Date: October 1998			

BRANZ
THE RESOURCE CENTRE FOR BUILDING EXCELLENCE

STUDY REPORT

No. 81 (1998)

The Influence of Design and Procurement on Construction Site Waste Generation - A Pilot Study

Roman Jaques

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

ISSN: 0113-3675

Preface

The overall objective of this research was gain some understanding of the role that the design and tendering (procurement) processes have on the amount of material waste generated on building sites. This report used a tried and tested survey method, performed in a comparable construction environment (Australia), to gain New Zealand specific results. An extension of this report into a nation-wide survey covering the three main cities, will be carried out towards the end of 1998.

Acknowledgments

This research relied heavily on the goodwill of 38 architects, quantity surveyors and contractors, who donated their time in the completion of the questionnaires. Mark Smithers of Deakin University, Geelong, Australia, is gratefully acknowledged for providing material on which to base the BRANZ questionnaires. Technical comment on the final draft by Auckland Regional Council's Peter Mittermuller is also appreciated.

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

Readership

This report is intended for waste management engineers, environmental engineers, designers, and researchers.

THE INFLUENCE OF DESIGN AND PROCUREMENT ON CONSTRUCTION SITE WASTE GENERATION - A PILOT STUDY

BRANZ Study Report No. 81 **Roman Jaques**

REFERENCE

Jaques, R. 1998. "The Influence of Design and Procurement on Construction Site Waste Generation - A Pilot Study". BRANZ, SR 81. 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. This pilot study focused on a subset of this, with an aim to "*determine the potential for waste reduction on construction sites, within the design and procurement stages of the building process*". To gain an understanding of just what this potential is, a survey was carried out based on a comparable survey in a similar construction environment (Australia). Architects, quantity surveyors and contractors, mainly from the Wellington region, were surveyed. From the results, it can be concluded that:

- there is very little importance placed by architects on waste minimisation compared to other design criteria

- good component sizing, standardisation of room dimensions to reflect standard sheet sizes, careful attention at the design stage to avoid variations on site, and assistance in creating a buildable design that allows for a logical sequence in construction are all considered to be effective design stage measures which reduce the output of waste

- where possible, contracts should be set up so that waste reduction efforts are financially beneficial to the client.

The pilot study will be extended into a nation-wide survey, covering the three main cities, towards the end of 1998.

Contents

Page No.

List of Tables

List of Figures

1. THE INFLUENCE OF DESIGN AND PROCUREMENT ON CONSTRUCTION SITE WASTE GENERATION

1.1 Introduction

The research reported here is part of a 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 (and in association with the Auckland Regional Council's and the Auckland City Council's Project C + D[1], and more recently the Resource Efficiency in the Building Industry[2] programme) various initiatives are being developed and implemented. Initiatives range from reusing and recycling building materials through to the trialing of on-site waste reduction demonstration programmes.

The overall objective of this research was gain some understanding of the role that the design and tendering (procurement) processes have on the amount of material waste generated on building sites. Specifically, it was to "*determine the potential for waste reduction on construction sites, within the design and procurement stages of the building process*".

To achieve an understanding of this potential, a survey was necessary to establish how the building industry perceives its influence on waste generation; what the current building practices are; and what waste issues the industry regards as important. This report used a tried and tested survey method[3], performed in a comparable construction environment (Australia), to gain New Zealand specific results. A comparative study between the two nation's responses was not part of the required objective, but similarities are noted in Section 4.1.

1.2 Study Background

Anecdotal evidence suggests that the influence of the design and procurement processes on the generation of construction waste is not understood fully by the building industry. It is suspected that very few building industry representatives fully understand how the procurement process influences waste generated "downstream" – that is, on the actual building site. The author is unaware of any other New Zealand investigations into how the building fraternity sees the "pre-build" stages influencing material waste generation. This report documents such an investigation.

There are national and international research papers and guidelines which target good design procedures for assisting waste minimisation[4,5]. There are also a number of published papers investigating the influence of using alternative procurement systems[3,6]. Most waste management programmes are based around "end-of-pipe" solutions, rather than targeting the design and procurement stages[7,8,9]. These end-of-pipe solutions target such issues as policy implementation, guidelines for cleaner production, appropriate material selection and recycling/disposal opportunities.

There are many ways that resource efficient buildings, which generate little waste in their construction, can be approached at the design stage. One of the more forward-thinking methods is to incorporate flexibility into the design. By incorporating flexibility, the building's useful lifetime can be maximised. This suggestion is said to

increase first costs marginally[10], and requires stronger columns and floors to carry higher loadings, larger service ducts than initially required and oversizing the electrical service supply to allow for future upgrading.

A report which examines design and procurement-related issues more specifically and using more traditional methods, was the CIRIA report "*Waste minimisation and recycling in construction - technical review*"[11]. Design issues which were recognised as ways of decreasing waste generation, include:

- increased use of prefabricated parts
- increased use of multi-functional materials to reduce overall requirements
- reduced use of composite components where practical.

Some researchers have gone a step further, proposing new procurement systems to incorporate all resource use (not just material waste, but also pollution and energy) in a more holistic Bill of Quantities[12]. The implication is that a more representative measure of the environmental (as well as financial) costs, in terms of benefits derived, will be possible. This type of approach is part of the life cycle assessment approach – that is accounting for environmental matters in addition to financial ones – and is one of the principle goals of sustainable construction.

Other studies cover the tendering (procurement) process in relation to material waste, but only as one of a number of environmental issues needing to be addressed during the construction process[7,13].

There are a number of New Zealand and Australian publications and studies which examine design-based issues in addressing construction material waste. A selection are examined here.

A Wellington City Council publication[14] examined the potential for the building industry to adopt some form of waste reduction strategy, by way of cleaner production. Waste production is outlined in four sections - "Preparation", "Operations", "Contracting and Education", and "Reuse and Recycling". The procurement process is only briefly touched upon, with the suggestion of writing waste management responsibilities into contracts. Design issues are also only outlined briefly, with prefabrication, modular construction and efficient framing all cited as being resource efficient. The focus of the document, however, was on "other" issues, such as site preparation, purchasing, handling and storage, and methods of disposal and reuse. A seven step programme for cleaner production (based on a Ministry for the Environment publication[15]) gives a practical, simple method of addressing these waste issues on a building site.

The Auckland Regional Council's *Project C + D* report[1] also includes some information on design-related waste issues. The report found that "*A whole range of issues arise when one looks at the contribution of the design professions....to waste generation. An important long term contribution to waste reduction in the construction industry would be an ongoing programme of assessing the waste implications of commonly used materials, products, construction methods and practices. These findings could be fed back to designers....and generally disseminated*

through the industry". The Project C + D report challenged the merits of using wasteful building systems, and highlighted two specific examples:

- design based on angled (as opposed to orthogonal) construction, and
- non-standardised design (ie where sheet sizes do not conform to building element sizes).

A recently published Australian document[16] examined the management of material waste at the design stage from a different perspective. They see the "key role" designers and allied professionals have in waste avoidance as being the development of new approaches that "*design out elements not needed for functional or structural purposes, and incorporate measures that will enable de-construction at the end of the buildings life*". Thus, designers should consider such options as:

- making buildings which are flexible in their provision of amenities
- designing for ease of dismantling for maximum recovery, and
- incorporating waste minimisation practices into the design.

Just how these vague themes would be developed into practical, viable solutions is not immediately obvious, with no clues being given to the designer.

1.3 Survey Design and Operation

The BRANZ survey was based on an Australian study completed in 1996[3]. Both studies sought to identify effective waste control methods and to develop an understanding of possible approaches that might be taken to reduce waste generation.

Although the BRANZ survey closely follows the structure of the Australian study, there are some significant differences. These differences are reflective of the differing building cultures (eg in the terminology used to define procurement types) and the survey design itself (eg the pre-questionnaire one-on-one interviews of building professionals was not used by BRANZ). The BRANZ surveys were slightly shorter than their Australian counterpart, in order to promote a maximum return. Also, the Australian survey population was larger, comprising of approximately 136 architects, 72 quantity surveyors, and 60 contractors.

