THE NEW SOUTH WALES INSTITUTE OF TECHNOLOGY

AN INVESTIGATIVE STUDY OF COMPUTER GUIDANCE SYSTEMS FOR PROJECT COST CONTROL

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Abstract

The problem under investigation is the failure of current project cost control processes in Australia to adequately examine alternative design solutions due primarily to the imposition of time and cost constraints. Hence project optimisation does not occur--the cost of a design is controlled but rarely is a design formulated to comply with a pre-determined budget allocation. This thesis attempts to improve current practice through the introduction of a computer guidance system called "COSTPLANNER" devised to enable implementation of complex optimisation and control procedures between the stages of conception and tender while simultaneously improving speed and accuracy.

In order to arrive at a workable solution the investigative study is subdivided into three main sections. First, traditional methods of project cost control are discussed in order to ascertain the basic philosophies which will need to be preserved. Second, current levels of computer involvement are analysed to arrive at the essential elements which any computer-based system must

possess. Third, a framework for a complete computer-guided cost planning package, incorporating the necessary mechanisms to enable more thorough investigation and overcome restrictions currently imposed by insufficient time, is designed in detail.

The investigation has highlighted that design optimisation must be initiated at an early stage before valuable time and money is spent documenting a scheme that is inherently cost expensive. Also, to enable proper exploration of alternative solutions either the number of areas to be investigated must be reduced or the speed with which such areas are examined increased. The use of computers to undertake cost control activities means that the latter is an achievable goal that does not resist acknowledged attempts by the National Public Works Conference (N.P.W.C.) in Australia to encourage industry standardisation.

The major conclusion reached is that current practice can be significantly improved through the utilisation of computer guidance systems at all stages in the design of a project. Preparation time of feasibility reports can be reduced by ninety-three percent, sketch design cost plans by forty-five percent and tender document cost plans by thirty-four percent--an overall reduction in time and cost of fifty percent[1]. In addition to the

[1]Based on project valued at five million dollars with eighty percent of cost identified as building work.

obvious benefits of making instantaneous changes to cost information, full reports including life cycle costing, value analysis and cost-benefit analysis studies as applicable are automatically prepared. Implementation of computer guidance systems to improve efficiency is not only desirable but absolutely essential, although it is an area which to date has been suprisingly ignored.

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PREFACE

The scope of this thesis is designed to form the second stage in a long-term objective related primarily to the production of a successful and commercially suitable cost planning package that covers all aspects of economic investigation from the time of conception to that of contract tender for all types of buildings.

The first stage, already completed, involved the gathering of experience pertaining to computerised cost planning techniques for a specific field, which was defined as primary and/or secondary public schools in New South Wales[1]. The third and final stage will be required to achieve the above long-term objective based on the information and experience compiled in stages one and two.

The second stage is without doubt a vital step in the establishment of a complete cost planning package for use by quantity surveyors, architects and others in the project team. It draws on the experience obtained during previous investigations, researches traditional practices

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[1] Craig A. Langston, "Computerised Cost Planning Techniques", 2 Vols. (B.App.Sc. project, New South Wales Institute of Technology, 1982).

and gathers together available information about computerised cost planning systems currently under development.

From this wealth of practical and theoretical data a framework can be prepared that builds on the advantages and avoids the disadvantages that have been identified therein. Such a framework can then form the basis for the design and construction of the requisite computer instructions that will evolve through testing and further experience into the ultimate cost planning system.

This thesis was prepared in accordance with Kate L. Turabian, A Manual for Writers of Term Papers, Theses and Dissertations, 4th ed. (Chicago: University of Chicago Press, 1973) and the requirements of the New South Wales Institute of Technology. The text was written and edited on a Zardax wordprocessor using an Apple //e micro-computer and reproduced on a Brother HR-1 letter quality daisy wheel printer.

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CHAPTER I

INTRODUCTION

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INTRODUCTION

The Problem

Cost control of building design is justified if cost is equated with form and function and is recognised as a design limitation. The fundamental problem is that the potential of present project cost control activities is not being fully exploited. Techniques have been developed to enable optimisation of design concepts so that the maximum value for money is attained. Generally these techniques are not common practice in Australia and must encourage serious doubts as to the satisfactory protection of the client's interest and hence fulfilment of contractual obligations.

Pre-construction cost control and its lack of compatibility with subsequent construction offers the greatest scope for improvement. Currently duplication of work exists between cost control processes undertaken before and after tender and little sharing of resources can be identified. Attempts to create a common and accessible data base for cost information have not succeeded to date and are plagued by difficulties associated with co-operation and market competitiveness.

The single most significant deficiency at present is the failure to employ control processes that allow a design concept to be created to achieve a set cost target. Instead designs are prepared and control activities initiated to determine the likely cost that will result. This situation is considered unsatisfactory and demands a new approach to the way in which traditional cost techniques are implemented.

Objectives

The predominant objective for any work undertaken as part of a Masters degree course is to endeavour to provide a contribution to knowledge. In this regard the specific objective to be employed must be capable of producing a result that enables greater insight into the subject under investigation.

The subject mentioned above is computer guidance systems for project cost control. This term is hereinafter held to apply to the following definition:

> An interactive network of cost planning procedures operating under the supervision of a set of computer-based instructions which together can act as a format for efficient estimating, monitoring and controlling of all cost related aspects of the building project from the time of conception to that of contract tender (ie. during the design stage).

The term hence covers all types of buildings and canvasses all components of the cost planning process. The provision of feedback information and the production of documents to suit a wide range of special interests and requirements are considered to be within the field of concern. Estimating costs for the purpose of preparing a tender, tendering strategies and contract administration activities are beyond the scope of the definition.

As part of the investigation process three main areas shall be examined in detail. Each shall be classified as pertaining to a particular section of the cost planning evolutionary progression. These areas comprise:

1. The past--traditional methods of project cost control
2. The present--computer storage and guidance systems
3. The future--framework for complete computer-guided cost planning package

The overall objectives are: (1) to describe the state of cost control activities in current usage exclusive of computer aids, (2) to summarise and critically analyse the work which has been undertaken in the field of computer storage and guidance systems for cost planning, and finally (3) to show in a practical context how a computer guidance system can be designed and successfully employed to create significant advantages over traditional methods of cost control.

The Past--Traditional Methods of Project Cost Control

Evolution is the process of gradual change over a long period of time involving survival of the strong and adaptable species and extinction of those that are inherently weak or unsuited to the demands of their changing environment. Systematic improvement is the means by which the evolutionary progression can be utilised to arrive at an optimum end result. But evolution is not confined merely to life--it can apply to cost planning as well!

Cost planning has evolved from crude methods of estimation to highly complex and time consuming activities that must conform to a wide variety of procedural rules and constraints. Economic demands now make it essential to look at a number of alternative design solutions in order that the overall construction cost and/or life cycle cost can be minimised. The time spent on effectively examining options must be weighed against the time allowed for the task, which is a function of the level of fees paid by the client. Education of clients in the range and benefits of cost planning activities is important.

Traditional methods of project cost control refer to cost planning activities undertaken before the advent of computer assistance. The majority of cost planning activities undertaken today hence can be classified as traditional. They have managed to continue in popular use simply because the limited amount of investigative work that takes place enables the process to fall within the available fee margin.

The inadequacies of traditional practice have led to the realisation that the cost planning process is on the threshold of significant evolutionary change. While the mechanics of cost control are well established, the amount of time associated with their employment precludes thorough investigation. The primary role of cost planning today seems to be costing a design[1] and then reducing or eliminating components if the cost is too high instead of instructing the designer at an early stage in ways that would enable the project to fall within the allowable budget.

Traditional methods of project cost control, due to their evolutionary position, have been labelled as "the past". Such a classification justifiably indicates that cost planning activities of this form are of historical

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[1] James Francis Mooney, "Systems of Cost Planning and Their Use in the Design Stage of the Building Programme" (M.Bldg. thesis, University of New South Wales, 1978), p. ix.

interest only. It is suggested and will later be shown that the future of project cost control lies not in the creation of new philosophies but in the implementation of new procedures. In fact many such procedures are already available in various stages of development.

Traditional methods also suffer from the inherent problem of human error. While any system that interacts with man will possess this disadvantage, the extent of its influence and ways in which it can be reduced are of interest when discussing systematic improvement. In a science that relies heavily on manipulation and sorting of cost data, areas, percentages and the like such a component must be of significance to any procedural changes that may be made.

But in what form will this heralded evolutionary change take place? Guidelines are required to control the directions for efficient investigative techniques and reduce the time associated with same. Either the number of cost significant areas need to be reduced or the pace at which these areas can be analysed increased.

Computers are suggested as the means by which time-minimisation can be achieved while maintaining or expanding the range of design alternatives researched. The speed and accuracy of the computer, its accessibility and in particular its versatility are considered as prime attributes that reflect and further promote this not-so-new technology.

The Present--Computer Storage and Guidance Systems

On the previously described evolutionary scale the past is reluctantly but nevertheless undeniably followed by the present. Although change can come slowly to some sectors of the community the introduction of computers has been a relatively rapid innovation. The low cost of personal computers has been a major reason for this trend together with the existence of computer software[1] capable of performing specific labour-saving functions.

Cost planning in "the present" has also become an area in which computers have an application. Their scope to date has fallen into one of the following categories:

1. Computerised storage of specific cost plan information with automatic manipulation and printing options

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[1]Software is a general term that describes all of the written procedures and rules that control computer operations. For the purpose of this discussion software is divided into two types--user-written programmes and operation system code. A user-written programme describes the data [information] that the user wants the machine to process and contains a series of instructions that detail the operations to be performed on that data. The operation system is composed of collected sets of symbolic instructions (CODE) that supervise the various capabilities of the computer and cannot be altered.

