for architects was around 40%, with 35 replies. For the quantity surveyors, 40% (ie 14) responded and 38% (ie 30) of the contacted contractors replied. The reason for the low response rate (compared to the pilot survey) for all the groups is unknown, but it is thought that the influence of the Christmas rush perhaps deterred potential respondents.

Seventy-one percent of all Auckland architectural practices[7] contain four practitioners or less. However, it was found that ninety-four percent of all the Auckland practices surveyed contain four practitioners or less. This discrepancy may have introduced a bias. The introduction of possible bias due to practice size misrepresentation should be investigated in future studies.

2. QUESTIONNAIRE RESPONSES

2.1 Architectural Practices: Set-up and Attitudes to Material Waste

The survey captured a diverse range of architectural practices. Diversity was gauged by the number of participants employed within the firm, as well as the type of project likely to be undertaken by the practice. Architectural practices ranged in size from sole practices through to a maximum of 12 architects.

Table 1 shows the type of work undertaken by the practices surveyed. It can be seen that the most common were the domestic, commercial and refurbishment categories. Note that the 'other' category included restaurants, health care clinics, project management and accommodation. Forty-three percent of the practices were involved in more than three types of project, with 17% specialising in a single type of project (eg Domestic).

Table 1: Project type - architectural practices (question A2)

Project Type	Percentage
Domestic	93%
Commercial	71%
Refurbishment	50%
Education	29%
Industrial	21%
Recreation	21%
Hospitals	14%
Maintenance	7%
Other	29%

Most (80%) architectural practices surveyed did not rate waste minimisation as an important design consideration, or gave a neutral response (Question B1). Eighty percent also replied that they do not have a waste minimisation design strategy, with the rest replying that they have a system (whether formal or informal) in operation. Waste minimisation design strategies ranged from 'designing to suit material panel sizes' through to 'pre-cutting/nailing and recycling demolition timber' and 'utilising as much of existing building materials on site for renovation work' (Question B2).

By far the largest majority of architectural practices (88%) utilised fixed sum contracts for their operations (Question C1). Negotiated contracts (at 48%) were the only other common contract type. Also, there was a trend towards using the negotiated and project management forms of contract more (Question C2).

2.2 Quantity Surveying Practices: Set-up

A diverse range of quantity surveying practices were surveyed. Most of the practices were principally involved in commercial (50%), with refurbishment, industrial, educational and domestic construction all at 42% (Question A2). The 'other' category included fast-food outlets and service stations. The size of the respondents' practices ranged from sole practices through to 30 employees (one assumes that this was for the company nation-wide) (Question A4).

Fixed sum contracts proved to be the most popular form of procurement method, used by 50% of those surveyed (see Table 2). Project management and negotiated contracts were also popular, but significantly less so. At the bottom end of the scale, novation was used by only 15% of those surveyed.

Table 2: Procurement distribution – quantity surveying practices (question C1)

Procurement type	Percentage
Fixed sum	50%
Negotiated	38%
Project management	35%
Reimbursable contract	31%
Design and build	23%
Novation	15%

It was asked if there was a trend towards using any particular procurement method more (Question C2). Just under half of those asked thought there was a trend, and of those, 'fixed sum' and 'negotiated' were the most popular procurement types.

2.3 Contractors' Practices: Set up and Attitudes to Material Waste

As for the pilot survey, contractors from general construction firms, rather than specialist firms, made up the largest trade group (Question A2). Other trades represented were: wall framing, truss fabricators and ceiling work. Thirty contractors responded to the survey in all. Practice sizes ranged from sole operators through to 70 employees (Question A3).

Contractors were asked how they thought designers could minimise waste arising in their particular trade (Question B5). The descriptive-based answers were grouped into categories for analysis (see Table 6). Note that some respondents fitted into more than one category. The two most popular design-based choices were to increase the range of material sheet sizes (to reduce off cuts) and to reduce the complexity of buildings.

Table 3: Methods of waste minimisation (question B5)

Waste Minimisation Methods	Percentage
Range of sheet sizes	41%
Simplify design	29%
Structural awareness	18%
Modular components	18%
Prefabrication	15%
Better communication	6%

Building contractors were also asked what they thought the principal causes of waste were (Question B3). Their descriptive-based responses were grouped into the six categories shown below (see Table 4). Note that some responses fitted into more than one category. The majority of contractors cited non-standard sizing and non-standard design as being the principal causes of waste. The 'other' category contained issues such as no storage space and no contingency plans.

Table 4: Principal causes of waste among trades (question B3)

Causes of Waste	Percentage
Non-standard sizing	53%
Non-standard design	35%
Improper packing	21%
Poor transportation	18%
Handling on site	18%
Inaccurate detailing	15%
Other	32%

2.4 Graphical Interpretation

Sixteen common questions, each having a five-point response range, were directed at both architects and quantity surveyors. For a list of these questions, please refer to Appendix A. Correspondence Analysis – a descriptive technique designed to quantify qualitative data – was the statistical method used to analyse the raw data. When viewing the graphs, the key consideration is how far the data is spread from the centre. On each of the graphs, the x-axis represents 'dimension 1', where zero is the neutral point, with the weighting progressively increasing the further away the data is. The term 'inertia' is also used on the axes. Inertia represents the weighting or importance of a result. Dimension 1 has the highest amount of inertia, so is the most important of the two axes.

For more information on the statistical analysis and graphical interpretation, refer to Section 2.4 of the pilot study[4].

Initially, a general impression of what building professionals see as being critical influences that can lead to resource efficiency in construction, and which issues are seen as unimportant, are investigated. These issues are then explored further by focusing on two of the building professions (architects and quantity surveyors) individually.

2.4.1 Building professionals' responses

Refer to Figure 1 for the following analysis. The graph examines building professionals' views, combining both architects and quantity surveyors responses to 16 common questions. It should be noted that since the sample of architects is much larger than that of the quantity surveyors (about three times), the combined graph reflects the views of the architects more than it does the quantity surveyors.