Twenty representatives from each of the following construction-related professions – architects, quantity surveyors and contractors – were randomly chosen from the 1997/1998 Wellington Yellow Pages. The survey was briefly discussed over the phone, and participation was requested. Covering letters, survey questionnaires and postage paid reply envelopes were then sent out to those who responded positively. It was estimated that the average completion time for the questionnaire would be around 20 minutes. Copies of the covering letter and the questionnaires are provided in the Appendices.

	Respondents		
	Wellington Region	**Other**	**TOTAL**
Architects	12	2	14
Quantity Surveyors	11	1	12
Contractors	10	2	12

Table 1: Questionnaire reply rate

About 88% of those called were from the greater Wellington region (see Table 1). Although concentrating on a small region (and sample size) may not be nationally representative, only an indication of what is happening regarding waste management was sought for the New Zealand case. This is a preliminary survey, which will be refined before a national-wide study is conducted.

Three distinct types of survey forms were sent out, targeting the three professions – architects, quantity surveyors and contractors. The architectural and quantity surveying forms are similar, with mostly qualitative information being asked in a short answer format. The contractor survey deals with similar design-based waste themes, but focuses more on long answer questions. This survey was divided into sections: the general nature of the responding organisation; formal waste minimisation measures being applied in the construction industry; how waste might arise through the procurement process; and an examination of what the most effective design-stage methods are for reducing waste (refer Appendices).

The reply rate was: architects - 14/20 (70%), quantity surveyors - 12/20 (60%), and contractors - 12/20 (60%). The high rate of return may be attributed to a number of factors, including:

- a verbal commitment given over the phone by all respondents
- the included pre-addressed business reply paid envelope
- the predominantly short-answer nature of the survey.

When interpreting the results of a questionnaire such as this, which attempts to gauge a business's activity in a potentially sensitive field (such as environmental/management strategies), the results are reliant on the honesty of the respondent. Naturally, each respondent wants to portray their organisation in a positive light, especially in such a highly competitive industry. It is hoped that the guaranteed anonymity of these questionnaires assists in the veracity of the replies. However, potential compromises to impartiality should not be overlooked when reviewing this study's results.

1.4 Terms and Definitions

These are to provide specific definitions to terms which may not be known to the reader, or may only be known in a general sense. Most of the procurement terms are adapted from the Australian study[3].

Cleaner Production - Using less materials and/or energy, while producing less waste to carry out a particular process.

"Design Waste" or "Waste" - For the survey, this is only the building material waste which occurs during construction, as a result of decisions made during the design process.

Procurement Types - The procurement process is the method of establishing the relationship (contract) between the contractor and the client involved in a construction process. There are at least six procurement types being used in the New Zealand construction industry today. It is unknown which procurement types are the most

popular, as there have been no recent studies carried out. For a more formal description of the procurement types, refer to the New Zealand Standard (NZS 3910 "*Conditions of Contract for Building and Civil Engineering Construction*")[17]. A brief explanation of each type and its implications for waste generation is outlined below.

A. *Design and Build* - where one contracting organisation takes sole responsibility for the design and construction of a client's project. This has very good possibilities in terms of waste minimisation, as any holistic approach has the potential for considerable saving in terms of good communication, smart design and the adoption of a site waste management plan.

B. *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. There are few incentives or opportunities to reduce waste, mainly because the contractor has no input into the building design with design and construction being separate processes.

C. *Negotiated* - where design drawings and an estimate of the project cost are prepared. A selected contractor is then approached with whom a price is negotiated. The builder provides input into the design development. This type of procurement has good potential for waste reduction, as efforts made by the design team can be recognised and incorporated into the building cost.

D. *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. Again, this method has good potential for waste minimisation, with direct liaison between the construction manager and the design team resulting in improved buildability, and consequently a limit in the number of variations.

E. *Reimbursable Contract* - where the hours and labour are agreed upon, and the profit margin established. The contractor is reimbursed for materials as the project progresses. This method is used mainly where speed is paramount and has few options for waste minimisation, as ultimately it is affected by time restrictions and the associated profit margin.

F. *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. This method of procurement is dependent on the method of pricing the initial documents (prepared by the client), as to whether waste minimisation possibilities are accounted for. However, since the contractor is included in the design phase, this may prove beneficial in waste reduction terms.

2. QUESTIONNAIRE RESPONSES

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

The questionnaire 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 nine architects.

Table 2 shows the type of work undertaken by the practices surveyed. It can be seen that the most common were the commercial, domestic and refurbishment categories. Note that the "Other" category included religious, medical, correctional and police structures. Eighty six percent of the practices were involved in more than three types of project, with the remainder (14%) specialising in a single type of project.

Project Type	Percentage
Commercial	86%
Domestic	79%
Refurbishment	71%
Industrial	50%
Education	50%
Maintenance	21%
Recreation	36%
Hospitals	29%
Other	43%

Table 2: Project type - architectural practices (question A2)

Most architectural practices (71%) surveyed did not rate waste minimisation as an important design consideration, or gave a neutral response (Question B1). Seventy four percent replied that they do not have a waste minimisation design strategy, with the rest replying that they have some form in place – whether actually operational or not was not asked. Waste minimisation design "strategies" ranged from 'good housekeeping' methods (such as the recycling of fill material), through to a single practice which designed assemblies based on known sheet material sizes (Question B2).

By far the largest majority of architectural practices (93%) utilised "Fixed Sum" contracts for their operations (Question C1). "Negotiated" contracts (at 79%) and "Design and Build" (at 57%) were also very common. Also, there was a trend towards using the negotiated form of contract more, and to a lesser extent the fixed sum contract (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 (100%), refurbishment (83%) and domestic (83%) construction (Question A2). The size of the respondents' practices ranged from sole practices through to 32 employees (it was assumed this figure was for the company nation-wide) (Question A4).

Fixed sum contracts proved to be the most popular form of procurement method, used by 92% of those surveyed (see Table 3). Project management and negotiated contracts

were also popular, but significantly less so. At the bottom end of the scale, novation was used by only 17% of those surveyed.

Procurement type	Percentage
Fixed Sum	92%
Project Management	75%
Negotiated	50%
Reimbursable Contract	42%
Design and Build	17%
Novation	17%

Table 3: Procurement distribution - quantity surveying practices (question C1)

It was asked if there was a trend towards increasing the use of any particular procurement method (Question C2). Half of those asked thought there was a trend, and of those, 67% chose "Negotiated" procurement.

Quantity surveyors' attitudes on waste minimisation were not asked for. In hindsight, not asking this question was an oversight.

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

A shorter questionnaire was used for building contractors, with more emphasis being placed on long descriptive answers (see Appendices for details). Contractors from general construction firms, rather than specialist firms made up the largest trade group (Question A2). Other trades represented were: concreting, internal fit-outs, ceiling and partition work. Twelve contractors responded to the survey in all. Practice sizes ranged from sole operators through to companies having 400 employees (Question A3).

Contractors were asked in what ways 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 4). Good dimensioning and the use of modular components were the most popular choices by contractors. The use of prefabrication got surprisingly little support, given that it is often cited as being resource efficient in overseas literature[4,9,18].

Waste Minimisation Methods	Count
Good dimensioning	5
Modular components	4
Other	3
Over design	2
Poor communication	2
Prefabrication	1

Table 4: Methods of waste minimisation (question B5)

Building contractors were 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 5). Note that some responses fitted into more than one category. The majority of contractors cited non-standard design and non-standard sizing as being the principal causes of waste. Thus, there was general agreement that shifting away from regular/standard design patterns generates more waste. This theme is repeated in Section 2.6 Descriptive Feedback from Contractors.

Causes of Waste	Count
Non-standard sizing	5
Non-standard design	5
Inaccurate detailing	3
Handling on site	2
Poor transportation	2
Improper packing	2
No storage space	2

Table 5: Principal causes of waste among trades (question B3)

2.4 Analysis of Five-Point Ordinal Data

Sixteen common questions, each having a five-point response range, were directed at both architects and quantity surveyors. In the architects' survey, these questions are covered in Sections B3, B4 and B6. In the quantity surveyors' survey, these questions are covered in Sections B1, B2, and B3. Because each section contained multiple unnumbered questions, the questions have been numbered for reporting (refer Appendix 6: Sixteen Common Questions).