2. Computer guidance systems (perhaps including part or all of the above)

Although the former has a definite role and carries numerous advantages that save time and reduce errors, it does not assist the investigation of design alternatives other than changing the cost of an element or sub-element and viewing the instantly displayed results. It certainly does not analyse or optimise the concept of the design prior to the development of a formalised scheme nor show the effects on cost of plan shape or storey height. Feedback and/or storage of base costs--which may be used to compare new projects with historical information--may or may not be included in the first category.

Computer storage systems and computer guidance systems can each be found in various stages of development (including full development) for use in the control of project costs. The disparity in sophistication is relatively great and the approaches diverse. But just as there are many types and versions of software there are also many models of computer hardware[1]. Communication

[1]Hardware is the physical portion of a computer system. Hardware is the term used to describe the electrical and mechanical parts of the computer as well as the peripheral devices. One major piece of hardware is the central processing unit (CPU). It performs all of the data operations and contains a storage area, called memory, that is used for short term data retention. Peripheral devices include such equipment as disks and disk drives, printers, plotters and VDU terminals.

difficulties associated with different combinations of the above usually advocate purchase of software followed by purchase of compatible hardware. Unfortunately this can become expensive. But that is only one side of the coin as large development costs are also to be considered.

From an evolutionary point of view it is computer guidance systems that offer the greatest potential. These systems shall form the nucleus of any discussions pertaining to "the present" state of cost planning. Since only twenty percent of a project's cost can be affected after documentation has begun[1], it is important that cost planning activities be concentrated on the remaining eighty percent available during the concept stage. Computer guidance systems must direct themselves to this area of investigation--an area that in the past has been largely ignored.

The Future--Framework for Complete Computer-guided Cost Planning Package

Future evolutionary trends pertaining to cost planning must involve computers. There can be little doubt that computers will become more powerful and more flexible and the amount of marketable software will continue to increase. New technology will enable greater amounts of

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[1] P.S. Brandon, "A Framework for Cost Exploration and Strategic Cost Planning in Design", Chartered Surveyor Building and Quantity Surveying Quarterly, September 1977, pp. 60-63.

accessible storage medium to be utilised and complex tasks to be handled with more efficiency. Simultaneously the size and cost of computers will probably further decrease.

Computer guidance systems therefore require to be continually updated to meet the needs of this changing environment. The direction of this development can be divided into two fundamental stages:

1. Research and design of a framework for a complete computer-guided cost planning package

2. Creation of the requisite computer instructions that will enable the framework to be implemented and take advantage of the latest technology available.

The former is one of the principal objectives to be fulfilled during this thesis. Achievement of the latter is seen as a worthy area for separate study that shall be completed at a subsequent date.

Future cost planning procedures shall incorporate traditional philosophies and techniques operating under the supervision and guidance of a well designed set of computer instructions. The principles of designing to a cost shall be enhanced and allowed to flourish since the computer will be able to rapidly review a large number of design options. Costing a given design that has been derived from the above optimisation process can then be undertaken in more detail once documentation has commenced.

A variety of facilities for printing the contents of each cost plan at various stages during the pre-tender period are an integral part of the overall package. Feedback for design research objectives--an inherent facet that assists optimisation of future designs--shall be compiled and stored for later reference.

Methodology

The cost plan evolution has been described hereinbefore as transgressing the passage of time from the past to the future. The shortcomings of traditional practice are seen as being rectified by the implementation of computer guidance systems aimed at optimisation and time-minimisation of existing philosophies. This can be undertaken by a logical approach to the concepts of analysis and interaction. The new procedures shall operate under the supervision of a control medium but the framework for same shall incorporate the traditional philosophies of cost planning that still govern current practice.

The nature of this framework for a complete computer-guided cost planning package for all buildings at all stages of development between conception and contract tender is largely unknown. It shall be designed after information pertaining to traditional practices has been documented and the advantages, disadvantages and limitations of existing computer storage and guidance systems explained.

Chapter II shall deal with traditional methods of project cost control including current philosophies of cost planning and current procedures that govern these philosophies. Chapter III shall critically analyse the work already completed on computer storage and guidance systems and obtain information useful in the preparation of new procedures. Chapter IV shall be charged with the responsibility of designing the framework for a complete computer-guided cost planning package that will be the basis for future implementation. Finally Chapter V will summarise the results of this investigative study and set the stage for the creation of the ultimate cost planning system.

CHAPTER II

TRADITIONAL METHODS OF PROJECT COST CONTROL

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Background

General

This chapter covers the philosophies of cost planning together with the various estimating methods that can be used with same. It is not intended to be a complete or detailed account, though the important aspects pertaining to project cost control are canvassed to form a foundation for future decisions. For more information on estimating methods refer to suitable publications such as those by Ferry[1] and Mooney[2].

What is Cost Planning?

Cost planning is the means that enables the objective of project cost control to be achieved. It is a process used during the design stage of a particular

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[1] Douglas J. Ferry, Cost Planning of Buildings, 3d ed. (London: Granada Publishing, 1972), pp. 5-13.

[2] Jim Mooney, Cost Effective Building Design, (Sydney: University of New South Wales Press, 1983), pp. 88-92.

scheme to help minimise the cost of construction and subsequent usage and maximise the function that is anticipated by the client.

The objective of cost planning has been defined many times by various authorities and institutions. The following definition, however, was formulated by post-graduate students of the Master of Science (Building) degree course during 1975 at the University of New South Wales[1]:

> Cost planning is a process which brings cost information to bear systematically upon the evolution, construction and maintenance of a project so as to rationalise the relationship between capital and maintenance costs, quality, utility and appearance and to provide a framework for the control of costs in order to obtain the optimum value for money appropriate to the project.

It is an extremely appropriate definition because it highlights the integral components of evolution, construction and maintenance and emphasises that the object is to provide value for money.

The philosophy of cost planning can be divided into two main ideological groups--those that pertain to costing a design and those that pertain to designing to a cost. It is like the difference between black and white. Costing a design means simply that--methods of estimation that can

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[1] Jim Mooney, "The Future of Cost Planning", The Building Economist, June 1976, p. 1.

arrive at a cost for a given design. Naturally some sort of formalised scheme needs to be in existence for this process to function. Designing to a cost on the other hand means guiding the development of a scheme so that it not only sets a budget amount and ensures that the project does not exceed same but can provide the client with the greatest value for money possible.

Hence traditional methods of project cost control, including estimating methods, fall into one of these mainstream categories depending on their intended application. Each method is designed to tackle a particular area of the cost control process but no single method is capable of undertaking all facets of cost planning while still managing to satisfy the overall objective.

Components of Cost Planning

The individual estimating methods or components used during cost planning activities range from those that are quick yet susceptible to error to those that require measurement of quantities and hence are more likely to approximate the final tender amount. Cost planning is seen as the overall discipline to which each component has a distinct contribution. The primary cost planning components are described in this section as prerequisite theory to enable better understanding of the sections which follow. They can be summarised as:

1. The unit method
2. The cube method
3. The superficial area method
4. The storey enclosure method
5. Comparative estimates
6. The interpolation method
7. Approximate quantities
8. Elemental cost analysis

The unit method. This method utilises a fundamental unit of the project to predict the overall cost. The number of units involved is multiplied by the cost per unit obtained from historical information. Examples of units include the number of beds for a hospital, the number of students for a school and the number of cars for a parking station. This method takes no account of the content of the design and hence relies on similar historical information for its accuracy. It also takes no specific account of plan shape complexity or number of storeys.

The cube method. The cost of a building is given by the volume of space enclosed subject to certain measurement rules multiplied by the cost per cubic metre. It is in fact a calculation of the air which the building displaces but does not truly represent the quantities of floors, walls, ceilings, etc., that directly affect total cost. The cube method is inaccurate and unreliable and has generally fallen from favour. It similarly disregards the influence of plan shape and storey height and makes no real attempt to account for internal contents.

The superficial area method. This is a relatively accurate and reliable method of predicting the cost of a project where the storey height is resonably constant. It involves measurement of the floor area at each level multiplied by a rate obtained from a similar or collection of similar projects. The comments made previously pertaining to shape complexity and number of storeys still apply. The superficial area method is nevertheless possibly the most common type of estimate for use at a preliminary stage for suitable projects.

The storey enclosure method. In this method the areas of the various floors, roof and the containing walls are measured, each is weighted by a different percentage and the resultant figures totalled to give the storey enclosure area. This area is then multiplied by a single rate obtained from other projects. It is an ingenious method that takes account of plan shape, storey height and overall building height. It involves measuring twice the area of each floor including an additional percentage for upper floors, the area of the roof and the area of external walls. Its disadvantage--as with all single-price estimating methods--is the inherent inaccuracy that exists because the specific details of the design are ignored.

Comparative estimates. This cost planning component involves using the actual costs for a previous project of similar purpose and size. Its accuracy is obviously totally dependant on the extent of similarity that exists and the availability of relevant cost feedback. Standard projects lend themselves readily to this method.

The interpolation method. Using comparative estimates initially, this method attempts to adjust the obtained cost by any one of a number of constraints including unit, cubic content, superficial area and storey enclosure area all as before described. It is really little different than using a rate per unit of measurement and applying it directly except that interpolation can be used to adjust for other differences apart from size and shape such as glazing area, quality of finishes and extent of internal subdivision.

Approximate quantities. When the design of a project is more than an idea or a few lines on paper, the measurement of approximate quantities will achieve a better result than single-price estimates. Murphy[1] states:

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[1] John Joseph Murphy, "A Comparative Study of Cost Planning for School Buildings" (M.Sc. thesis, University of New South Wales, 1974), p. 18.

> Estimating by approximate quantities is obviously the safest method to use, even if only because it is closer to the method used by the estimator in preparing the tender.

Quantities of major components are measured and all minor items of labour and material are included in the rates used. This method of cost estimating is more relevant to the drawings being prepared since it can take account of some or all of the cost significant items.