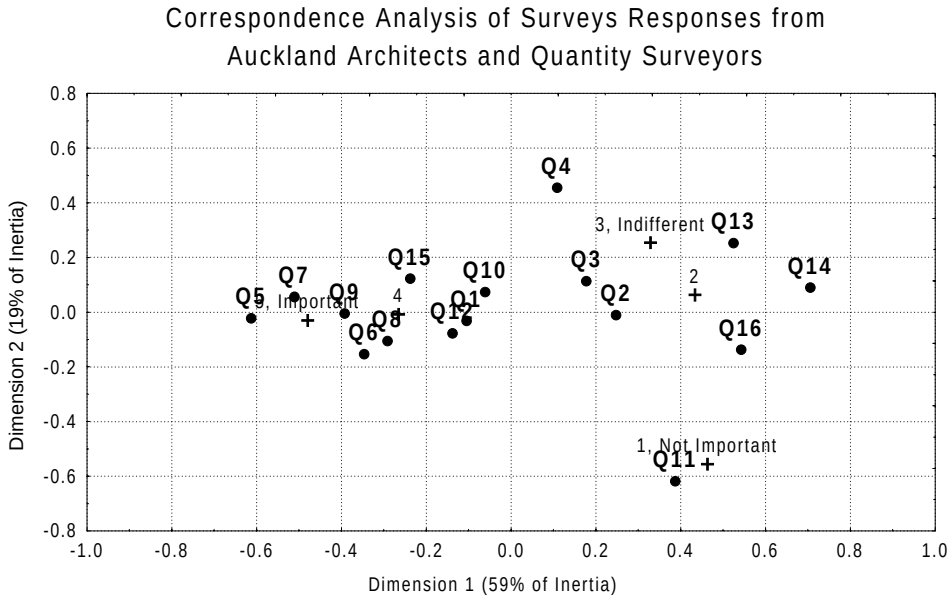

Figure 1: Correspondence analysis of Auckland building professionals.

The strongest conclusion is that both groups find the following statements unimportant:

- "*because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable*" (Question 14);
- it is "*only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings"* (Question 16)
- "*the current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on more projects*" (Question 13).

There is strong agreement in the importance of the statements:

- "*the creation of a buildable design that allows for a logical sequence of construction*" (Question 7)
- "*avoid variations occurring on site*" (Question 5), in terms of waste minimisation.

2.4.2 Architects' responses

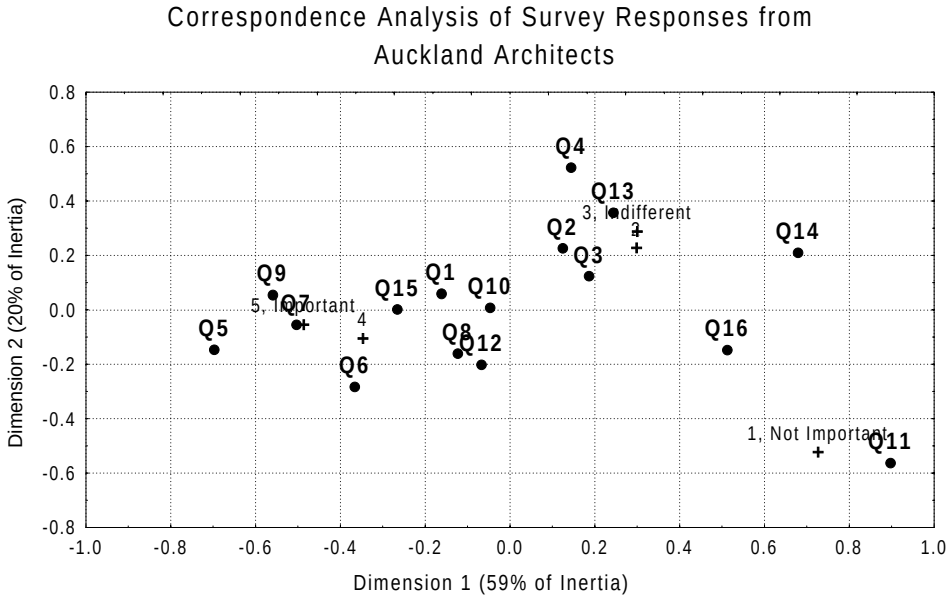

Figure 2: Correspondence analysis of survey responses from architects.

- Architects find that "*using computer aided drafting and design*" (Question 11) is not important.

Architects find the following statements important, in terms of waste minimisation:

- "*making waste reduction efforts financially beneficial to the client*" (Question 9)
- "*creating a buildable design that allows for a logical sequence in construction*" (Question 7)
- "*providing accurate and integrated project information*" (Question 5).

2.4.3 Quantity surveyors' responses

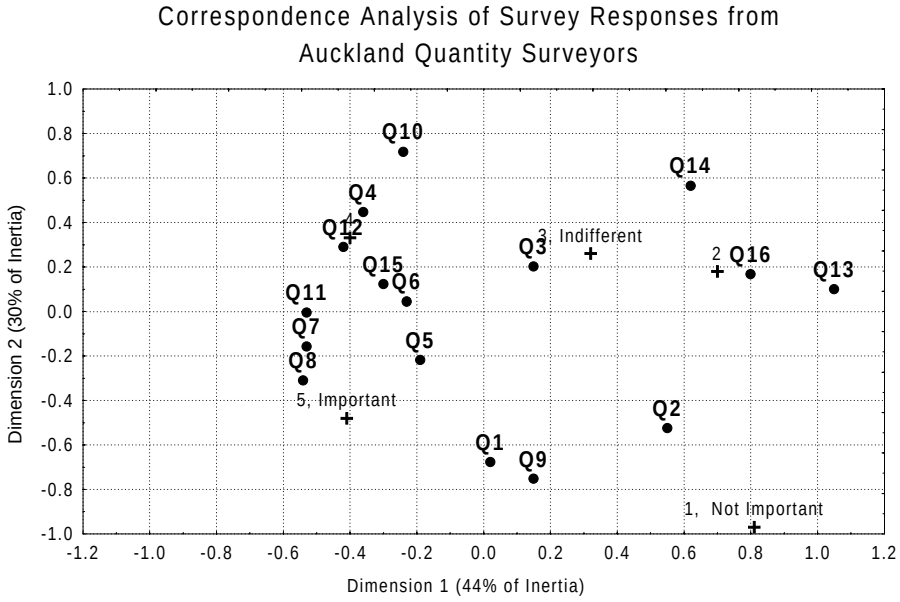

Figure 3: Correspondence analysis of survey results for quantity surveyors.