Various methods of interpreting the qualitative results of the survey were trialed. Interpretation by standard statistical means was complicated because of the small sample size and therefore the coarseness of the information. Because of this, standard graphical analysis (as was performed in the Australian research) proved to be inconclusive. The most appropriate statistical analytical method found was *correspondence analysis*. Correspondence analysis[19] is a descriptive technique designed to simplify large amounts of information into two-dimensional arrays (graphs). Results were analysed using the STATISTICA[20] computer programme.

Correspondence analysis can be used to quantify qualitative data. For example, in this survey the bulk of the information is presented in a qualitative fashion, based on a five point categorical scale. Answers were graded from 1 = "Not Important", through to 5 = "Important". Although the responses are numerically defined, they are actually qualitative in nature. This results from the fact that there may be large differences between one respondent's reply of a "2" rating, compared to another respondent's "2" for the same question. This is because each respondent has a different idea of the weighting of the numbers in the 5 point scale.

Correspondence analysis avoids the problem of some other statistical analyses, where (potentially) meaningless averages are calculated. For example, if an average of the responses was calculated to be a "3" it would be described as a neutral result, which is not an accurate description if there was a polarised response.

When viewing the correspondence analysis graphs (Figure 1, Figure 2, and Figure 3), 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. Thus, the further to the right one travels, the higher the weighting of the "not important" response. The converse is true for the left hand side of the graph, where the further to the left one travels, the closer to the "important" category.

The y-axis represents "Dimension 2", where once again, zero equates to the neutral zone. The y-axis has been left out of the analysis, because the meaning is difficult to interpret and is inconsistent between the groups.

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 tabular and histogram representations of the questionnaire replies, and background information on correspondence analysis, refer Appendix 7: Correspondence Analysis Explained.

2.4.1 Graphical interpretation

When viewing the graphs it can be seen that "not important" is on the right hand side, with "important" on the left hand side.

A) ARCHITECTS' RESPONSES

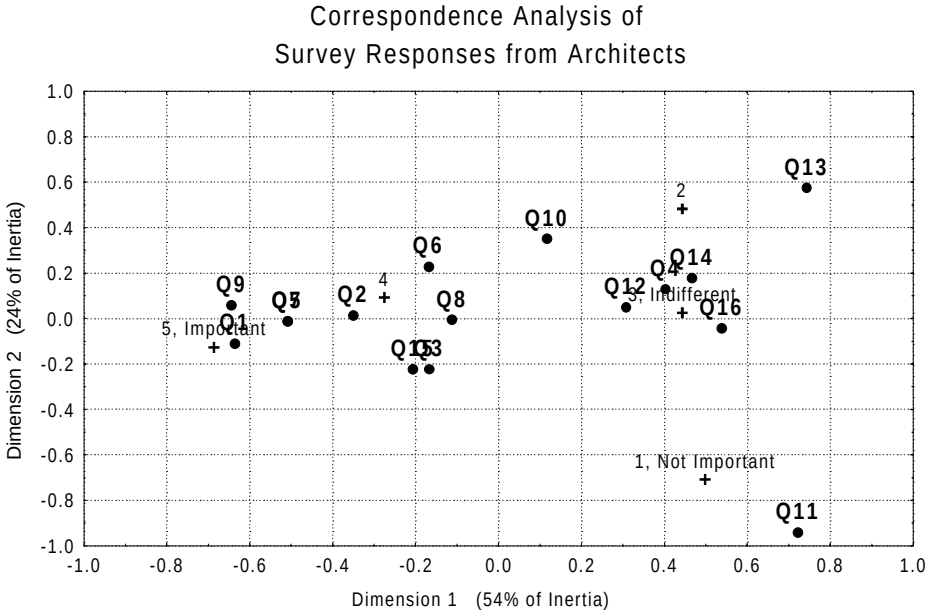

Figure 1: Correspondence analysis of survey responses from architects

Architects find that *"using computer aided drafting and design"* (Question 11) is not important, and they disagree with the statements that:

⇒ "*the current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on more projects"* (Question 13)

⇒ "*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 carparks and residential buildings*" (Question 16).

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)

The following two statements were cited as limitations on their efforts to minimise design waste:

⇒ "*providing accurate and integrated project information*" (Question 5)

⇒ *"project cost limits"* (Question 1).

B) QUANTITY SURVEYORS' RESPONSES

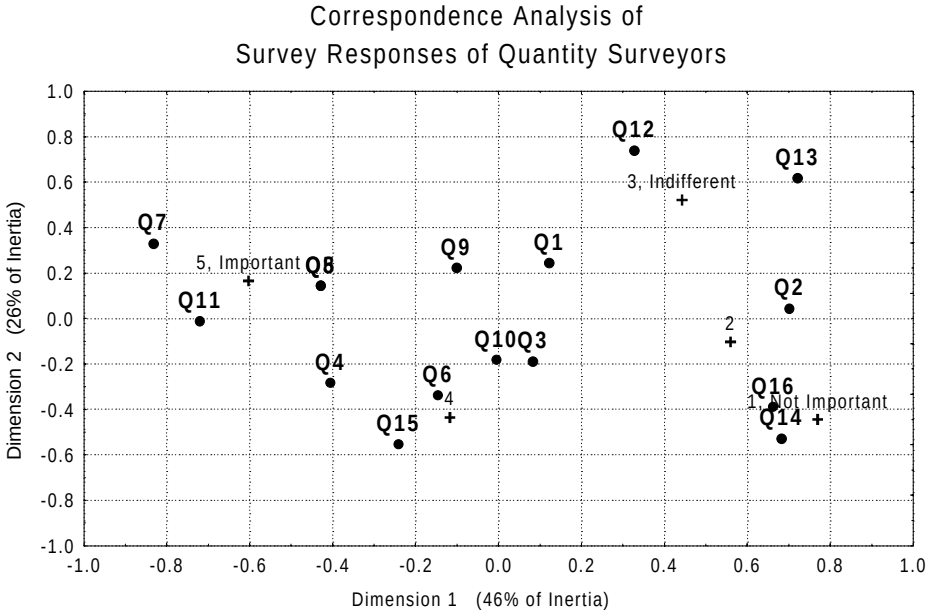

Figure 2: Correspondence analysis of survey results for quantity surveyors

Quantity surveyors disagree with the statements:

- "*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)
- "*because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable*" (Question 14).

Also, quantity surveyors thought that the *"clients brief"* is a limitation on efforts to minimise waste (Question 2).

They 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).

C) QUANTITY SURVEYORS' AND ARCHITECTS' REPONSES COMBINED

Refer to Figure 3 for the following analysis. The graph combines architects and quantity surveyors, to observe the convergences of two groups.