Elemental cost analysis. This is the procedure of dividing the project into a number of recognised groups, measuring each and applying rates that reflect the content as anticipated or documented. By following defined rules for the measurement of these groups cost information from past projects can be used with relative confidence. This method may use superficial areas or approximate quantities priced and totalled according to the relevant elemental groups.

The Building Cost Information Service of the Royal Institution of Chartered Surveyors (RICS) in December 1969 published a "Standard Form Of Cost Analysis" in an apparent attempt to reconcile the theory of cost planning with the practical requirements of its application. The stated aim of this document was ". . . to produce standardisation of cost analysis and a single format for presentation". Widespread use of this standard form, which is divided into six groups comprising a total of thirty-three elements, significantly improved the efficiency of cost planning techniques and encouraged greater exchange of information.

The Quantity Surveying Section of the New South Wales Government Architect's Branch in December 1974 published the "National Public Works Conference List and Definitions of Sub-elements including Units of Measurement" (latest edition released in 1980). The list contains forty-seven elements and approximately nine hundred sub-elements which many agree compares unfavourably with the British standard form of cost analysis. The traditional approach to element definition has been expanded to provide a system that is more suitable to the objective of widespread collection, storage and future use of cost information.

Table 1 lists the National Public Works Conference List of Elements. Elemental cost analysis will be discussed further in relation to the example of traditional methods of project cost control hereinafter.

Building Price Index

Building price indices carry a large responsibility when used in cost planning operations. It is their task to update historical cost data, to predict future increases or decreases in labour and materials that are likely to occur and to adjust costs for relevant market conditions. The

TABLE 1

NATIONAL PUBLIC WORKS CONFERENCE
LIST OF ELEMENTS

Code	Element	Code	Element
00 PR	Preliminaries	30 CE	Centralised Energy Systems
01 SB	Substructure	31 AR	Alterations
02 CL	Columns	32 XP	Site Preparation
03 UF	Upper Floors	33 XR	Roads, Footpaths and Paved Areas
04 SC	Staircases		
05 RF	Roof	34 XN	Boundary Walls, Fencing and Gates
06 EW	External Walls		
07 WW	Windows	35 XB	Outbuildings and Covered Ways
08 ED	External Doors		
09 NW	Internal Walls	36 XL	Landscaping and Improvements
10 NS	Internal Screens and Borrowed Lights		
11 ND	Internal Doors		
		37 XK	External Stormwater Drainage
12 WF	Wall Finishes	38 XD	External Sewer Drainage
13 FF	Floor Finishes	39 XW	External Water Supply
14 CF	Ceiling Finishes	40 XG	External Gas
		41 XF	External Fire Protection
		42 XE	External Electric Light and Power
15 FT	Fitments		
16 SE	Special Equipment	43 XC	External Communications
		44 XS	External Special Services
17 SF	Sanitary Fixtures		
18 PD	Sanitary Plumbing	45 XX	External Alterations
19 WS	Water Supply		
20 GS	Gas Service		
21 SH	Space Heating	46 YY	Special Provisions
22 VE	Ventilation		
23 EC	Evaporative Cooling		
24 AC	Air Conditioning		
25 FP	Fire Protection		
26 LP	Electric Light and Power		
27 CM	Communications		
28 TS	Transportation Systems		
29 SS	Special Services		

accuracy of selected combinations of traditional methods of project cost control can be seriously weakened by an unreliable building price index.

Any selected or devised building price index should satisfy the following list of performance criteria:

1. The index should be constructed from readily available information

2. It should comprise a labour and a material component integrated in a particular identifiable proportion

3. The index should allow for the market condition[1] to be separately assessed

4. The base used for the index should be of sufficient distance from the present to enable establishment of trends but not so far that the accuracy of information is diluted

5. The ingredients of the index must be identifiable so that it may be used intelligently

6. The index must be capable of being kept up to date using information that is never more than three months behind the present

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[1]Market condition is a variable that reflects the movement in the form of an index by the profit and overheads policy that the building contractor wishes to apply to his tender. Cost planning procedures hence need to take account of this variable if the budgeted project cost is to be realistic. John Andrew McCrae, "Building Cost Indices: Theory and Practice", (M.Sc. thesis, University of New South Wales, 1974), p. 25.

7. The intervals at which the index is adjusted should be suitable to its purpose and usage

8. The present value of the index should reflect the anticipated final cost of a building which is to be commenced at the present time

It is suggested that any index used for cost planning purposes be one that takes account of market conditions in one form or another.

Costing a Design

Definition

Costing a design covers the majority of cost planning techniques whose main purpose (in theory) is to develop the most economic form of a given design[1]. The emphasis is intended to be placed on the phrase "of a given design" since this cost planning philosophy does not investigate alternative design solutions. It does, however, identify cost significant items contained in the scheme which may be deleted or substituted during the project's design stage. The principles of costing a design are well known as this philosophy is easily the most common process now in use in Australia. But its advantages, limited as they may be, are not being fully capitalised upon at the present time.

[1] Mooney, Cost Effective Building Design, p. 25.

Principles of Costing a Design

The initial decisions which significantly involve the developing design are made by the architect. They may be based on aesthetic considerations, previous projects, experience or even an assumed economic configuration. But no objective analysis is undertaken and no facts are compiled to verify the choices made. The sketch plans are prepared as a result of the initial decisions.

This is the point at which the quantity surveyor[1] usually becomes involved. His task is largely pre-defined as estimating the cost of the project using one of the many methods available to him and thence preparing the initial cost plan. The quantity surveyor monitors the costs as the drawings progress and makes suggestions (although these are not necessarily implemented) about possible savings. Very little constructive criticism pertaining to design decisions takes place for reasons that are more concerned with maintenance of good relations than cost planning.

During the pre-tender period the cost plan[2] is continually revised and since there are obviously less

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[1]A quantity surveyor is a professional consultant who traditionally measures quantities of building works but today can be found working in many varied fields relating to building economics.

[2]A cost plan is a document prepared at various stages during the pre-tender period that summarises the expected cost status of the project after implementation of the cost planning process.

unknowns the design contingency, sometimes called design risk, is continually reduced. The final cost plan document is intended to emulate the cost expected during tendering on a bill of quantities[1] based on the same set of drawings. If the cost plan is founded on the pricing of measured quantities and due consideration of market conditions has been made then this will usually be the result.

The main theoretical functions of costing a design can thus be summarised as:

1. Estimating the cost of sketch plan drawings allowing for an anticipated level of quality and finish and using knowledge of assumed building practice

2. Compiling the costs and building areas into a document that enables interpretation and formalisation of the project's status

3. Updating of this document either by issuing new cost plan versions or issuing cost statements of the alterations that have occurred at various pre-determined stages in the development of the drawings

4. Exchanging of information pertaining to possible changes to the original design, though any analytical investigation is seen as within the gambit of the designing to a cost philosophy

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[1]A bill of quantities is a list of the items of materials and workmanship involved in a project and fulfils the purposes of providing a common basis for tendering and aiding subsequent contract administration activities.

5. Preparing the final cost plan which is usually submitted just prior to completion of the bill of quantities

The manner in which the design and cost control activities interrelate for this philosophy is shown in table 2. It is important to note that the level of interaction is largely governed by whether or not the developing cost is remaining within the budget allowance originally anticipated.

Costing a Design in Practice

It was previously stated that in theory costing a design refers to the majority of cost planning techniques whose main function is to develop the most economic form of a given design. In practice, however, this apparently is not the case. Costing a design in the most part is the control of a project's developing construction cost with reference to a pre-determined budget amount. If the derived cost is below the budget then no further investigation at that particular stage is carried out. If the derived cost is above the budget then items of cost significance are identified and either: (1) deleted, or (2) substituted with a less expensive alternative.

Government projects frequently have the budget set by a government-employed quantity surveyor who is independent of the quantity surveyor involved in the cost