Figure 3 provides analysis of quantity surveyors. Quantity surveyors find the following statements unimportant:

- "*the current limitation of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on a wider scale*" (Question 13)
- "*it is only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings"* (Question 16).

Conversely, quantity surveyors rated the following statements as very important:

- "*creating a buildable design that allows for a logical sequence in construction*" (Question 7)
- "*selecting materials to avoid unnecessary cutting*" (Question 11)
- "*using modular components within a design, as a method of waste reduction*" (Question 8)
- "*the use of prefabrication of building elements will reduce the amount of building waste generated*" (Question 12).

2.5 Written Answer Feedback from Architects and Quantity Surveyors

ARCHITECTS

Architects were asked if alternative methods of procurement offer improved opportunities for waste minimisation strategies to be adopted (Question C3). Twenty percent thought that alternative procurement methods would improve waste strategies, while 43% thought that it would only result in improvements sometimes.

Once again, there were only a few suggestions on which methods offered the greatest advantages and why. Some of the suggestions put forth included:

- *"Novation - contractor has vested interest in saving money"*.
- *"Each has its own advantages and disadvantages - eg 'Fixed Sum' has propensity to waste but can also promote savings if prices keen. 'Negotiated' has more possibilities for savings during construction but also allows more flexibility/changes etc, which leads to increased waste"*.
- *"Negotiated – allows designer/owner/builders to work together….. to reduce waste"*.
- *"Fixed sum - if a building is fully designed and documented a more accurate quantification could be implemented with a direct reduction on waste"*.
- *"If those involved in the procurement process are not waste conscious then reimbursable work may be least effective, with fixed pricing or similar most effective"*.
- *"Waste minimisation is either a cost or a saving to the client, builders and contractors. Designers will always respond to their clients needs which are cost driven. If waste was a cost of construction the whole industry would get its act together"*.

As for the pilot study, the 'fixed sum' form of procurement was suggested by a high number of those surveyed, as an alternative method of procurement to offer improved opportunities for waste minimisation strategies. This contradicts the results of the Australian study[5], where the respondents thought that this offered few opportunities in terms of waste minimisation. Although to some degree these statements were qualified in the Australian study, this survey suggests that there is either some misunderstanding in the architectural fraternity about the relationship between the different procurement methods and waste minimisation, or the New Zealand construction industry is significantly different to Australia. Research is needed to prove (or disprove) the validity of the Auckland region results.

Architects were asked what measures could most effectively be taken at the design stage to reduce waste occurring on site (Question D1 and see Table 5). The popularity of 'attention at the design stage', which results in a logical flow for the construction of the building, is evident. This is followed closely by 'modular construction' (where repetitive building structure is used), and 'drawings fully complete' so as to avoid variations from the proposed design. Architects responses are grouped into general themes in Table 5.

Table 5: Architects' design stage measures to reduce waste (question D1)

Measure	Count
Attention at design stage	9
Drawings fully complete	8
Modular construction	8
Other	7
Careful material selection	5
Component sizing	5
Early costing	3
Good communication	3
Prefabrication	3
Limit special components	1

Comments that are related to 'attention at the design stage' include:

- "*…careful design taking into account as many sub-trade disciplines as possible…*"
- "*….make agreement with owner to design for reduction in waste*"
- "*Think about the design and implications*"
- "*More time spent on design issues - is more design issues solved before construction*"
- "*More documentation provided (drawings and specifications) before construction, with schedules of quantities and programs provided by contractors before consultation*".
- "*accurate and extensive quantities scheduling*"
- "*accurate brief by client. Taking time (money) to assess needs (desires) before start of process is invaluable*".

Some remarks from architects expressed pessimistic views when addressing construction waste during the design process. These included:

- "*without knowing the project in enormous detail at the outset it is not possible to identify site wastage*".
- "*There are other design choices such as dimensional standardisation…but I'm of the opinion that for most design work its neither practical, nor is it an issue to the average practitioner. I see prefab and/or modular design as a short term expediency for a given one-off set of circumstances.*"
- "*none"*

Six 'no replies' out of 35 responses were also forthcoming. The author is unsure of why no responses were given to this question. It is suggested that, because the answer required more consideration (rather than just a quick reply), respondents chose not to answer it.

QUANTITY SURVEYORS

Quantity surveyors were asked whether alternative methods of procurement offer improved opportunities for waste minimisation strategies to be adopted (Question C3). Fifteen percent thought that this was true, with about half of those surveyed agreeing this was true sometimes. The quantity surveyors were asked to elaborate on what they thought the alternative mechanisms were. Of all the respondents, only one responded with a long answer:

"*There has to be a cost incentive to reduce waste. The only incentive at present - the more waste the less margin on all procurement methods other than 'reimbursable contracts'. The more competitive the procurement method the less margin, therefore minimal waste/more profit. 'Fixed Sum' procurement is generally the more competitive method for this purpose.*"

Question D1 asked what measures could most effectively be taken at the design stage to reduce waste occurring on site. Answers were grouped into seven themes, according to the responses (see Table 6). There was no common theme which was picked by the majority of the respondents, with 'smart design' (a generic category) being the most favoured of all the categories.

Table 6: Quantity surveyors' measures to reduce material waste

Measure	Count
Smart design	4
Total design involvement	3
Educate Client/Supplier	2
Good communication	2
Modular design	2
Careful material selection	1
Drawings fully complete	1

'Smart design' responses included:

- "*framing centres coinciding with wall board widths and heights*"
- "*designers were not so precious about their designs and were more willing to listen to the lateral thinkers in the industry who can better help them select more efficient products to build with.*"

2.6 Descriptive Feedback from Contractors

The contractors' questionnaire was structured differently from that of the architects and the quantity surveyors. Disregarding company details, contractors were only asked four questions - all requiring longer written answers, as opposed to multi-choice type questions. Written answers focused on the quantities and causes of waste, and the potential for waste mitigation.