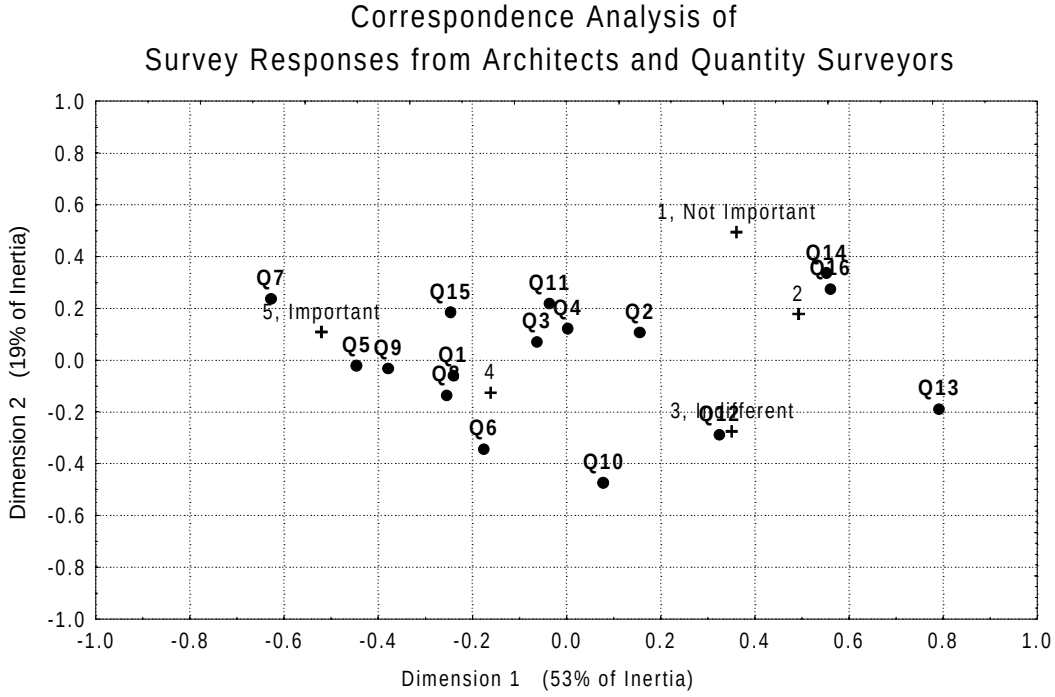

Figure 3: Correspondence analysis of survey results from architects and quantity surveyors

The strongest conclusion is both groups disagree that "the current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on more projects" (Question 13); and also with "the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable" (Question 14); and 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).

In terms of waste minimisation there is strong agreement that these statements are important: "*the creation of a buildable design that allows for a logical sequence of construction"*, (Question 7) and "*avoid variations occurring on site"* (Question 5).

It is also interesting to note which questions "drop out" from the architects' importance list when combined with the quantity surveyors' questions and vice versa.

The factors that drop out from architects importance include:

- "*making waste reduction efforts financially beneficial to the client*" (Question 9)
- "*providing accurate and integrated project information*" (Question 5)
- "*project cost limits*" as a limitation on their efforts to minimise design waste (Question 1).

The factor that drops out from the quantity surveyors' importance list when combined with architects is:

- "*selecting materials to avoid unnecessary cutting*" (Question 11).

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). About 33% thought that alternative procurement methods would improve waste strategies, while 50% thought that it would only sometimes. There were only a few suggestions on which methods offered the greatest advantages and why. Some suggestions put forth didn't match other research, such as the proposition that "Fixed Sum" was the best procurement method. According to the Australian study[3] the fixed sum procurement method offers few opportunities for waste control, due to the inflexibility of the relationship between the contractor and the client. This suggests that there is either some misunderstanding in the architectural fraternity of the relationship between the different procurement methods and waste minimisation, or New Zealand is significantly different from Australia.

The replies included:

- Fixed sum was "*the best*", as negotiated, project management and reimbursable contracts "*worried less about waste minimisation beyond any cost savings it might make from it*"
- "W*orking closely with* {the} *contractor while negotiating price offers opportunities to discuss materials and methods that can help minimise waste*"
- "*Negotiated - in builder's interest to minimise waste but as part is at design stage - designer can take on board builder's suggestions and incorporate into design rather than be driven by their advice*"
- "*If contractors are really interested in the cost savings then design/build gives them the incentive to pursue waste minimisation on site*"
- "*I believe design and build offers many advantages as the architect/designer is an integral part of the construction contractor*".

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 7). The popularity of "component sizing and standardisation" in the form of setting heights and room sizes to reflect sheet lengths, is very high. This was closely linked to the next most popular statements "careful attention at the design stage" and "careful material selection". Architects' responses are grouped into general themes in Table 6.

Measure	Count
Component sizing and standardisation	8
Attention at the design stage	4
Repetitive construction	4
Careful material selection	4
Good education	3
Drawings fully complete	3

Good communication	3
Early costing	2
Prefabrication	2

Table 6: Architects' design stage measures to reduce waste (question D1)

QUANTITY SURVEYORS

Quantity surveyors were asked whether alternative methods of procurement do offer improved opportunities for waste minimisation strategies to be adopted (Question C3). Twenty five percent thought that this was true, with half of the replies agreeing sometimes. Some elaboration on what the quantity surveyors thought the mechanisms operating were was given by the respondents. Examples include:

- "*Any method where a contractor gains financially from waste minimisation offers greater advantages. Obviously, this does not include a Reimbursable Contract*"
- "*Tendered contracts should result in the least waste, as a reduction in waste will increase profit*"
- "*I would suggest Design/Build has incentives..... Architects seem to have no comprehension of waste so reduction will only be achieved where its in the builders interests*".

Quantity surveyors were also asked what measures could most effectively be taken at the design stage to reduce waste occurring on site (Question D1). Answers were grouped into seven themes, according to the responses (see Table 7). The most popular categories were "modular design", "good communication" and "careful material selection". "Good communication" was involvement of the contractor at the design stage, and between the contractor, client, and other building professionals. The "other" category contained issues such as good client/supplier education and packaging waste.

Measure	Count
Modular design	6
Good communication	5
Careful material selection	4
Total design involvement	3
Smart design	3
Drawings fully complete	3
Other	2

Table 7: Quantity surveyors design stage measures to reduce waste (question D1)

"Smart design" responses, were:

- "A *practical understanding of the construction process...*"
- "*Adequate design time including design options at an initial stage to confirm the preferred option based on a logical sequence of construction as well as being cost effective*"
- "*The use of properly facilitated Value Management sessions to assist in optimising value for money in the design, but also in deciding on material choice - for which waste minimisation can be a criterion*".

2.6 Descriptive Feedback from Contractors

The contractors' questionnaire was structured differently from that of the architects and the quantity surveyors, reflecting the highly diverse nature of their operations. Disregarding company details, only four questions were asked – all requiring longer written answers. The written questions focused on the quantities and causes of waste, and the potential for waste mitigation.
The types of building materials – along with their associated expected waste – were included in Questions B1 and B2. Contractors were asked to list the building materials that are used regularly as part of their trade, and the proportion that is wasted during construction. There were huge ranges in the estimated proportion of wastes for the individual building materials. From Table 8 it can be seen that nearly all the results of the overseas studies (the BRE[21] and CIRIA[10] studies) fall within the New Zealand results range. The exception to this rule is for timber.

It should be noted that the New Zealand figures are based on information gained through this survey only, compared to the results from the United Kingdom which were averaged over many site inspections. No surveys from Australia and New Zealand for individual materials (based on large sample populations) are available.

Material	NZ predicted waste figures	Comparative figure from CIRIA study[17]	Comparative figure from BRE study[19]
Timber	5 - 10%	10%	12.3%
Reinforcing steel	0 - 10%	3%	3.3%
Particleboard	3 - 10%	5-7%	-
Plasterboard	5 - 15%	10%	9.5%
Concrete	0 - 15%	2-3%	10%
Roofing	2 - 20%	5-6%	10%
Weatherboard	5 - 20%	-	-
Fixings	2 - 50%	-	7.1%

Table 8: Estimated New Zealand waste percentages compared with overseas surveys

Contractors where asked to list what they thought their principal causes of waste were (Question B3). The responses included:

- "*An inherent part of the manufacturing process where custom-made goods don't necessarily give optimum utilisation of production facilities*"
- "W*all lining areas not corresponding to available sheet sizes*"
- "*Inaccurate detailing as to construction requirement*"
- "*Lack of a variety in width sizes for plasterboard.. Should have 900mm and 1000mm in addition to the standard 1200mm*"

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

- "***Building shapes*** *that are non-rectangular and do not suit standard production modules*"
- "*Can't comment but probably very little*"

- "***Angular design***"
- "*Lack of practical knowledge of detail required"*
- "*Need more accurate decisions to reduce later alterations in design changes and variations*"
- "***Room sizes to suit material size** and timber spans"*
- *"Over Design*"
- "***Room sizes and configuration**"*
- "*Over 50% of our waste can be attributed to poor design, at a time when cost efficiencies are important; **the non-modular grid patterns used by architects are amazing**. **Common building product sizes** are well known in the industry*".