TABLE 2

DIAGRAMMATIC REPRESENTATION OF THE
COSTING A DESIGN PHILOSOPHY

```
      Architect                               Quantity Surveyor


sketch design drawings
        I   I
        I   ------------------------------------
        I                                      I
        I                                      v
        I                              initial cost plan
        I                                    I   I
        I   ----------------------------------   I
        I   I                                    I
        v   v                                    I
 preliminary drawings                            I
        I   I                                    I
        I   ----------------------------------   I
        I                                    I   I
        I                                    v   v
        I                              revised cost plans
        I                                    I   I
        I   ----------------------------------   I
        I   I                                    I
        v   v                                    I
final working drawings                           I
        I   I                                    I
        I   ----------------------------------   I
        I                                    I   I
        I                                    v   v
        I                               final cost plan
        I
        I
        I
        v
   tender drawings
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planning process. The budget amount is derived from a standard procedure which, in simplified terms, utilises information from past projects. Any new design--ignoring special factors and site works which are both separately allowed for--should be capable of being built for the same price as an average of previous projects escalated and adjusted to the new tender date.

Costing a design in the above dialect is widespread. Very little optimisation takes place on an objective and formalised level--intuition seems to play an important role in the decision making process. Generally alternatives are only analysed on specific instruction, not as a matter of course. In crude terms the philosophy of costing a design when used in practice is merely another form of cost estimation. This situation is considered an unsatisfactory one and fails to achieve the overall cost planning objective of providing value for money.

Designing to a Cost

Definition

Designing to a cost covers the majority of cost planning techniques whose main purpose, unlike the costing a design philosophy, is to develop the most economic design solution possible. It is implied that alternative methods of achieving the intended result be examined quantitatively as an essential aid to the decision making process. Since neither the architect nor the quantity surveyor nor any other member of the project team can reasonably fulfil this objective in isolation, a co-operative effort is required.

In order that this philosophy can function properly it must be implemented before any formalised attempt at documentation has begun. A feasibility study optimally examining all possible design solutions in respect to cost is ideal, but in practical terms the scope of investigation should be confined to a much smaller selection.

Principles of Designing to a Cost

The architect, in association with the quantity surveyor and other consultants, formulates a number of proposals that all have the capability of achieving the intended design objectives. The quantity surveyor then proceeds to investigate each such proposal from a cost point of view and rank them in order of merit. After further discussions with the architect and perhaps further investigation an optimum configuration, based on cost and performance, in respect to the original selection is nominated as the concept design. Using this information the sketch plans are subsequently prepared.

During the design process the architect, the quantity surveyor or others may suggest more specific ways in which the project may be further optimised. Such suggestions should take the form of a collection of proposals as before described, and each proposal should be objectively investigated using quantitative techniques. As each cost plan is prepared an opportunity is provided to review the status of the project.

The main theoretical functions of designing to a cost can be summarised as:

1. Conducting a feasibility study prior to commencement of formalised documentation that quantitatively investigates possible design solutions from a cost point of view

2. Establishing a concept design that will form the basis for development of sketch plan drawings

3. Estimating the cost of sketch plan drawings using the levels of quality and finish and knowledge of design intention previously defined at the feasibility stage

4. Compiling the costs and building areas into a document that enables interpretation and formalisation of the project's status

5. Updating of this document either by issuing new cost plan versions or issuing statements of the alterations that have occurred at various pre-determined stages in the development of the drawings

6. Suggesting relevant alternatives for improvement of the project incorporating investigation and

selection as before described

7. Preparing the final cost plan which is usually submitted just prior to completion of the bill of quantities

The manner in which the design and cost control activities interrelate for this philosophy is shown in table 3. It is important to note that the level of interaction is largely governed by the co-operation achieved between architectural and economic constraints.

Designing to a Cost in Practice

Designing to a cost is generally not being used in Australia at the present time. The philosophy relies fundamentally on co-operation between the architect and the quantity surveyor at the concept stage as well as during the development of the selected design. It is therefore necessary that the quantity surveyor take a more prominent role in the design of the project, especially before sketch plan stage has been reached. It is only during this period that significant cost savings are possible, for after commencement of documentation the basic concept is fixed and design alterations are thus non-productive and impractical to implement. Until initial decision making is changed from the role of the architect to that of all members of the project team this efficient cost planning process will remain merely of academic interest.

TABLE 3

DIAGRAMMATIC REPRESENTATION OF THE
DESIGNING TO A COST PHILOSOPHY