The survey focused on the types of building materials that contractors use regularly as part of their trade and the proportion of these materials that is wasted during construction. Once again, there were large ranges in the estimated proportions of waste for the different building materials. From Table 7 it can be seen that nearly all the results of the overseas studies (the BRE[1] and CIRIA[2] studies) fall within the New Zealand results' range.

Table 7: Estimated New Zealand waste percentages compared with overseas surveys

Material	Auckland predicted waste figures	Comparative figure from CIRIA study[2]	Comparative figure from BRE study[1]
Timber	2 - 20%	10%	12.3%
Fibre Cement board	5 - 10%	-	-
Particleboard	2 - 15%	5-7%	-
Plasterboard	5 - 20%	10%	9.5%
Concrete	0 - 10%	2-3%	10%
Reinforcing bar	0 - 5%	3%	3.3%
Fixings	2 - 5%	-	7.1%
Roofing	2 - 10%	5-6%	10%

Contractors listed what they thought their principal causes of waste were (Question B3). Common themes are in bold type. The responses included:

- "*inappropriate use of product at design stage (eg size, application, openings)"*
- *"irregular shapes"*
- *"buildings not being designed to suit* ***standard sheet sizes****"*
- *"lack of care in the delivery, handling, storage and fixing of material"*
- *"design not specific to waste loss/material availability not* ***specific to sizes required*** *cutting to fit"*
- ***"sheet sizes****/suitable size of timber available at time of delivery"*
- *"timber: buying exact lengths; allowances for defects; over ordering in case of problems"*

- *"loss, damage, theft but chiefly offcuts being of unusable size"*
- *"buildings not designed to **suit board sizes**"*
- *"offcuts and unavailability of **correct size of material**"*
- *"poor use on site/poor design/poor quantity surveying work"*
- ***"standard purchase lengths** don't correspond to requirements of job*".

Contractors were then asked what aspects of waste generated as part of their trade, could be attributed to decisions made in the design and specification stage of a building (Question B4). Bold text indicates common themes. A wide variety of responses were forthcoming, including:

- "*modular design, tailored for **component sizing"***
- "***over-design leading to more waste**"*
- "*very few, if any*"
- "*design to **suit sizes of product** available only where sizing is out of step with sheet sizes*"
- "*stud heights that don't **suit sheet sizes"***
- "*rooms not **built to sheet sizes"***
- "*careful design*"
- "*room designs to **fit sheet sizes"***
- ***"sheet sizes** often don't suit the sizes of rooms*"

From the bolded comments, it can be seen that the emphasis for contractors is on the use of standardised forms (room and material sizes) to fit whole material sizes.

3. ONE-ON-ONE FOLLOW-UP INTERVIEWS

3.1 Background to the Interviews

One of the recommendations of the pilot study[4] was that a series of one-on-one interviews be conducted with building professionals. There were two main reasons given for conducting these interviews:

1) "*the long answers were generally poorly responded to, with some building professionals giving only the briefest indication of their attitude or opinion on an issue*", and
2) "*the reasons behind the respondents choosing the particular answer they did was largely left undetermined. This was especially true of the multi-choice answers where there was no chance for elaboration on view points*".

For many of the questions in the questionnaire, knowing the 'hows' and 'whys' behind the answers would provide a better insight into professionals' attitudes and current and possible future practices. Understanding these motivations is important.

Conducting formal one-on-one interviews as originally envisioned proved to be unnecessary. This was because of the way in which the Auckland survey was answered, compared to the pilot survey[4]. The major difference was in the response to the long answer questions, which the Auckland respondents answered in more detail. It is unknown why this was the case. Of the 35 Auckland architects who replied, 29 answered the long answer question. Of the 14 Auckland quantity surveyors who sent back their questionnaire forms, 11 responded to the long answer questions. Thus, formal interviews exploring the long answer questions were not conducted.

Instead, short informal telephone interviews were conducted, targeting two issues that the author believed would contribute to the understanding of waste mitigation in the construction industry. These two issues were:

(1) application of computer aided drafting and design (CADD) and

(2) the use of prefabrication.

As only an indication of how a sector of the construction industry (ie architects) viewed these issues was required, only six phone interviews were conducted.

3.2 The Two Issues

3.2.1 Issue #1: CADD usage

Computer-aided drafting and design (CADD) is generally recognised[8] as being beneficial in terms of waste reduction due to efficiencies in repetitive structures, ease of changes, and flexibility in handling, processing, transference and storage of documentation (see Section 4.1 in the pilot study[4] for further details). For example, a very successful waste minimisation trial conducted on a large Australian building site[9] cited CADD benefits such as computer transfer of drawings and information and reduced drawing sizes. For smaller practices however, it is suggested[10] that it is not economically viable nor beneficial to use CADD for one-off projects. Certainly for smaller projects, the opportunities for repetitive and standardised work, which CADD packages handle easily, are less frequent.

Several CADD-related questions were directed at Auckland architects in the survey, including - "*To what extent is CADD used in your practice*?" Forty-six percent of the architects surveyed responded that they were frequent users of CADD.

In 1997, BRANZ commissioned a nation-wide survey of computer use in the New Zealand building industry[11]. Respondents included architects, draughtspersons, builders, engineers, inspectors, designers, quantity surveyors, trade persons, suppliers, educators and others. Ninety-eight percent of all respondents were existing computer users (which the report considered to be disproportionably high). CADD programs were used by 46% of the 340 respondents.

Forty-one architects responded to the national survey. They were asked to rate the importance of various computer applications, including 2D and 3D CADD packages. CADD packages were assessed on a scale of 1 (not important) to 10 (cannot do without it). Of the 41 architects who responded to the nation-wide survey, 34 (83%) indicated that they regarded the use of CADD as being important (ie a rating of 6 or higher was given) to their practice. [17 (41%) of the 41 rated both 2D and 3D CADD applications as being important]. Practice sizes (ie the number of architects employed within a practice) were unknown, but these results do show the significant importance placed on CADD by the architects surveyed who were computer users in 1997.