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

3. SUMMARY

During 1998 BRANZ conducted a survey of measures and techniques used by building professionals in their dealings with construction waste. The focus was on how the design and procurement stages of the construction process influence waste generation.

Sixty building professionals were randomly picked from the Wellington 1997/1998 Yellow Pages. Fourteen architects, twelve contractors and twelve quantity surveyors responded. Although the questions were mostly qualitative in nature, the bulk of the answers required only short responses. Replies were forthcoming from a diverse range of sizes and types of architectural, quantity surveying and contractor practices.

The results are presented with the relevant question number in brackets. From the results, it seems that:

FOR ARCHITECTURAL PRACTICES

- Seventy one percent surveyed did not rate waste minimisation as an important design consideration (Question B1), with not one practice having a formal strategy specifically targeted to reduce waste in place (Question B2).
- The following statements are 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), and
  - ⇒ "*as a limitation on their efforts to minimise design waste project cost limits*" (Question 1).
- Architects didn't agree that, in terms of waste minimisation:

⇒ "*the current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on more projects*" (Question 13)

⇒ "*because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable*" (Question 14), and

⇒ "*it is only practicable to implement effective waste reduction strategies on large scale repetitive projects*" (Question 16).

- The top four measures which were cited as those that could most effectively be taken at the design stage to reduce waste occurring on site, in order of decreasing importance (Question D1):

  ⇒ good component sizing

  ⇒ careful material selection/attention at the design stage/the use of repetitive construction (all of equal weighting).

FOR QUANTITY SURVEYING PRACTICES

- Seventy five percent of practices thought that alternative procurement routes sometimes offered improved opportunities for waste minimisation (Question C3).
- Sixty seven percent agreed with the statement "*the use of elemental Bills of Quantities in their traditional form provide no incentive to adopt waste minimisation strategies as such strategies are not rewarded by lower tender figures*"; and 84% did agree with the statement that "*involvement of the contractor during the design stage will lead to a reduction in waste on site*" (Question C4).
- 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).

- The top three measures which were cited as being most effectively taken at the design stage to reduce waste occurring on site, in order of decreasing importance, (Question D1):

  ⇒ modular design

  ⇒ good communication between all parties, and

  ⇒ careful material selection.

FOR BUILDING CONTRACTORS

- Contractors saw the principal causes of waste as resulting from non-standard design and non-standard sizing. Inaccurate detailing also was seen as being important, probably because of the extra effort necessary in finding suitable solutions to design problems (Question B3).

- When contractors were asked how designers could minimise waste arising in their particular trade, “good dimensioning” came top of the list. The use of modular components was also cited by many as being beneficial from a resource efficient point of view (Question B5).

4. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 Discussion

The BRANZ survey sought to *"identify methods for achieving better construction material waste control methods and develop an understanding of possible approaches that might be taken to reduce waste generation"*.

These results (conclusions and recommendations) should be seen as indicative only of what is happening currently in the Wellington region, and may be regionally specific. This regional dependence may be especially true for where there are fundamental structural differences in waste management, with different landfill and cleanfill prices and population concentrations[2]. It is suspected that although there would be similarities between all regions in New Zealand, further regional-specific research on waste control methods and possible approaches would be necessary (see 4.3 Recommendations).

Computer aided design and draughting (CADD) was not seen as being beneficial in terms of waste minimisation. This view is confirmed by the 1996 Australian study[3]. However, there seems to be opposition to this view in some other international studies. In a Canadian study[22] the benefits of CADD application were seen to include "... *scheduling precise delivery dates and maintaining "as built" status at all times*...", while an earlier Australian study[23] found that contractors who utilised CADD found that this led to waste savings through ensuring accuracy, efficient updating of documents and less material use.

There were many similarities in the results of the New Zealand survey and those found in the Australian survey[3]. For example, both studies found creating a buildable design that allows for a logical sequence in construction, providing accurate and integrated project information, making waste reduction efforts financially beneficial to the client, and the involvement of the contractor at the design stage, were all important in terms of waste reduction initiatives. These design-based initiatives are supported by other overseas studies, and have been mentioned as workable practices[6,9,11].

There were other similarities between the Australian and New Zealand practices, such as the uptake of waste reduction strategies. Both countries have informal systems operating, with the emphasis on "good housekeeping". This casual attitude towards waste management may be reflective of the issues highlighted in the New Zealand survey such as project cost limits, the client's brief, or waste's perceived importance compared with other design-related issues. There may be other reasons (which were not explored in this survey) why formal waste management practices are not more common in New Zealand. These reasons could include such issues as the perceived difficulty in adopting a pro-active waste management stance, or the availability of practical solutions which can be easily adopted to a range of projects.

In the Australian study[3] it was found that for the majority of architectural practices, alternative procurement routes held no advantages over the traditional routes in terms of waste minimisation. The study proposed that this may be more reflective of the experience and interests of the respondents, than of the waste control issue itself. By far the majority of the New Zealand respondents surveyed thought that alternative routes

did have advantages over the traditional ones, in terms of waste minimisation. However, only a few of these respondents gave their reasoning for adopting this stance. Further investigation of this area is needed before conclusions are drawn.

There were also some design issues which were proposed in overseas research as being positive in terms of waste management, but which were not supported by this study. An example of this was where a neutral response was given to the importance of using prefabricated components (Question 10), in terms of waste minimisation. The 1996 Australian survey[3], and many international studies[10,21,23] all viewed the use of prefabricated components as being important for waste minimisation. Once again, further investigation, probably best in the form of one-on-one interviews, is needed to find the reasons for this.

4.2 Conclusions

The following conclusions are all directly related to the replies from the surveys.

- There is very little importance placed by architects on waste minimisation, compared to other design criteria. Aligned with this is the opinion that the priority at the design stage is project costs.

- Good component sizing and standardisation of room dimensions to reflect standard sheet sizes are considered to be effective design stage measures which reduce the output of waste.

- Careful attention at the design stage to avoid variations on site by providing accurate and integrated project information, and assisting in creating a buildable design that allows for a logical sequence in construction, are important in terms of reducing waste generation.

- Where possible, contracts should be set up so that waste reduction efforts are financially beneficial to the client, as this is seen as being a good motivator.

4.3 Recommendations

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

- There seems to be a discrepancy between what the sampled population of the New Zealand building industry values as being beneficial in terms of waste management, and what overseas researchers have found. Indications of the differences between this survey and overseas research was most apparent in some of the 5-point graded questions. Differences for those questions included a large spread in the New Zealand results (indicating a wide range of opinion), and/or neutrality, or an entirely opposing view on a specific issue. These differences (and the reasons for them) are important, but may not reflect the national situation. Thus, it is necessary to perform a larger, nation-wide survey, which would represent the New Zealand building industry as a whole, before firm conclusions can be drawn. The recommendation, therefore, is to extend the survey, so that each of the larger New Zealand centres (Auckland, Wellington, and Christchurch) is represented.

- Following on from above, the reasons behind the respondents choosing the particular answers they did, was left largely undetermined. This was especially true for the multi-choice answers where there was no chance for elaboration on view points. For many survey questions, knowing the "whys" or "hows" (ie the reasoning behind the questions) is just as significant and important as the replies themselves. The recommendation for the next survey, is that there either be some option for the respondent to elaborate upon their answer, or else the questionnaire be performed in a different manner – for example, by pre-arranged phone interviews or person-to-person interviews. In both cases, critical extra information would be easily gained, because of the less structured interview style.

- The long answer questions were generally poorly responded to, with some building professionals giving only the briefest indication of their attitude or opinion on an issue. This may be reflective of the respondents viewing the New Zealand survey as being a time waster, too long or just inconsequential. Although the survey was regarded by the author as being compact and quick to fill out, this may not be the initial impression when first encountered by a new respondent. It is recommended that, for the next survey, one-on-one interviews will be carried out in parallel to the written survey.