```
      Architect                              Quantity Surveyor

                                       feasibility study
                                             I   I
          -------------------------------------  I
          I                                      I
          v                                      I
sketch design drawings                           I
        I   I                                    I
        I   -----------------------------------  I
        I                                    I   I
        I                                    v   v
        I                              initial cost plan
        I                                    I   I
        I   -----------------------------------  I
        I   I                                    I
        v   v                                    I
 preliminary drawings                            I
        I   I                                    I
        I   -----------------------------------  I
        I                                    I   I
        I                                    v   v
        I                              revised cost plans
        I                                    I   I
        I   -----------------------------------  I
        I   I                                    I
        v   v                                    I
final working drawings                           I
        I   I                                    I
        I   -----------------------------------  I
        I                                    I   I
        I                                    v   v
        I                               final cost plan
        I
        I
        I
        v
   tender drawings
```

Cost Planning Techniques and Associated Disciplines

General

Having covered the primary methods of estimation and the basic cost planning philosophies, there remains several techniques and associated disciplines that may be employed during costing a design or designing to a cost processes. They facilitate optimisation and hence are classified as relevant to the objective of supplying value for money. The four main areas of interest are:

1. Cost modelling
2. Life cycle costing
3. Value analysis
4. Cost-benefit analysis

Cost Modelling

Definition. Cost modelling may be defined as the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost. The objective of this cost planning technique is to simulate a situation in order that the problems posed will generate results which may be analysed and used in the decision making process of design. It is important that the model builder understands his model in order that he might know that the conclusions are valid in reality.

Classification of models. A simplified classification highlights four main types of cost models. First, there are empirical or causal models which are based on observation, experiment and analysis that give rise to the derivation of fundamental relationships. Second, there are statistical models. These are based on recognised statistical techniques such as regression, which measure relationships in a sample of data. They may also be of a stochastic nature. Third, there are algebraic models, which are based on formulae that may--for example--represent building morphology in algebraic terms for a computer-aided iterative process. Finally there are physical models, which are based on a design by physical measurement and the application of unit rates (for example, approximate estimating, spatial planning and elemental estimates).

Many models will of course incorporate two or more of the above types and all of them may be represented in a digital or possibly an analogue computer where the relationships can be adequately described.

Objectives and principles of a building cost model. The objectives can be defined as: (1) to establish a pattern for economic control of building design by using diagnostic development processes in a similar way to that of the designers, (2) to establish a link between design cost control and construction cost control, and (3) to introduce more assurance into economic policies for construction investment.

The approach to the model in the context of the above objectives is likely to be: (1) the assembly of a hypothesis no more accurate than the designer's first view as to whether the building is possible at all, (2) the refining of such a hypothetical cost plan to the level of an analysis as to whether to proceed further, and (3) the translation of the resultant plan into hard facts (for example, quantities, specification and drawings).

In addition certain principles will need to be established for practical use and compatibility with the decision making process of design, such as: (1) data for use in the model must be structured in such a way that it can represent the greatest degree of refinement compatible with the design stage reached, (2) it must allow the fast assembly of a particular hypothesis for simulation, testing and analysis, (3) cost data must be capable of a continuous process of updating and evolvement without excessive time being required, and (4) the hypothesis must be assembled against data which bears an understandable relationship with design principles (for example, the fundamental use of space).

Cost modelling in building design. It is becoming apparent that accurate cost modelling of building design problems has considerable potential for improving design solutions. In mathematical terms, modelling a design problem establishes the feasible solution space for that problem. The solution space is bounded by functional constraint relationships linking the design variables. For each point within the solution space there is some external measure of effectiveness (usually cost) which is called the objective function. The values of the design variables which identify this point then provide the optimal design solution.

Methodology. Drawing upon experience in other operational research applications it is possible to identify a methodology which meets the needs of the cost modeller, namely:

1. Define the problem
2. Identify the independent variables
3. Derive the objective function
4. Derive the functional constraints
5. Test the behaviour of the model
6. Identify the optimal solution
7. Test sensitivity of the optimum

The precise nature of the problem must be explored, the accuracy of information available carefully assessed and the potential uses of the model defined.

Identification of the independent variables requires insight into the nature of the design problem, while the objective function is usually simply stated as "cost". Definition of the functional constraints requires knowledge of the technical, legal and financial constraints upon the design variables. The constraints must be expressible as equalities or inequalities relating the dependent design variables.

Before it is used to produce design solutions the model must be comprehensively tested to determine its validity. Having established an optimal design solution it is usual to test the effect which small changes in the variable values have upon the optimal objective function value (minimum cost). In simple mathematical terms this involves testing the gradient of the objective function around the optimum--this process being known as sensitivity analysis.

Optimisation. Once developed, the cost model must be optimised in order to determine the best design solution. To obtain the true optimum design it is necessary to consider all of the variables at once--for if one attempts to optimise the variables singly, unless some sophisticated decision process is employed such as dynamic programming, the final result will be wildly sub-optimal and will invalidate the use of the model.

The majority of cost models for building design which have been published are distinguished by the mathematical characteristics of: (1) the number of variables involved, (2) the discontinuous nature of both objective and constraint functions, (3) the non-linear nature of both objective and constraint functions, and (4) the number of stochastic rather than deterministic relationships.

Life Cycle Costing

Definition. Life cycle costing, costs-in-use and recurrent cost analysis are all names for the technique that enables a quantitative assessment of the capital and maintenance costs of a building project over a specified lifetime. The basic objective is to provide information during the design stage that can aid in the decision making process. This information will be used to compare the initial cost of building components in terms of their expected durability and performance.

Life cycle costs can be grouped under three headings. First, costs associated with the building development, which include principal and interest payments on capital borrowing, amortisation of the building and site improvements. Second, costs associated with the operation and maintenance of the completed project itself by virtue of the materials from which it is constructed and finished and the services it contains. Third, costs associated with the function carried out in the building.

Life cycle costing raises fundamental questions about design decisions and the role of standard cost control procedures. Ferry[1] states:

> It has been felt by many people that cost targets have for too long been expressed purely in terms of capital cost, and that in order to meet these targets materials and constructions have been used which are low in first cost but which will require constant expenditure on maintenance and repair during the life of the building. If only, it is argued, the architect were allowed to spend more money initially on better materials these would pay for themselves in the long run.

Discounting. When analysing the costs of maintenance and operating expenses at various stages during the future life of a building project it is necessary to discount such costs to a "present value" amount. The present value means the amount of money which would have to be invested today in order to accumulate the amount needed at a later date. The procedure hence involves making an estimate of the likely level of interest rates and inflation over the specified lifetime.

Due consideration must also be given to tax allowance for depreciation, which will tend to mitigate the overall cost effect.

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[1] Ferry, Cost Planning of Buildings, p. 166.

Advantages and disadvantages of life cycle costing.
There are both significant advantages and disadvantages of this well known technique. The advantages are as follows:

1. A quantifiable comparison of construction and maintenance costs that assists in selection of building components aimed at providing value for money

2. In addition to other cost planning techniques life cycle costing can supply useful information for decision making

3. It justifies the use of more expensive materials that otherwise may have been selected on a subjective and rather questionable basis

The disadvantages of life cycle costing are largely dependant on the project type and its occupancy after construction. They can be summarised as follows:

1. There is no guarantee that use of theoretically durable materials will significantly reduce maintenance costs

2. The client may not be interested in saving on maintenance and running costs if he will not retain use and/or ownership of the building

3. Funding may dictate the need for minimum capital costs to be achieved

4. Obsolescence may occur through fashion changes rather than component lifetime and hence durable materials

may not be appropriate

5. Difficulties are present in accurately forecasting future interest rate and inflation levels

6. Difficulties are also present in assessing the extent of maintenance and repairs that are likely to occur

7. Over long periods of time life cycle cost forecasting can be very inaccurate

Notwithstanding the disadvantages life cycle costing is still an important cost planning technique.

Usefulness. The forecasting of operating costs for a project is often useful, but this does not always mean that a life cycle cost study will have any relevance to the client. Where such studies are justifiable the following should be kept in mind:

1. The shorter the period involved the more accurate the forecast is likely to be. As an alternative the use of an artificially high rate for discounting will have much the same effect by attaching little value to anything which may happen in the very distant future

2. While the results of the study will be of use as one of the factors that can be utilised in arriving at a decision, it would be most unwise to come to a decision about alternatives on a life cycle basis alone unless the calculated advantage of one of them is substantial

In order to achieve the maximum impact from any life cycle cost study, careful consideration should be given to their evaluation at the design stage when, if it is necessary, it is still possible to make changes and achieve a more balanced relationship between capital and recurrent costs.

Value Analysis

General. Value analysis, value engineering and value management are all terms used to describe the optimisation process through which unnecessary product cost is identified and eliminated. Cost effective solutions are determined by the comparison of the relative values of alternative possibilities taken from the infinite number of options available.

Value analysis grew out of the need to improve the relationship between cost of a product and its function during the stringencies of World War II. A system was developed that presents an organised way of challenging unnecessary cost which could then be applied to the fields of both manufacturing and services.

Definition. Value analysis is the study of the relationship of design, function and cost of any product, material or service with the object of reducing its cost through modification of design or material specifications, manufacture by more efficient processes, change in source of supply (external or internal) or possible elimination or incorporation into a related item. Stated simply, however, it is a discipline that facilitates identification and elimination of unnecessary product cost.

From an operational viewpoint, value analysis is the conscious systematic application of a set of techniques that identify needed functions, establish values for them and develop alternatives to perform these functions for minimum cost.

Value. Value is a difficult term to define with any accuracy, but generally has the following components:

1. Value is relative and is not an inherent feature of anything
2. Value can be measured only by comparison
3. Value is the relationship between what someone wants and what he is willing to give up in order to get it

In value analysis four categories are usually recognised as encompassing the total concept of value; these being use value, esteem or aesthetic value, cost value and exchange value. Use value describes the power of an item to accomplish an end. Esteem or aesthetic value describes the feature or attractiveness of an item that causes it to be desired. Cost value represents the effort that must be expended to acquire an item. Exchange value is the quality of an item that allows trading the item for something else.