It is difficult to make a direct comparison of these two concepts - ie the importance of CADD usage versus the extent of its use - as they may be asking very different questions. For example, just because a CADD package is frequently used, does not necessarily mean that it is viewed as important in a practice's day-to-day operations. It may only mean that CADD is used in non-essential applications, for which it could be easily substituted by some other means. [Also, even if the two concepts were equivalent, a direct comparison could only be tentatively made because of the uncertainties of each sample population (ie area sampled and the distribution of practice size).]

Other CADD-related questions were asked of architects in the Auckland region survey, including:

1. Whether they regarded CADD as being important in terms of waste minimisation?
2. Whether contractors received electronic versions of the working drawings?

Sixty-three percent of the Auckland architects surveyed did not view using computer-aided drafting and design as being important, in terms of waste minimisation. This is a similar response to the Australian study[5]. Of the practices that used CADD extensively, only 45% allowed contractors to use electronic versions of their drawings either some or all of the time. Two respondents added in the margin that they were about to allow contractors to use electronic versions in the near future.

The general questions that need answering on CADD usage are - *is CADD usage really resource efficient? what are the barriers to CADD usage? and does CADD have greater application in larger practices/projects?*

3.2.2 Issue #2: prefabrication

The Auckland survey found a high number of respondents who were indifferent to the application of prefabrication as a means of reducing construction waste. Thirty percent (10) respondents gave prefabrication a neutral (ie "3") response. There have been few explanations why this should be the case, and yet this response is not unprecedented in overseas research[8] – see Section 4.1 in the pilot study[4] for further details.

A BRANZ architect[10] questioned the benefits of prefabrication, and saw it as a double-edged sword – although prefabrication/standardised design may be good in one area, in all likelihood it would negatively impact things in other areas. For example, it may take much longer to design a building according to a preset size, leading to compromises in the resulting placement of fixtures and openings. Also, the application of prefabrication is very dependent on building type, being more applicable to commercial/larger projects.

So, why did the architects surveyed give such an indifferent response to the use of prefab as a method of reducing construction waste? The one-on-one interviews set out to explain this by investigating the reasons why respondents answered the way they did.

The general question on the use of prefabricated building elements that was investigated was – *why is prefabrication of building elements not seen as beneficial in terms of resource efficiency?*

3.3 The One-on-one Interview Questions

The following questions were posed to those interviewed.

1) How many architects are employed in your practice? (To make sure a variety of practice sizes were interviewed).

2) Is your practice using CADD at present?

3) Why are more firms not using CADD now? (Only 31% are using it more than sometimes according to the Auckland survey).

4) Do you think that CADD will have more application in the future for all practices, when Q3. changes?

5) Do you think that CADD has greater application to larger practices, which are more likely to be engaged in repetitive work?

6) Why do you think CADD is not seen to be important in terms of waste minimisation?

7) Do you see using prefabrication of building elements as beneficial in terms of resource efficiency? If not, why not?

3.4 Results

Only six architects were interviewed over the phone, as it soon became evident that themes were being repeated. An abbreviated transcript of the answers to the questions asked are in the appendix. The *amalgamated* answers to each of the questions are:

Question #1:

Architects from practices of various sizes were interviewed.

Question #2:

Half of the practices were using CADD. Only one of the interviewees had not used CADD at some time.

Question #3:

Costs were the number one reason for firms not using CADD - both set up costs (capital and training) and continuing costs (up-date packages and re-training). For a smaller practice, CADD is a significant capital outlay. The issue of costs was closely followed by (and linked to) perceived (in)efficiencies in the use of CADD. It is thought that for most projects, manual drafting is still faster overall. The restrictions of CADD (eg in sketch design, in renovation work, in non-repetitive work) was also cited by several interviewees as hampering its acceptance and use in many practices.

Question #4:

It was thought by all interviewees, that if its costs drop and efficiencies in its use increase, CADD would have more application to the architectural fraternity.

Question #5:

All architects interviewed thought that CADD had greater application to larger practices/repetitive work.

Question #6:

The general view was that CADD wasted paper (compared to manual drafting), for a variety of reasons. Only a few cited the benefits of CADD for generating fast takeoffs (Bills of Quantities).

Question #7:

There was unanimous agreement that prefabrication of material elements is beneficial in terms of resource efficiency.

The results of the one-on-one interviews were that:

- Computer-aided drafting and design was not seen to be important to most architectural practices because of its limited application, due to its slowness as a tool and restricted applicability.
- CADD has greater application to larger practices/repetitive work.
- Costs were the number one reason for firms not using CADD.

- The use of prefabrication of building elements was thought to be very beneficial for resource efficiency/waste minimisation, by all the telephone interviewees.

The last result – on the use of prefabrication – directly conflicts with the Auckland mail-survey, where a neutral response was given. It is unknown why the same question resulted in such opposing answers, but it is possible the mail-survey was misinterpreted. This issue should be explored in future research.

These results are discussed in Section 4.0.

4. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 Discussion

The BRANZ survey sought to gain some understanding of the influence that the design and tendering (procurement) processes have on the amount of material waste generated on building sites. Specifically, the survey sought to "*define at least two critical influences that can lead to a more resource efficient construction (reduced generation of waste material) and that are of practical use to New Zealand builders*". The Auckland region was targeted as the most appropriate region to survey, because of its more active Territorial and Local Authorities' attitudes on waste mitigation. As a consequence of increasing environmental pressure, this stance is likely to become the norm in other regions.

The following results (conclusions and recommendations) are more representative of smaller practices in the Auckland region - that is practices of four architects or less - and therefore may not reflect views of the larger practices. Also, for some issues where technology is concerned (such as those relating to CADD), these results are very time dependent (due to innovations), and may be subject to change.

As for the pilot study[1], there were many similar themes in this Auckland region study which quickly became evident, including the importance placed on:

- providing accurate and integrated project information
- creating a buildable design that allows for a logical sequence in construction
- the use of standardised forms - both in the room and material sizes.