- Speaking to some of the architects after the survey was complete, the author found that there were two questions (C3 and Question 16), which were found to be ambiguous. Their answers (and presumably also a portion of the other respondents' answers) were dependent on how they interpreted the questions. The recommendation is that these two questions be clarified before repeating the survey again.

- The assessment of the results from the New Zealand survey was more difficult than originally anticipated. This was mainly because of the small response population. It is recommended that for the next survey, more than 30 representatives from each profession are obtained from the three main centres (Auckland, Wellington, and Christchurch).

Appendix 1: 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 waste currently destined for the landfill. As part of this research program, I am examining what is currently happening during the design and procurement stages, as well as the potential for waste mitigation during these stages. Waste generated as a result of the construction and disposal stages is being covered elsewhere in the research program.

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 March 1998. The questionnaire examines such issues as the limitations on an architects' efforts to minimise waste, and the perceived importance of various waste reduction measures during the design process.

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 November 1998.

Sincerely

Roman Jaques
Building Technologist

Appendix 2: Architects' Questionnaire

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 programme looking into waste reduction in the construction industry as a whole. Please complete and return by the end of March 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. The builder provides input into the design development.
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. Used mainly for where speed is paramount.
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.

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: .....

A2 Which of the following type of project 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, 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 that are employed 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 Do you adopt a strategy for minimising design waste?

Yes ☐ No ☐

If "yes" then please describe the measures that are implemented (over page):

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)

Avoiding 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 CAD 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)

It is only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings.

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 practice turnover 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 alternative methods of procurement offer improved opportunities for *waste minimisation* strategies to be adopted?

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 "*Minimising Construction Waste*" - by Smithers and McDonald, for the Recycling and Resource Recovery Council, Victoria, Australia.

Appendix 3: Quantity Surveyors' Questionnaire

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 the design process, and the potential for reducing building material waste. It is part of a much larger research programme looking into waste reduction in the construction industry as a whole. Please complete and return by the end of March 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. The builder provides input into the design development.
4. **Project Management** - the project manager adopts a consultants 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. Used mainly for where speed is paramount.
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.

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: .....

A2 Which of the following type of project 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, 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 quantity surveyors that are employed in your practice: ....

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

B1 How importantly would you rate the following factors as limitations on efforts to minimise 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)

B2 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)

Avoiding 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)

Selecting materials to avoid unnecessary cutting.
Not Important **1 2 3 4 5** Important (Please circle)

B3 To what extent would you agree or disagree with the following statements?

The specification of new material, unfamiliar to building workers, increases waste generation on site.
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 a larger scale.

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)

It is only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings.

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 practice turnover 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 is system is becoming more extensively used: No. **1 2 3 4 5 6 7 (see above)**

C3 Do alternative methods of procurement offer improved opportunities for *waste minimisation* strategies to be adopted?

Yes ☐ No ☐ sometimes ☐

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

C4 To what extent do you agree or disagree with the following statements?

The use of elemental Bills of Quantities in their traditional form provide no incentive to adopt waste minimisation strategies as such strategies are not rewarded by lower tender figures.

Don't agree **1 2 3 4 5** Agree totally (Please circle)

A tendering system based on the resources required to build would lead to greater control of wastage in the design stage.

Don't agree **1 2 3 4 5** Agree totally (Please circle)

Involvement of the contractor during the design stage will lead to a reduction in waste on site.

Don't agree **1 2 3 4 5** Agree totally (Please circle)

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 "*Minimising Construction Waste*" - by Smithers and McDonald, for the Recycling and Resource Recovery Council, Victoria, Australia.

Appendix 4: Contractors' Questionnaire

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 the design process, and the potential for reducing building material waste. It is part of a much larger research programme looking into waste reduction in the construction industry as a whole. Please complete and return by the end of March 1998.

For the purposes of this questionnaire, the following definition has been used:

- **Design Waste** - waste of building materials occurring at the point of construction but arising from decisions and actions taken during the design 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.

A1 Name of your organisation: .....

A2 What is your trade?.....

A3 Please indicate the number of people that are employed in your organisation.....

Section B This section examines waste minimisation.

B1 Please list the building materials that are used regularly as part of your trade

B2 On average what proportion of each of the materials that you have listed is wasted during construction? Please place a percentage against each item in your list above.

B3 What do you think are the principal causes of waste occurring as part of your trade?

B4 What aspects of the waste that is generated as part of your trade do you think can be attributed to decisions made in the design and specification stage of a building project?

B5 In what ways do you think that designers can minimise waste arising in your particular trade?

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

Appendix 5: Bar Charts of Combined Questions

The follow graphs show the response rates for the combined questions answered by both architects and quantity surveyors.