Value versus quality. Value analysis is a useful way to reduce costs. It can be applied not only in the engineering field where it originated but also to services, management control, information resources and capital projects. Properly applied, value analysis does more than maintain quality at reduced cost, it can actually enhance quality. Quality analysis and value analysis are but two sides of the same coin.

The basic objective of value analysis is to provide a specific function at the lowest cost without affecting quality. Quality analysis, on the other hand, seeks to improve quality without increasing cost if at all possible. To be effective value analysis must be applied to the heels of quality analysis--only thus can the maximum benefit be obtained. The later the change is made the more it costs to make that change and the less the saving that can result.

Application. Value analysis is a direct and tactical way in which production may be improved in the construction industry. The current trends in the industry are towards standardisation; value analysis is linked with but not dependant on standardisation. Although value for money in building has always been a salient factor in the deliberations of the building owner, it has never been more important than it is now.

The process of value analysis relies on the satisfactory execution of three basic steps:

1. Isolation of the function
2. Creation of methods to accomplish that function
3. Refining of one alternative into a successful innovation (a dynamic process)

Designers are generally capable and cost conscious but effective design (involving cost reduction) can only be achieved if:

1. There is an adequately informed brief and available information together with data on alternative methods, materials, tolerances and finishes
2. Sufficient feedback between production experts and designers is provided
3. Relevant cost information is provided by an able estimator

<u>The mechanics of value analysis</u>. There are four stages of analysis, namely:

1. Identification of elements, functions, costs and values

2. Search for alternatives at lower cost

3. Selection of functionally acceptable lower cost limits

4. Presentation of the selected redesign

Within this framework are a series of basic questions that summarise the mechanics of the process[1]. These questions, given in table 4, are used as a means of clarifying the major components of the investigation process when used in practice.

The strength of value analysis lies in its dependence upon careful appraisal of information and subsequent comparison of solutions. It should be stressed that value analysis is seen as a process of development in design and hence relies on dynamic rather than passive evaluation.

Cost-benefit Analysis

Definition. Cost-benefit analysis is a specialised aspect of value analysis, but unlike value

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[1] Gage was responsible for originally proposing these questions and many other authors have subsequently adopted his thinking and used it as the basis for value analysis discussions. William Lionel Gage, Value Analysis, (London: McGraw-Hill, 1967).

TABLE 4

LIST OF BASIC QUESTIONS DEPICTING MECHANICS OF VALUE ANALYSIS

A.	Information:	1.	What is it?
		2.	What does it cost?
		3.	How many parts?
		4.	What does it do?
		5.	How many required?
B.	Speculation and Evaluation:	6.	What is the primary function?
		7.	What else will do?
		8.	What will that (7) cost?
C.	Plan:	9.	Which of the three ways of doing the job shows the greatest difference between "cost" and "value"?
		10.	Which ideas are to be developed?
D.	Development:	11.	What other functions and specification features must we incorporate?
E.	Selling:	12.	What do we need to sell our ideas and forestall objections?

analysis it looks at the even wider implications of a product and tries to include those intangiable items that do not reflect direct expenditure or revenue but which, nevertheless, affect value. It is particularly suitable to the evaluation of public projects where cost is not a principal criteria of acceptability.

Cost-benefit analysis is therefore defined as an estimation and evaluation of net benefits associated with alternatives for achieving defined public goals. A cost-effectiveness analysis is considered to be a special form or subset distinguished by the difficulty with which public benefits can be identified in terms of dollars.

Purpose. Public spending is becoming increasingly important around the world. Furthermore, as resource scarcity becomes more severe every year, all governments are compelled to make intelligent choices in the projects they wish to undertake. From a large number of competing projects only a few can be chosen for implementation. As public projects are commonly large scale in nature and frequently have irreversible consequences the need for careful analysis is apparent.

Usefulness. Cost-benefit analysis is a generic term embracing a wide range of evaluative procedures which lead to a statement assessing costs and benefits relevant to project alternatives. The variety of problems addressed and the ingenuity which must be exercised in estimating costs and benefits make it particularly difficult, if not impossible, to design an all-purpose procedure.

Cost-benefit analysis uses a decision criterion identified as the Potential Pareto Superiority criterion which labels a project as superior if those who gain from the project could compensate those who lose so that as a final result none would be worse off. This criterion identifies net benefits to whomsoever they might accrue and forms the basis for a more detailed review of design criteria.

Example of Project Cost Control--National Public Works Conference Cost Planning Procedures

General

A discussion of the traditional methods of project cost control would not be complete without reference to the guidelines set out in the National Public Works Conference (N.P.W.C.) "Cost Control Manual" (1980 Edition). This document attempts to unify and improve pre-existing cost planning activities in Australia by standardisation of procedures, elemental building components and methods of presentation.

Probably the greatest disadvantage of the early Australian cost planning practice was the lack of consistency resulting from the number of variations in approach that existed. Almost every major user of cost planning techniques had a unique version of the "standard" Australian cost planning form, which had been stylised to satisfy some particular requirement of their practice.

The guidelines have been adopted by government departments involved in housing, education and public building and by many private practitioners, and as a consequence are seen as a basis for future development work. Furthermore, the National Public Works Conference cost planning procedures are used here as an example for two reasons. First, they contain a large quantity of theoretical information that is particularly useful to cost planning activities. Second, their applicability to future development work requires investigation at this stage to ensure that they are fundamentally suitable.

The introductory remarks to the Cost Control Manual (hereinafter referred to as "the Manual") state the reasons for the development and implementation of a standardised cost planning system:

> The Manual represents a highly successful effort in co-ordination between the disciplines engaged in both public and private sectors of the building and construction industry. In particular, it demonstrates the sort of thing which government alone can do to develop with its resources the total sharing of results to the benefit of the whole industry, and it is for its achievement within this philosophy that the greatest emphasis should be placed on it as a comprehensive set of standards in Cost Control.

The scope of the Manual covers aspects of cost control ranging from receipt of the brief to completion of actual construction as denoted by the following stages:

1. Cost Control Stage A (brief)
2. Cost Control Stage B (outline proposals)
3. Cost Control Stage C (sketch design)
4. Cost Control Stage D (documentation)
5. Cost Control Stage E (tender)
6. Cost Control Stage F (construction)

Stages A to E inclusive are grouped under the heading of pre-construction cost control while Stage F is classified as construction cost control. In agreement with the intended scope for this thesis only Stages A to D inclusive are of further interest. They comprise two main control processes identified in the Manual as: (1) cost budgeting and (2) cost planning, although the former is in reality a division of the latter by definition.

Cost Budgeting

The purpose of cost budgeting is to establish the sum of money within which it is expected that the project will be later cost planned. The budget amount is based on historical information obtained from similar type projects adjusted for time, locality and specific factors. Subsequent design must initiate and develop a scheme that does not exceed this budgeted cost.

The project design team are normally responsible for establishing an initial budget at the brief stage (Cost Control Stage A) and a final budget at the sketch design stage (Cost Control Stage C). An interim budget may be required in certain circumstances at the outline proposals stage (Cost Control Stage B) and shall take a similar form to that of the initial budget. Tables 5 and 6 are examples given in the Manual illustrating the content of each budget type.

The initial budget is based on functional areas, units and rates with additional allowances for circulation space all escalated to the required date. Project specifics including site works are separately costed and when added to the former and adjusted for locality provide the nett project cost. Contract contingencies, rise and fall, fees and loose furniture and equipment are thence included to arrive at the gross amount for the budget.

The final budget is similarly calculated except that instead of using area information from previous projects they are obtained from measurement of sketch design drawings. If the functional areas have maximum prescribed limits it is the responsibility of the final budget to ensure that these limits are not exceeded. Cost planning processes used before preparation of this budget

TABLE 5

ILLUSTRATION: BLACK TOP T.A.F.E. COLLEGE
INITIAL BUDGET--COST CONTROL STAGE A

Accomodation Areas (including circulation)
(for 300 Effective Full Time [E.F.T.] pupils)

Areas	Pupils	m2/pupil	m2	Rate	Cost
L.R.C.	80	0.68	54.4	$480	$26,112
Amenities	300	0.44	132.0	540	71,280
Cafeteria	300	0.46	138.0	601	82,938
Staff/Office	300	0.82	246.0	440	108,240
Lecture Rooms	50	2.88	144.0	450	64,800
Laboratories	50	16.41	820.5	540	443,070
Services/Stores	300	0.24	72.0	505	36,360
Toilets	300	0.35	105.0	795	83,475
					916,275
Travel/Engineering Areas					
Travel/Engineering	300	2.06	618.0	329	203,322
Lifts					nil
Ancillary Buildings					nil
Centralised Energy					nil
					1,119,597
Time Adjustment					
Base Date (1/12/79) - B.P.I. 134.0					
Current Date (24/9/80) - B.P.I. 145.0 Increase 8.2%					91,807
					1,211,404
Project Specifics					
Alterations					nil
Site Works and External Services - 7.5% of $1,211,404					90,855
Special Factors:					
Site Conditions					nil
Climatic Conditions					nil
Excessive Height					nil
Non-standard Contract Procedures					nil
Temporary Work					nil
					1,302,259
Locality Adjustment					
Locality Index - 105 5% of $1,302,259					65,113
					1,367,372
Special Provisions					
Contract Contingencies - 2.5% of $1,367,372 Allow:					35,000
Rise and Fall					nil
Fees					140,000
Loose Furniture and Equipment					80,000
Brief Stage Cost/Initial Budget					$1,622,372

TABLE 6

ILLUSTRATION: BLACK TOP T.A.F.E. COLLEGE
FINAL BUDGET--COST CONTROL STAGE C

Accomodation Areas (including circulation)
(measured from sketch plan TC-01)

Areas	m2	Rate	Cost
L.R.C.	52	$480	$24,960
Amenities	133	540	71,820
Cafeteria	130	601	78,130
Staff/Office	260	440	114,400
Lecture Rooms	144	450	64,800
Laboratories	810	540	437,400
Services/Stores	76	505	38,380
Toilets	115	795	91,425
			921,315
Travel/Engineering Areas			
Travel (A1)	357	310	110,670
Travel (A2)	175	210	36,750
Engineering (E1)	105	348	36,540
Lifts			nil
Ancillary Buildings			nil
Centralised Energy			nil
			1,105,275

Time Adjustment

Base Date (1/12/79)	- B.P.I. 134.0		
Current Date (24/9/80)	- B.P.I. 145.0	Increase 8.2%	90,632
			1,195,907

Project Specifics

Alterations			nil
Site Works and External Services:			
XP	Site Preparation	$18,500	
XR	Roads, Footpaths and Paved Areas	26,300	
XK	External Stormwater Drainage	14,900	
XD	External Sewer Drainage	17,300	
XW	External Water Supply	5,400	
XG	External Gas	4,900	
XE	External Electric Light and Power	18,500	105,800
Special Factors:			
	Site Conditions - extra footings		15,000
	Climatic Conditions		nil
	Excessive Height		nil
	Non-standard Contract Procedures		nil
Temporary Work			nil
		C/F	1,316,707

TABLE 6 - Continued

		B/F	1,316,707
Locality Adjustment			
Locality Index - 105	5% of $1,316,707		65,835
			1,382,542
Special Provisions			
Contract Contingencies	- 2.5% of $1,382,542	Allow:	35,000
Rise and Fall			nil
Fees			140,000
Loose Furniture and Equipment			80,000
Brief Stage Cost/Initial Budget			$1,637,542

are primarily aimed at cost optimisation while those used after are primarily aimed at cost control.

Once established, the final budget should not be exceeded except for major changes in design instructed by the client or changes in building price indices if permitted by the client's budgeting requirements. In the event of the budget being exceeded the project team must be informed immediately so that remedial action can be taken.

Functional analysis is the method of estimation utilised in the previous examples of initial and final budgets. The development of functional unit costs involves the collection of the various functional area cost allowances for a particular building type and the determination of a rate per functional unit. The functional unit must be of uniform number throughout the building and the facilities must be equally shared for this procedure to apply.

Development of functional unit costs is highly successful in establishing budgets for schools, hospital wards, car parks and the like but becomes ponderous when the various functions within a building are not uniformly used or where there is little interaction between one activity and another. By clearly defining the various space requirements of a building and the costs of same it provides greater flexibility and accuracy to cost budget procedures and identifies those functional areas of different quality and thereby cost.

Cost Planning

Cost planning activities function between outline proposals stage (Cost Control Stage B) and documentation stage (Cost Control Stage D) inclusive. The purpose is to initially obtain a scheme that provides value for money to the client and then to ensure that such scheme does not exceed the prepared budget. The following documents are prepared as a result of cost planning activities:

1. Outline proposal cost statement (Stage B)
2. Sketch design cost plan (Stage C)