Likewise, there was a lack of importance placed:

- by architects on waste minimisation, compared to other design criteria (including the lack of plans/strategies enforced or in operation)
- on implementing effective waste reduction strategies on large scale repetitive projects
- on CADD tools as a means of waste minimisation.

As mentioned in the pilot study, these design-based initiatives are supported by other overseas studies[4,11], and have been mentioned as workable practices. Also, there were many similarities in the results of the Auckland survey and those found in the Australian study[8].

Examples of design based initiatives include:

⇒ creating a buildable design that allows for a logical sequence in construction – this is beneficial in terms of resource use

⇒ (sub)contractors advocating the use of standardised forms (both in the room and material sizes), so that cutting sheet materials to fit can be reduced

⇒ making waste reduction financially beneficial to the client

⇒ providing accurate and integrated project information.

Other, non-design issues were also cited by both the Auckland and the Australian study[8], including the adoption of informal 'good housekeeping' waste reduction strategies reflecting a casual attitude towards waste management and the agreement that alternative procurement routes did not have any significant advantages over the traditional route in terms of waste minimisation.

In the Auckland survey a more detailed investigation into the implications of CADD usage was explored, compared to the pilot study. It was found that CADD is viewed very differently to some other international studies. International studies[7,10] suggest that CADD is particularly beneficial in scheduling precise delivery dates, maintaining 'as built' status at all times, ensuring accuracy, and efficient updating. However, New Zealand results bore out a different story, where CADD was seen as limited in its application being slower than manual drafting and wasting paper. No mention was made of most of the beneficial uses cited by the overseas research. The only consensus view of the beneficial use of CADD by Auckland architects was for increased efficiencies in repetitive work.

The marked negative CADD response to the question "*Why do you think CADD is not seen to be important in terms of waste minimisation*?" could, in part be due to the way in which the question was phrased. Focusing on the negative aspects of CADD usage, in hindsight, may have resulted in stifling the more positive aspects. This question should be altered for any future research, to get an unbiased view.

4.2 Conclusions

The following conclusions are directly related to the replies from the Auckland survey, amalgamating information from both the mail-out questionnaires and the one-on-one interviews. It should be noted that many conclusions are common with the pilot study. Here, several critical influences which can lead to more resource efficient construction (reduced generation of waste) are proposed.

- There is very little importance placed by architects on waste minimisation compared to other design criteria. This is supported by the lack of waste minimisation plans/strategies operating or being enforced.

- Accurate and integrated project information is viewed by architects as being beneficial in mitigating waste. Making waste reduction efforts financially beneficial to the client is also seen by architects as important.

- Quantity surveyors think there are a few measures that could be taken to reduce waste: selecting materials to avoid unnecessary cutting and using modular components and prefabricated building elements.

- Both architects and quantity surveyors think that creating a buildable design that allows for a logical sequence in construction and avoids variations on site, minimises the amount of waste materials.

- Contractors think the dominant theme to be addressed to avoid waste generation is the use of standardised forms (both in the room and material sizes), so that cutting

sheet materials to fit can be reduced. Also, simplifying the design to reduce waste was rated very highly by contractors.

- CADD is seen by architects as a waste generator rather than a waste reducer, both in terms of materials (paper generated) and time (for all but repetitive design).

4.3 Recommendations

The following recommendations are the author's view on how this research should be progressed.

- Several critical influences that can lead to a more resource efficient construction (reduced generation of waste material) and that are of practical use to New Zealand builders, have been found. Influences include those issues outlined in Section 4.2. It is recommended, that the findings be incorporated into local and regional body initiatives - such as the Auckland Regional Council's *Resource Efficiency in the Building and Related Industries*.

- There still seems to be some misinterpretations of the mail-out questionnaire. An example of this is the CADD answers, which were at odds with those given in the phone interviews. It is suggested that the reasons why respondents replied as they did be further investigated, by doing a follow-up telephone interview.

- Once again, assessment of the results of the (Auckland) survey were hampered by the small response population. The reasons for this were different from the pilot study however. In this survey, the difficulty was the lack of available participants, reflective of the city's (read nation's) small population. The only recommendation for this would be to increase the area being surveyed/studied.

APPENDIX A: SIXTEEN COMMON QUESTIONS

The following numbering was assigned to the sixteen questions, common to both architects and quantity surveyors, in the survey.

QUESTION

1. How importantly would you rate project cost limits as a limitation on efforts to minimise waste?
2. How importantly would you rate the client's brief as a limitation on efforts to minimise waste?
3. How importantly would you rate limited design time as a limitation on efforts to minimise waste?
4. How importantly would you rate lack of variety in the sizing of components and materials as a limitation on efforts to minimise waste?
5. How importantly would you rate providing accurate and integrated project information in terms of waste reduction?
6. How importantly would you rate avoiding variations occurring on site, in terms of waste reduction?
7. How importantly would you rate creating a buildable design that allows for a logical sequence in construction, in terms of waste reduction?
8. How importantly would you rate using modular components within a design, in terms of waste reduction?
9. How importantly would you rate making waste reduction efforts financially beneficial to the client, in terms of waste reduction?
10. How importantly would you rate using prefabricated components, in terms of waste reduction?
11. How importantly would you rate selecting materials to avoid unnecessary cutting, in terms of waste reduction?
12. To what extent do you agree that the use of prefabrication of building elements will reduce the amount of building waste generated.
13. To what extent do you agree that the current limitations of prefabricated and industrialised building techniques are too great to allow these methods to be adopted on a larger scale.
14. To what extent do you agree that because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable.
15. To what extent do you agree that the priority at the design stage is the economics of the building and the clients interest. Any waste control being purely a by-product of cost control.
16. To what extent do you agree that it is only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings.

APPENDIX B: FORM LETTER SENT TO BUILDING PROFESSIONALS

<date>

<Address>

Dear <Name>

RE: Construction Waste Reduction Questionnaire

As discussed on the phone, I am a researcher interested in the methods of reducing construction industry material waste currently destined for the landfill. I would be very appreciative if you could fill out the attached questionnaire, and send it back in the reply paid envelope by the end of **November 1998**. The questionnaire examines causes of construction waste and the influence of the design and tendering processes on the amount generated. This information will feed into programs which target construction waste.