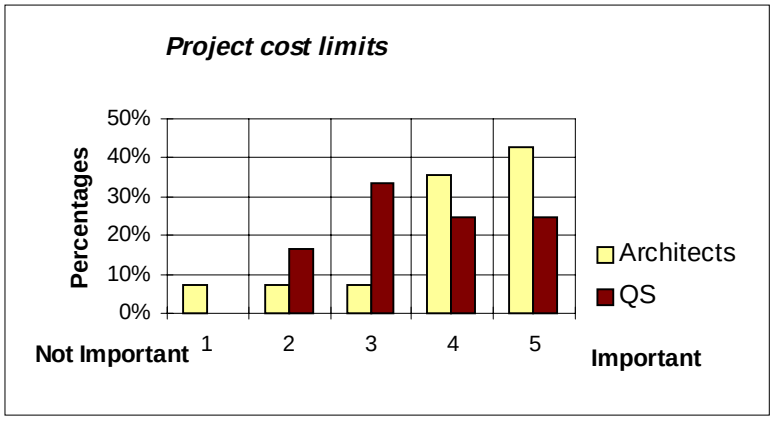

Figure 4: The importance of project cost limits

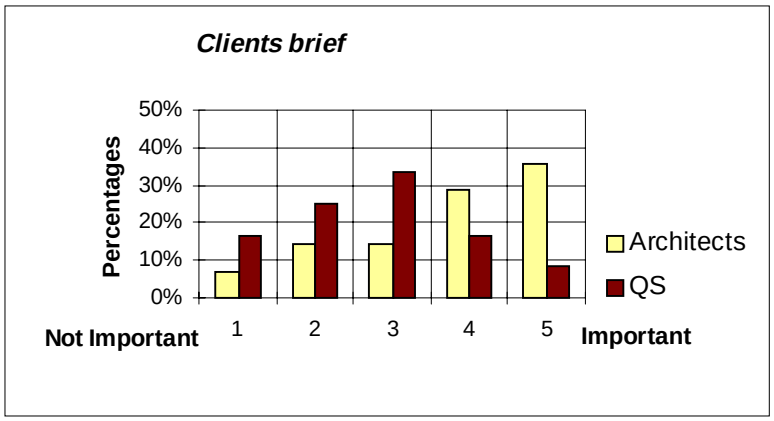

Figure 5: The importance of the clients brief

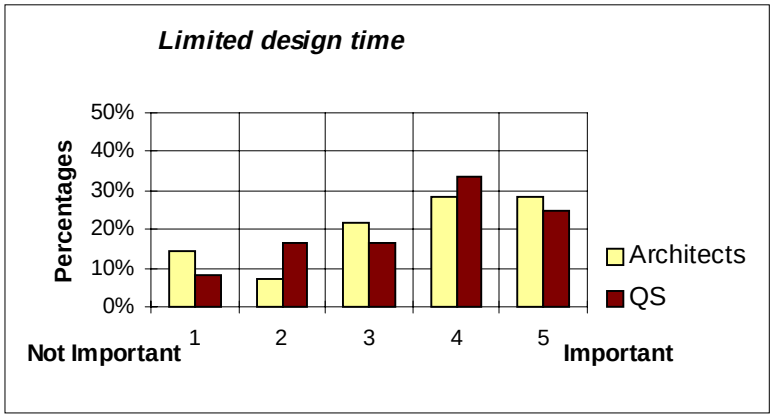

Figure 6: Limited design time

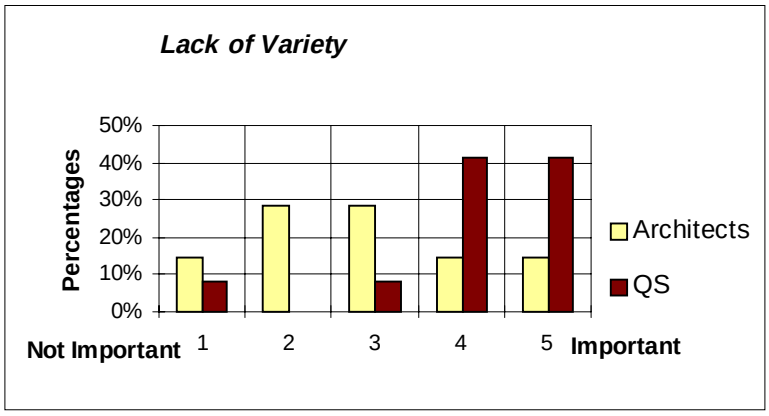

Figure 7: The lack of variety in the sizing of components and materials

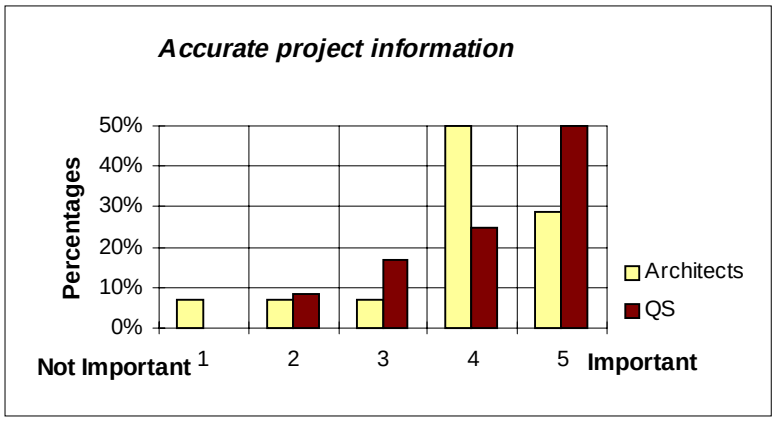

Figure 8: Providing accurate and integrated project management

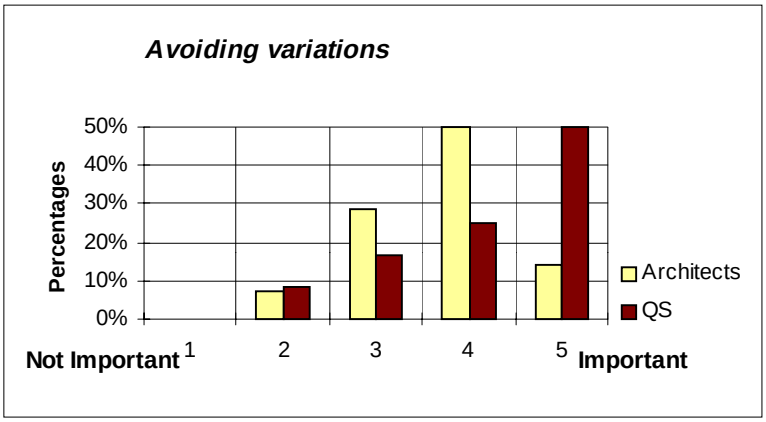

Figure 9: Avoiding variations occurring on site

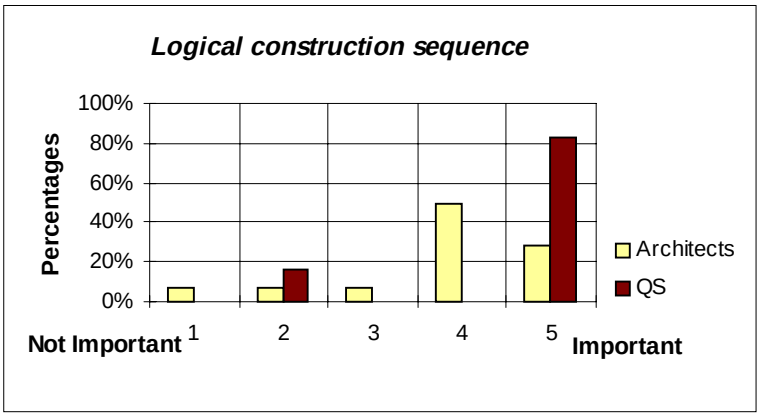

Figure 10: Creating a design that allows for a logical sequence in construction

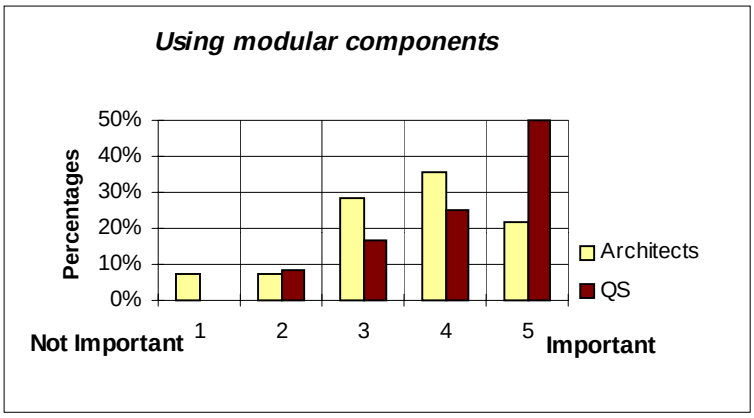

Figure 11: Using modular components within a design

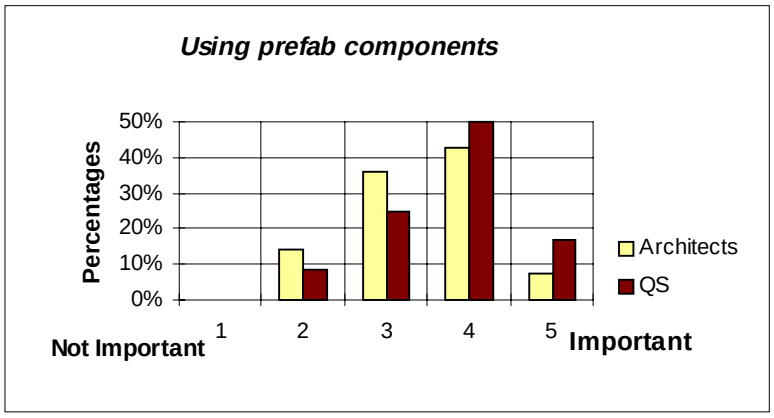

Figure 12: Using prefabricated components

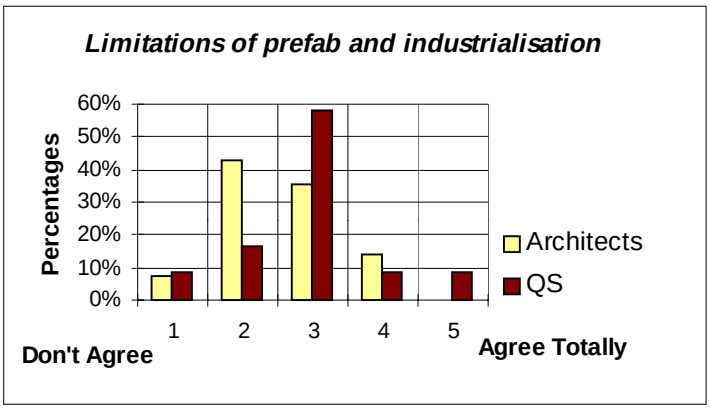

Figure 13: The current limitations of prefabrication and industrialised building techniques are too great to allow these methods to be adopted on a wider scale