3. Tender document cost plan (Stage D)

An interim cost plan is to be prepared after the sketch design cost plan if the design has been significantly altered to conform with the final budget.

After the initial budget has been finalised cost control based on outline proposals is implemented. The purpose of this stage is to isolate the best means of satisfying the requirements of the brief; the resultant scheme becoming the basis for the sketch design. This involves establishing comparative costs for several outline proposals in relation to size and type until the most effective solution is found. A statement of the investigation's results is then provided.

Cost control based on sketch design is required to ensure that the overall design is the most effective available in terms of the approved requirements, to confirm the final budget and to establish elemental cost targets. The method involves providing alternative estimates for different construction methods, materials, engineering systems, etc., during sketch design development. The sketch design cost plan is prepared and presented on at least an elemental basis with specific construction, finishes and services stated; elemental unit rates and quantities are required to be shown.

The final cost planning stage is undertaken during documentation and has the purpose of ensuring that the overall detailed design is contained within the final budget. Cost checks are provided during development to effectively monitor the cost. This is a continuous process which includes comparative cost studies, research and advice on the economic effect of proposed modifications including the use of alternative finishes and methods of construction, and preparation and submission of cost statements presented elementally on at least a monthly basis.

The tender document cost plan is prepared on a sub-elemental basis incorporating all changes made as a result of cost checks during development; sub-elemental unit rates and quantities are required to be shown. The cost plan is to be accompanied by a reconciliation statement comparing individual element totals, areas, etc., with those in the sketch design cost plan or interim cost plan as appropriate--all differences are to be fully reconciled.

Cost plans are required to be presented on standard forms--copies of which may be reproduced from the samples contained in the Manual. It is not the intention here to discuss the details of cost plan preparation nor to explain the numerous standard terms employed therein. Reference should be made to the appropriate sections of the Manual for more information on these topics. Further explanation of elements, sub-elements and their role in cost planning activities, however, is a worthwhile inclusion at this juncture.

Elements and Sub-elements

An element is a portion of a project which fulfils a particular physical purpose irrespective of construction and/or specification. A sub-element is defined as part of an element which is physically and dimensionally independent and separate in monetary terms. The Manual lists forty-seven elements (see table 1) and over nine hundred sub-elements for use in cost analysis activities for all types of buildings.

Cost plans are summarised by displaying the total elemental costs, elemental quantities, unit rates, percentages of the building cost and costs per square metre for the project and/or for each identifiable subdivision. The allowance for preliminaries costs, overheads, profit and the like are not separately identified in the cost plan. They are usually spread by a fixed percentage over the appropriate elements to which they pertain. The distribution of preliminaries costs in this manner alters elemental cost trends that render almost useless the detailed comparison of government projects with those of the private sector[1]. An example illustrating the content of a typical summary sheet is given in table 7.

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[1]Mooney, Cost Effective Building Design, p. 44.

TABLE 7

SAMPLE ELEMENTAL SUMMARY SHEET: MANNING GARDENS PUBLIC SCHOOL--TENDER DOCUMENT COST PLAN

Function	Cost Weighting	$/m2	Cost
FECA Rate/Cost	100.00	515.48	1768088
UCA Rate/Cost	40.00	206.19	209078
Building Rate/Cost	-	444.90	1977166
Nett Project Rate/Cost	-	583.53	2593190

Code	Element Group	BC %	$/m2	Cost
00	Preliminaries	-	-	-
01	Substructure	9.52	42.34	188169
02-11	Superstructure	48.65	216.44	961850
12-14	Finishes	18.20	81.00	359935
15-16	Fittings	8.14	36.19	160865
17-29	Services	15.49	68.93	306347
	BUILDING COST (BC)	100.00	444.90	1977166
30	Centralised Energy Systems	-	-	-
31	Alterations	-	-	-
32-36	Site Works	-	-	372566
37-44	External Services	-	-	243458
45	External Alterations	-	-	-
	NETT PROJECT COST (NPC)	-	583.53	2593190
46	Special Provisions	-	-	100932
	GROSS PROJECT COST (GPC)	-	606.24	2694122

Code	Element	BC %	$/m2	Quantity	Unit Rate	Cost
01 SB	SUBSTRUCTURE	9.52	42.34	4700 m2	40.04	188169

TABLE 7 - Continued

Code	Element	BC %	$/m2	Quantity	Unit Rate	Cost
	SUPERSTRUCTURE					
02 CL	Columns	1.58	7.02	4792 m2	6.51	31185
03 UF	Upper Floors	0.11	0.49	24 m2	91.13	2187
04 SC	Staircases	0.08	0.37	4 m2	406.00	1624
05 RF	Roof	19.15	85.18	5019 m2	75.42	378554
06 EW	External Walls	7.69	34.19	2148 m2	70.74	151959
07 WW	Windows	8.31	36.99	485 m2	338.93	164381
08 ED	External Doors	4.61	20.53	338 m2	269.93	91237
09 NW	Internal Walls	1.75	7.78	2278 m2	15.17	34557
10 NS	Internal Screens & Borrowed Lights	1.85	8.25	203 m2	180.54	36650
11 ND	Internal Doors	3.52	15.64	403 m2	172.50	69516
	SUPERSTRUCTURE	48.65	216.44	-	-	961850
	FINISHES					
12 WF	Wall Finishes	6.08	27.07	6350 m2	18.94	120291
13 FF	Floor Finishes	7.10	31.58	4700 m2	29.86	140341
14 CF	Ceiling Finishes	5.02	22.35	5001 m2	19.86	99303
	FINISHES	18.20	81.00	-	-	359935
	FITTINGS					
15 FT	Fitments	6.75	29.99	-	-	133290
16 SE	Special Equipment	1.39	6.20	-	-	27575
	FITTINGS	8.14	36.19	-	-	160865
	SERVICES					
17 SF	Sanitary Fixtures	1.74	7.73	159 No	216.07	34355
18 PD	Sanitary Plumbing	1.48	6.58	427 Fu	68.49	29246
19 WS	Water Supply	1.30	5.79	3430 m2	7.50	25724
20 GS	Gas Service	-	-	-	-	-
21 SH	Space Heating	1.93	8.58	3430 m2	11.19	38137
22 VE	Ventilation	0.24	1.07	3430 m2	1.38	4750
23 EC	Evapor. Cooling	-	-	-	-	-
24 AC	Air Conditioning	0.61	2.72	3430 m2	3.53	12100
25 FP	Fire Protection	0.40	1.78	3430 m2	2.31	7921
26 LP	Electric Light & Power	7.02	31.25	3430 m2	40.49	138890
27 CM	Communications	0.49	2.19	3430 m2	2.83	9724
28 TS	Trans. Systems	-	-	-	-	-
29 SS	Special Services	0.28	1.24	-	-	5500
	SERVICES	15.49	68.93	-	-	306347

Conclusions

The National Public Works Conference cost control guidelines are obviously well suited--in fact intended--for use with the designing to a cost philosophy. It is during the outline proposals stage (Cost Control Stage B) that such techniques and associated disciplines as cost modelling, life cycle costing, value analysis and cost-benefit analysis could be utilised to obtain an optimum scheme prior to commencement of documentation. The major reason for failure to implement an initial optimisation programme is insufficient time.

Mooney[1] advocates that cost planning is not assisted by fragmentation but rather is likely to be assisted by reducing the number of areas that require detailed consideration. He continues[2] by suggesting that the reason for lack of progress in using the designing to a cost approach is the multiplicity of factors which must be investigated under the current understanding of this technique. Architects and cost planners hesitate to involve themselves in a process which, whilst formulated to achieve the most economical design solution, may in practice also require a great deal of time and co-operation.

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[1]Mooney, Cost Effective Building Design, p. 42.

[2]Ibid.

The forty-seven standard elements developed by the National Public Works Conference are considered a highly useful cost planning aid, but the large quantity of sub-elements have no real benefit. The apparent purpose of the latter is to obtain a breakdown of items which could then assist in pricing future cost plans or for estimating exercises based on quantities. The introductory remarks to the Manual reveal that the system has been structured to suit computer use:

> The steps set out in the Manual have been developed with the intention that a comprehensive store of information which can be retrieved in a variety of forms will be eventually computer based. This will not detract from any procedure when it may be used manually and it is with this flexibility in mind that the whole of the Manual has been developed.

Coded bills of quantities[1] are seen as the source of elemental and sub-elemental unit costs.

Mooney[2] argues that controlling the target cost is more important to government departments that obtaining the most economic design solution. This does not mean that value for money has no relevance, rather having determined a budget for a project the most important facet remaining is to ensure that the target cost is not exceeded.

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[1]Bills of quantities for government projects are usually coded, which means that the element codes are placed in brackets after the item descriptions to which they apply. The element codes may also be "split".

[2]Mooney, Cost Effective Building Design, p. 48.

The necessity to test a large number of combinations in order to achieve the optimum economic solution presents such a formidable and time-consuming task that most cost planners avoid designing to a cost in favour of the easier costing a design method[1]. The need to obtain an optimum scheme before sketch plan preparation is not in contention. It is concluded, therefore, that improvement of traditional methods of project cost control rest upon an easily worked and less time-consuming approach to the designing to a cost philosophy which allows an architect to involve himself together with the project team in developing economic designs.

The answer can now be clearly seen. First, either the number of areas that require detailed analysis are decreased or the speed with which such an analysis is undertaken increased. The latter is considered more suitable. Second, co-operation between architectural, engineering and economic disciplines needs to be encouraged. This is primarily a function of time and information sharing. Hence an interactive computer-guided cost planning system based on the designing to a cost philosophy and utilising existing element divisions, definitions and procedures is recommended as the most viable direction for further study.

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[1]Ibid.

CHAPTER III

COMPUTER STORAGE AND GUIDANCE SYSTEMS

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COMPUTER STORAGE AND GUIDANCE SYSTEMS

Background

Definitions

Computer storage and guidance systems are considered to constitute the leading edge of present cost control practice. Brandon[1] states that there is a wide body of opinion, even found among the research funding groups, that we should be working at the leading edge of current practice. This is understandable as it simplifies the objectives of a research exercise and more importantly avoids the gulf arising between practice and research that experience has proven as a major obstruction to future development. This chapter is designed to summarise and critically analyse computer storage and guidance systems to supply insight into the status of leading edge technology.

Before continuing further it is necessary to define what is meant by storage and guidance. A storage system

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[1] P.S. Brandon ed., Building Cost Techniques: New Directions, (London: E. & F.N. Spon Ltd., 1982), p. 6.

is held to describe a set of procedures that facilitates acceptance, retention and manipulation of data and enables production of accurate reports. It may also assist the automatic collection of information designed for use as feedback in subsequent activities. A guidance system ideally should contain the above plus have the capability to generate data and supervise decisions that will eventually lead to the achievement of an optimal solution.

Storage systems can be equated with the costing a design philosophy described in Chapter II. They are useful in controlling the costs of a developing design and identifying the cost significant items contained therein. They can simplify traditional activities, increase accuracy and provide a more efficient method of quantitatively assessing design decisions. They suffer, however, from the inherent problem that the costing a design philosophy does not significantly assist optimisation and hence cannot possibly provide the best value for money to the client.

Guidance systems function on both costing a design and designing to a cost philosophies. They employ techniques and associated disciplines such as cost modelling, life cycle costing, value analysis and/or cost-benefit analysis to compare alternative solutions and assess the optimal scheme. Hence they contain all the advantages of storage systems but eliminate the main disadvantage. The ability of the computer is harnessed not only to assist manipulation of data and improve accuracy but also to overcome the problems currently imposed by insufficient time.

Computerisation

Computers are often considered as encompassing a revolution in modern technology. This notion can be easily justified by the significant impact that computerisation has generated on everyday life. The advent of the micro-computer[1] carries with it even greater revolutionary power because its low price allows it to be utilised in situations where a larger computer system is uneconomical. As new and important technological innovations are released certain areas of the community maintain their resistance to the effects of change. The construction industry is traditionally one such area and since project cost control is a subset of this industry it too must suffer a similar handicap.

As with past innovations not all businesses will accept computers at the same time and with the same degree of enthusiasm. There are advantages and disadvantages in being among the first to innovate--invariably many have

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[1] A micro-computer is a small, accessible and relatively powerful collection of hardware that is inexpensive to purchase and operate but which offers substantial flexibility in a wide range of activities. It differs from main-frame computers (larger installations) in all of the above categories.

learnt and will continue to learn from the mistakes of a few. But there have always been disadvantages in resisting change completely and being left behind by the initiative of market competitors. Although the price of computers is falling when compared against performance, postponing a decision on their introduction may also be postponing the benefits that are now possible. Gaining experience about the full capabilities of a particular system is also essential to developmental progression.