All the information provided will be treated in strict confidence and no information regarding any individual organisation will be made public. The attached questionnaire will be destroyed upon completion of the research.

If you have any questions about the questionnaire or the program in general, please contact me at BRANZ (04) 235 7600, or e-mail *branzraj@branz.org.nz*.

Thank you for your help. The research outcomes will be available from BRANZ in **March 1999**.

Sincerely

Roman Jaques
Building Technologist

APPENDIX C: SAMPLE QUESTIONNAIRE (ARCHITECTS)

BRANZ Construction Material Waste Questionnaire

Building Research Association of New Zealand Ph (04) 235 7600 Fax (04) 235 6070

This questionnaire examines what is currently happening during design and procurement, as well as the potential for building material waste mitigation during these stages. It is part of a much larger research program looking waste reduction in construction industry as a whole. Please complete and return by the end of **November 1998**.

The following procurement definitions have been used in this questionnaire:

1. **Design and Build** - where one contracting organisation takes sole responsibility for the design and construction of a client's project.
2. **Fixed or Lump Sum Contract** - where a client appoints an architect on a fee basis, who fully designs the project and prepares tender documents upon which competitive bids are received from main contractors
3. **Negotiated** - where design drawings and an estimate of the project cost are prepared. A selected contractor is then approached with whom a price is then negotiated.
4. **Project Management** - the project manager adopts a consultant's role for a fee with direct responsibility to the client for the overall management of the project, including liaison with design consultants.
5. **Reimbursable Contract** - where the hours and labour are agreed upon, and the profit margin established. Contractor reimbursed for materials as the project progresses.
6. **Novation** - preliminary project design and documentation are prepared sufficient for the works to be tendered and a price to be established. The successful tenderer takes over the responsibility for completing the design documents in the post tender and pre-construction stage.
7. **Waste** - building materials which are dumped, as a result of the design or construction process

All of the information provided will be treated in the strictest confidence and no information regarding any individual organisation will be made public. This questionnaire will be destroyed upon completion of the research.

Section A *This section examines the general nature of the responding organisation.*

Al Name of the organisation (optional):.....

A2 Which of the following type of projects would your practice normally undertake? (please tick):

1. Domestic	☐	6. Hospitals	☐
2. Commercial	☐	7. Education	☐
3. Industrial	☐	8. Recreation	☐
4. Refurbishment	☐	9. Other	☐
5. Maintenance	☐	**All of the above**	☐

If the 'other' box is ticked then please describe: .....

A3 Which of the project types listed above provides the greatest annual turnover? (please circle):
1 2 3 4 5 6 7 8 9

A4 Please indicate the number of architects in your practice:.....

Section B *This section examines current design waste minimisation measures.*

Bl How importantly would you rate waste minimisation amongst the other design criteria?

Not Important **1 2 3 4 5** Important (Please circle)

B2 Does your practice adopt a strategy for minimising design waste?

☐ ☐

Yes No

If 'yes' then please describe the measures that are implemented:

B3 How importantly would you rate the following factors as limitations on an architect's efforts to minimise design waste?:

Project cost limits
Not Important **1 2 3 4 5** Important (Please circle)

Client's brief
Not Important **1 2 3 4 5** Important (Please circle)

Limited design time
Not Important **1 2 3 4 5** Important (Please circle)

Lack of variety in the sizing of components and materials
Not Important **1 2 3 4 5** Important (Please circle)

B4 How importantly would you rate the following approaches in terms of waste minimisation?

Providing accurate and integrated project information.
Not Important **1 2 3 4 5** Important (Please circle)

Limiting variations occurring on site.
Not Important **1 2 3 4 5** Important (Please circle)

Creating a buildable design that allows for a logical sequence of construction.
Not Important **1 2 3 4 5** Important (Please circle)

Using modular components within a design.
Not Important **1 2 3 4 5** Important (Please circle)

Making waste reduction efforts financially beneficial to the client
Not Important **1 2 3 4 5** Important (Please circle)

Using prefabricated components.
Not Important **1 2 3 4 5** Important (Please circle)

Using computer aided design and draughting.
Not Important **1 2 3 4 5** Important (Please circle)

B5 To what extent is computer aided draughting and design used in your practice?
Not at all **1 2 3 4 5** At every opportunity (Please circle)

If CADD is implemented, do contractors receive electronic copies of the drawings?
Yes ☐ No ☐ Sometimes ☐

B6 To what extent would you agree or disagree with the following statements?

It is unthinkable to allow modular plan forms to dictate architectural design.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

The use of prefabrication of building elements will reduce the amount of building waste generated.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

The current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on more projects.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

Because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

The priority at the design stage is the economics of the building and the clients interest. Any waste control being purely a by-product of cost control.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

Modular co-ordination leads to repetitive designs that are not conducive to aesthetically pleasing building design.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

Effective waste reduction strategies are only practical on large scale repetitive projects.
Don't agree **1 2 3 4 5** Agree totally (Please circle)

Section C *This section examines how waste might arise through the procurement process.*

C1 Please indicate which forms of procurement the practice is currently involved with and, if possible, provide an approximate percentage value for construction value for each procurement system:

Type	✓	%	Type	✓	%
1. Design and Build			5. Reimbursable Contract		
2. Fixed Sum			6. Novation		
3. Negotiated			7. Other		
4. Project Mgmt.					

If 'Other' is ticked please describe further:

C2 Is there a trend towards increasing use of any one, particular, procurement method?

Yes ☐ No ☐

If 'Yes' please indicate which system is becoming more extensively used: No. **1 2 3 4 5 6 7 (see above)**

C3 Do the alternative methods of procurement (listed above) differ in their potential for effective *waste minimisation* strategies?

Yes ☐ No ☐ sometimes ☐

If 'Yes' then which systems would offer the greatest advantages and why, please comment.

Section D *This section provides an opportunity for qualitative feedback.*

Dl What measures could most effectively be taken at the design stage to reduce waste occurring on site?