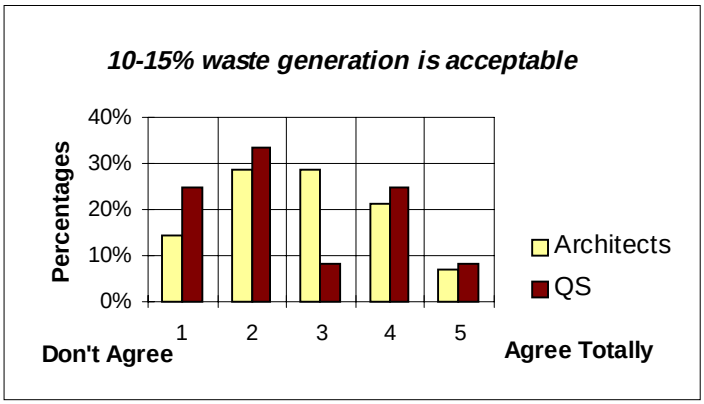

Figure 14: Because of the pressure to minimise construction time a norm of 10-15% for waste generation is acceptable

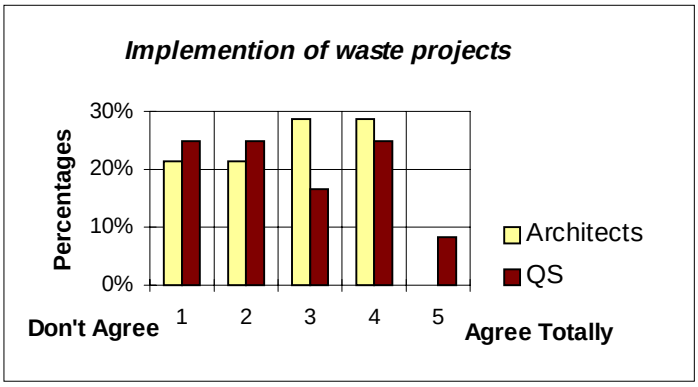

Figure 15: It is only practicable to implement effective waste reduction strategies on large scale repetitive projects such as multi-storey car parks and residential buildings

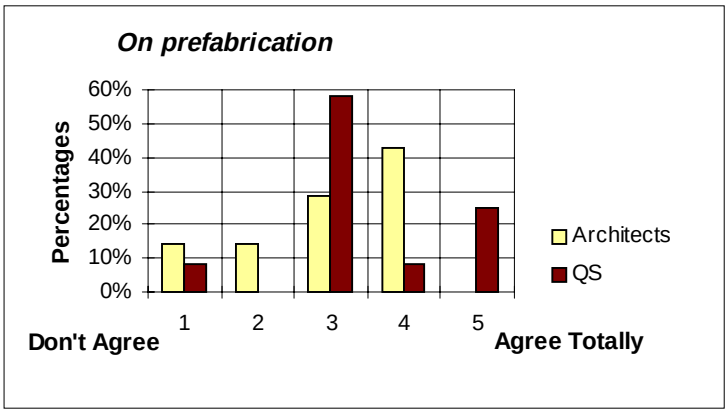

Figure 16: The use of prefabrication will reduce the amount of building waste generated

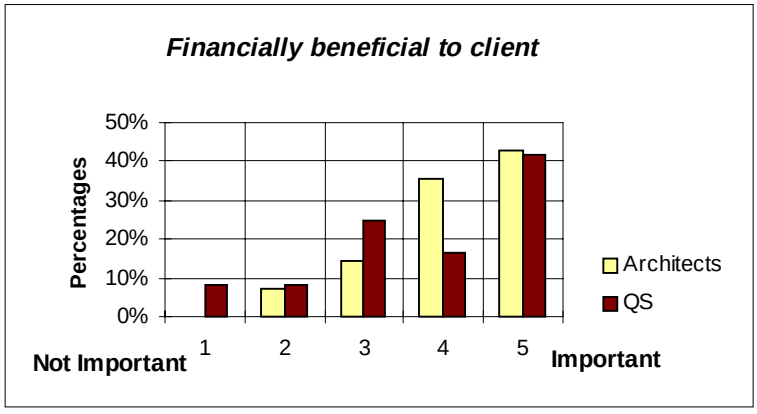

Figure 17: Making waste reduction efforts financially beneficial to the client

Appendix 6: 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 7: Correspondence Analysis Explained

Correspondence analysis is a descriptive/exploratory technique designed to analyse simple two-way and multi-way tables containing some measure of correspondence between rows and columns (from Massey University *Correspondence Analysis Introductory Overview* handout 1998). Correspondence analysis restructures the 16 five-grade survey questions directed at architects and quantity surveyors, into a 16 x 5 matrix. In the terminology of correspondence analysis, the 16 questions are reduced to two "dimensions", with the five point scale also being reduced to two dimensions. The three graphs (Figure 1, Figure 2, and Figure 3) are a two dimensional approximation of how the responses are spread in the 16 directions.

The term "inertia" is used on both the x and y axes. The higher this inertia figure, the more importance the data points have for that particular axis. The inertia percentage (say 55%) beside the Dimension axes "explains" 55% of the inertia; that is, the relative frequency values that can be reconstructed from a single dimension can reproduce 55% of the total Chi-square value. [Chi-square is a measure of the discrepancy existing between the observed and expected distributions, that is the closeness the theoretical data fits the empirical data].

References

1. Patterson, C. et al. 1995. "*Report on Preliminary Investigation into Construction and Demolition Waste in the Auckland Region*". Auckland Regional Council. Auckland.

2. Personal communication. Peter Mittermuller. February 1998.

3. 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.

4. Eberwein, B. et al. 1993. "*Resource Efficient Building - A handbook for Building Owners, Designers and Project Managers*". Environmental Protection Agency. Environmental Projects. Washington.

5. Hobbs, G. 1996. "*Management of Construction and Demolition Wastes*". Building Research Establishment, Watford. Information Paper IP1/96.

6. Guthrie, P. 1997. "*Waste Minimisation and Recycling in Construction - Site Handbook*". Construction and Industry Research and Information Association. Funders Report/CP/41. London

7. Halliday, S. 1994. "*Environmental Code of Practice for Buildings and Their Services*". Building Services Research and Information Association. London.

8. Innovative Waste Management. 1993."*Construction Materials Recycling Guidebook - A guide to reducing and recycling construction and remodelling waste*". Minnesota.

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

10. Construction Industry Environmental Forum BULLETIN. 1994. From the notes of the discussion workshop on 26th April 1994. "*Waste minimisation and recycling in construction . The role of the design process*". London.

11. 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.

12. Elliot, C and Palmer, A. 1996. "*Total Resource Assessment Based on Extension of Traditional Procurement Systems*". Heriot Watt University. Edinburgh.

13. Venebles, R et al. 1993. "*Environmental Handbook for Building and Civil Engineering Projects - CONSTRUCTION PHASE".* Volume 2: Checklists, obligations, good practice and sources of information. Construction Industry Research and Information Association. Special Publication 98, Research Project 459. London.

14. Forrest, P. 1997. "*Cleaner Production Guidelines for the House Construction Industry*". Wellington City Council. Wellington.

15. "*Cleaner Production Guidelines*". 1994. Ministry for the Environment. Wellington.

16. Hall, R. 1997. Environmental Protection Authority (EPA). "*Draft Construction and Demolition Waste Action Plan*". New South Wales Environmental Protection Authority. Sydney.

17. Standards Association of New Zealand. 1987. NZS 3910. "*Conditions of Contract for Building and Civil Engineering Construction*".

18. Graham, P. 1996. "*Waste Management*". Environment Design Guide. TEC pg 4. Royal Australian Institute of Architects. Canberra.

19. Krzanowski, W. J. 1988. "*Principles of Multivariate Analysis*". Clarendon Press. Oxford.

20. STATISTICA for Windows. StatSoft, Inc. Tulsa. 1997. WEB: www.statsoft.com.

21. 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.

22. Seaden, G. 1995. "*Construction Trends in the Context of Sustainable Development*". Institute for Research in Construction. Canada. From the proceeding of the Conference on "*Cost Effective Management of Constriction and Demolition Waste and Green Building Procurement*". Toronto.

23. McDonald, B. 1994. "*Waste Minimisation and Recycling Program*". RECON. Fletcher Construction Australia. Melbourne.