Thank you for your kind co-operation.
This questionnaire is based on "*Minimizing Construction Waste*" - by Smithers and McDonald, for the Recycling and Resource Recovery Council, Victoria, Australia

APPENDIX D: ABBREVIATED TRANSCRIPT OF ONE-ON-ONE INTERVIEWS WITH ARCHITECTS

Practices have been divided into 'smaller' (with three or less staff) or 'larger' (with four or more staff). See Section 3.3 for a list of the questions in their entirety.

Interview #1:

1). Smaller.

2). No.

3). Firms are not using CADD because they are unsure whether it is the right tool for them and if it will actually save them money. There is quite an outlay for a firm to take on board a CADD package - initial outlay, training, upgrades, maintenance etc. Practices are unsure whether better drawings result, as it is a different way of thinking. Certainly, in some aspects of drawing (eg sketch design) CADD still doesn't have much of an application.

4). Yes - when it comes down in cost and increases in user friendliness.

5). Yes - due to repetition and communicating between multi-disciplinary agents.

6). Didn't think much about this, although could see application in take-offs etc.

7). n/a

Interview #2:

1). Larger

2). No - but has worked in larger practices that have.

3). The expense verses the productivity. Currently, there are huge start-up costs, and the application of CADD work is not suitable for one-off projects (such as is the usual case in buildings). CADD needs to be thought of both in terms of up-front costs as well as yearly upgrading costs (which are substantial) as the programme gets revised.

4). Yes, but have to remember that the aspect of cost to run CADD as a percentage of fee income.

5). Yes. Think of CADD as a set of tools, which needs to pay for itself.

6). The amount of waste paper generated by computers is huge (in reprints and in packaging). Legally, there can be restrictions in the use of the transference of drawings electronically, making hard copies necessary anyway. Can see no efficiencies, as far as paper saving goes. Could not see any other benefits of CADD in terms of reducing material/time waste.

7). Yes - its a great way to build - mass production is always going to be more efficient than one-offs.

Interview #3:

1). Larger.

2). Yes.

3). Cost is the biggest issue - including the cost of add-on features, such as the printer. Was surprised to hear that only about 30% of architectural practices were making use of CADD. Thought that the large response from smaller firms would skew the results.

4). Yes - if you could prove it to be of use. There are also staff and training issues to be considered, as well.

Interview #3: continued

5). Yes, definitely.

6). With regards to Bills of Quantities/Takeoffs being performed, there is more detail to input, to get more produced. Some designers/CADD operators would see this as extra work without any extra money. This would work against projects, especially ones on smaller budgets.

7). Yes.

Interview #4:

1). Smaller.

2). Yes.

3). Don't know. A practice needs to put in the hours groundwork, which for some, is too much of a hassle. Clients don't see it as being beneficial, so not much client-driven demand. Perhaps set-up costs as well?

4). Yes.

5). Yes.

6). Re: paper waste - there are advantages and disadvantages. For example, there are more provisional prints using a CADD system. Re: Bills of Quantities - don't know as don't get involved in this.

7). Aren't sure, but guess that it does reduce material usage.

Interview #5:

1). Larger.

2). Yes.

3). A variety of reasons, including: too small a practice, work not suitable (for example renovation work, the age of people in the practice, and the large initial financial outlay required.

4). Yes.

5). Yes.

6). For paper generation - CADD wastes a large amount of paper. Why - because, often the screen only gives a small portion of the required view, so must print out piecemeal, to get the whole picture. For take-offs - CADD is good, as more exact.

7). Yes, because of the more controlled environment.

Interview #6:

1). Smaller.

2). No.

3). Because they are not perceived to be as efficient as manual drafting.

4). For most practices, yes, but not this one, which is more specialist. Have noticed when working with CADD that changes take a long time, though, once the plans are finished, it very quickly generates the other views.

5). Yes – CADD is especially good when there are dedicated staff, who are very competent with it.

6). Designers forget the human element, which goes way beyond specification. If people could be convinced, then changes would happen.

7). Yes.

References

1. Skoyles, E. 1976. *Materials Wastage - A Misuse of Resources*. Building Research Establishment. Watford. Sourced from the *Environmental Issues of Construction - a Review of Issues Relevant to the Building, Construction and Related Industries*. Vol. 2 - Technical review Special Publication 94. Construction Industry Research and Information Association. London.

2. Guthrie, P. et al. 1997. *Waste minimisation in construction - Site Guide*. Special Publication 133. Construction Industry Research and Information Association. London.

3. Sterner, E. 1998. *Consideration of Environmental Aspects in Tender Procedures.* Pps 230-236. From the Green Building Challenge '98 Conference Proceeding - Vol. 1. 1998. Vancouver.

4. Jaques, R. 1998. *The Influence of Design and Procurement on Construction Site Waste Generation – A Pilot Study*. Building Research Association of New Zealand (BRANZ). Study Report No. 81. Wellington.

5. Smithers, M. and McDonald, B. 1996. *Minimising Construction Waste - Strategies for the Design and Procurement Processes of Building Projects.* Prepared for the Resource and Recovery Council. Victoria.

6. Personal communication with Peter Mittermuller, Regional Waste Officer. May 1998. Auckland Regional Council. Auckland.

7. Architecture NZ. January/February 1997. *Architects '97 - supplement*. Auckland.

8. McDonald, B. 1994. *Recon: Waste Minimisation and Recycling Program*. Fletcher Construction. Melbourne.

9. McDonald, B. September 1994. *Building Construction Waste Minimisation and Recycling Project – A summary report*. Melbourne.

10. Personal communication with Alan Bulleyment, Building Research Association of New Zealand (BRANZ) Architect. December 1998. Judgeford.

11. Doherty, J. 1997. *A survey report of computer use in the New Zealand building and construction industry*. BRANZ Study Report No. 80. Judgeford.

12. Guthrie, P et al. 1997. *Waste minimisation and recycling in construction - technical review*. Construction Industry Research and Information Association (CIRIA) Funders Report/CP/44. London.

13. Seadon, G. 1995. *Construction Trends in the Context of Sustainable Development*. Institute for Research in Construction. Canada. From the Proceedings of the Conference on *Cost Effective Management of Construction and demolition Waste and Green Building Procurement*. Toronto.