Another argument in favour of the use of computers relates to the dramatic changes that have taken place in the construction industry since World War II. These changes are expressed in, amongst other things, a proliferation of building materials and increases in the size and complexity of buildings. The professions have not changed accordingly and have lagged behind the actual problems that they are required to deal with. Even if computers are not seen as a leap into the future they surely must be recognised as a means of catching up with reality.

There are many benefits that can be achieved through the introduction of computers. These include reducing production costs, better management and increasing speed and quality of service to the client. Potential reduction in production costs infers undertaking more work more quickly and with less auxiliary labour, thus lowering costs of running the business while increasing capacity for further work. It must be borne in mind that efficiency helps protect against other organisations which may attempt to offer an alternative service. Better management information helps identify what type of a job makes a profit and what type makes a loss. Speed and quality of service to the client can be achieved through avoiding large quantities of calculations, streamlining associated tasks, providing more useful information and examining a greater variety of alternative solutions.

Micro-computers offer the means for achievement of the above benefits provided that the tasks envisaged do not exceed their capabilities. Micro-computers are more accessible than large computers and are easier to learn and use. Those that are dedicated to a single operator respond more quickly than a large computer shared between numerous users. The most significant advantage is the relatively low purchase price, and although the cost of hardware is usually only a fraction of the total installation in real terms, it often forms the most identifiable outlay of capital.

Certain conditions need to be present for the achievement of benefits. Computers should be introduced, but introduced wisely and not hastily. The guidance offered should be followed and if necessary specialist advice should be sort. Haphazard introduction, perhaps based on the wrong motives, may produce benefits fortuitously, but it is more likely to result in monetary losses and disenchantment. Co-operation with others to lower the cost of making computers work should be pursued, including software development and sharing of valuable information which is costly to repetitively produce. When confidence exists between the business and the computer consideration may then be given to the initiation of bold and innovative ideas. Finally, computer scientists will not solve cost planning problems--cost planners will. Encouragement of the young who are most willing to include computers as part of their career is highly worthwhile.

Resistance to change must itself be resisted, for if businesses within the industry do not accept the new tools they will become vulnerable and inflexible relative to market competitors. Computerisation can lead to the removal of much of the drudgery associated with normal cost planning procedures and hence reductions in overheads can result. Attention can be more freely directed towards the improvement and versatility of service to the client while still maintaining acceptable levels of profitability.

Present Computer-based Cost Control Systems

The availability of computers today has led to their increased involvement in various facets of the construction industry. Computers inherently possess the ability to store, manipulate and update numeric data quickly and easily. In addition they can undertake complex calculations in minimum time and with undeniable accuracy. It is understandable, therefore, why computers are seen as having a distinct application in cost control activities.

There is currently a handful of computer-based systems designed to assist cost control activities in the construction industry. All deal in differing specific areas of the total field and satisfy the objectives upon which they are based with varying degrees of success. The cost control systems that are involved within the time span known as the design stage of project development shall be the subject of the remainder of this chapter.

Computer-assisted Design Appraisal

General

The software which enables computer-assisted design appraisal to be undertaken is called GOAL (an acronym for General Outline Appraisal of Layouts). GOAL is an example of how the ability of the computer to rapidly evaluate design alternatives is being used to appreciably increase the scope of an iterative design method.

The programme represents over ten years of experience in computer-aided design by the research group ABACUS through funding by the Science and Engineering

Research Council. ABACUS is the Architectural and Building Aids Computer Unit of Strathclyde. GOAL is used in a number of commercial architectural and engineering practices and public bodies throughout the United Kingdom and Europe. Many schools of architecture are integrating the programme into sketch design projects and it is apparent that the basic concepts are well recognised.

Information about GOAL was largely obtained from an article written by Sidney Newton[1] of the University of Strathclyde.

Detailed Summary

Cost estimating within the design activity. The main function of a cost estimate is, usually, to predict and translate a cost expressed in terms of operations (being a piece of work that can be completed by a person without interruption from others) to a cost expressed in terms of an activity (being an expression of the building users' requirements from a given space). Thus, what is ostensibly a simple numeric process, is in reality a highly complex mechanism for communicating cost information between the disciplines of design and construction.

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[1] Brandon ed., Building Cost Techniques: New Directions, pp. 192-209.

At the most general level design is seen as making explicit proposals for how a change from some existing state to some future state might be achieved. All facets of design are thus related either to describing a state of the system or to the mode of its change. In the context of the built environment it must be recognised that any particular state of the system is merely a sub-system of society at large, and that any mode of change will therefore have social, political, economic and aesthetic implications.

The costing process within GOAL. The basic philosophy of GOAL is to assist the design process. The designer generates an initial hypothesis and feeds in into the computer. GOAL then models the scheme and predicts future reality in terms of cost and performance. The designer evaluates the cost/performance profile received, modifies the design hypothesis accordingly and updates the information stored in the computer. This cycle is repeated until the most desirable combination of results is achieved.

Prior to running the programme the user constructs a standard data file for the particular building type under investigation, assuming a file does not already exist. The standard file contains the relative properties of alternative functional, constructional and environmental choices and therefore acts as a palette from which the more project specific files may be created.

The geometry of a scheme is described as floor-by-floor sketch plans with each space uniquely identified by a series of co-ordinates in three-dimensional space and labelled in respect of its functional type. Each surface of the building can then be allocated a discrete construction type selected from the standard data file. Finally, the project environment is specified in relation to the site (location, exposure, etc.), the building (orientation, fuel type, etc.) and financial constraints (capital cost limit, running cost limit, etc.).

Several aspects of building performance can be evaluated from this information, including:

1. Area quantities
2. Energy performance
3. Functional (planning) performance
4. Energy regulation compliance
5. Cost performance

All performance calculations are based on well-established techniques. For example, cost performance is a simple simulation of the estimating process common in practice.

A variety of cost structures may be described by the user in the standard data file, but the general form is one of a number of cost groups, each cost group having a number of elements. Associated with each cost element in each cost group is:

1. An element type index which indicates if the element is non-constructional, a floor, wall, glazing or roof

2. A construction type number, which is an index to the construction of that type held in the standard data file

3. A unit cost of the element

4. A unit quantity code (several different quantities are allowed, providing a parameter more closely identifiable with the element function)

In each case the unit rate is inserted by the operator and updated by an index if necessary. The requisite quantity is then calculated and multiplied by the relevant unit rate to give an elemental cost breakdown.

The designer can easily and interactively modify the design data including, by graphical means, the geometry. A systematic-cycling process is employed to provide the designer with a wealth of explicit information which can then be used in comparative evaluations of the differing design solutions and alternatives in order to approach a more efficient concept.

Output functions. The computer can calculate such fundamental information as running costs, capital costs and life cycle costs for each particular concept. Each project specific file is capable of generating information that can be displayed to the designer.

The first file, project geometry, stores plans and facilitates their manipulation, produces axonometrics, sections and simple perspectives and calculates area quantities and activity performance. The second file, project construction, calculates construction quantities pertaining to the current scheme. The third file, project environment, generates wall loss/gain performance statistics, plant requirements, annual energy consumption, lighting requirements and compliance with insulation regulations.

Critique

The cost model in GOAL is just a straight-forward automation of accepted costing procedures, but its speed means that it does not interrupt the flow of the design process. It also links the user to a centralised data base, which reduces duplication of information by the various disciplines and helps to overcome the increasing bureaucracy of statutory requirements, company strategies, etc. To a limited extent the programme is able to assist in solution generation and presents information in a familiar and traditional form.

GOAL does not really attempt to optimise a proposed concept other than through direct comparison of each selected scheme. The process fundamentally guiding the course of development is trial and error. Although the information produced after appraisal of each hypothesis remains consistent and legitimately comparable, no indication is provided as to the optimum combination of interacting variables nor in which direction they may be found.

Single elemental unit rates are only valid for a range of solutions quite close to the original and misleading predictions may be made where the design solution is altered radically. The programme also fails to give any automatic indications, in explicit terms, as to how well a proposed solution compares to the population of previous similar projects. Design performance can only be judged as good or bad in relation to other projects. Perhaps more significantly, the costing mechanism employed is inflexible and unsuited to the wide variety of alternative design methods adopted in practice.

Finally, it is apparent that this particular costing technique is fundamentally incompatible with preferred techniques later in the design process. Design is a dynamic activity with decisions being made and subsequently changed. If a cost model is to mimic such a process it too must allow previous decisions to be reviewed.

The major disadvantage of the computer-assisted design appraisal package is that the flexibility of the designer is constrained. The simplistic plan layout capabilities of the programme limit the designer's imagination to a collection of regular-shaped boxes assembled together in a particular arrangement. However, there is still a significant advantage in storing a sketch design in the computer. The data base created can be accessed by any member of the project team for whatever their specific purpose may be and changes made by the designer are instantly transferable to these other disciplines.

Conclusions

GOAL is a computer guidance system directed primarily towards architectural needs and secondly towards facilitating reliable cost control activities. Its basis centres around computer-aided design (CAD) technology resulting in functional areas being created and manipulated on a video screen rather than conventional drawings. High speed plotters connected to the computer are capable of reproducing the drawings onto paper when required. The system, if coupled with a more dependable and flexible cost control package, would illustrate the philosophy of designing to a cost in its purest context.

From a design point of view, GOAL represents an innovative and useful appraisal package that assists development of a basic concept while simultaneously reducing time. From a cost planning point of view, GOAL represents an excellent attempt at creating a data base that can be used by all members of the project team but fails to provide a truly suitable cost control framework. More importantly, however, it employs no integrated value analysis process to assist the comparison of alternative solutions.

Computerised Cost Planning System for Schools in New South Wales

General

This cost control package is an example of a computer guidance system. It was developed by Craig Langston as an Elective Project submitted to Mr. D. Lenard and Dr. D.J. Ferry as part of the Quantity Surveying Degree Course at the New South Wales Institute of Technology.

The computer instructions and related commentary function on PDP-11 hardware and are written in BASIC[1]

[1] BASIC is a programming language developed at Dartmouth College that is based on commands written in English. It is interactive and easy to learn and use.

compatible with Digital BASIC-11/RT-11 V2 operating software. The programmes and commentary are currently available for purchase and are identified by the name COMPUTECH #2.

Detailed Summary

Overview. This system deals with computerised cost planning techniques for primary and secondary public schools in New South Wales. The scope is intended to cover all aspects of cost control from the time of conception (referred to as the pre-sketch plan stage) up to the conclusion of formal documentation (referred to as the elemental estimate/cost plan stage).

The calculating and manipulating ability of the computer is harnessed to undertake the selected estimate type for the purpose of reducing time and human error and allowing greater exploration of alternative design solutions. The consistency, reliability and predictability of generated costs, areas and the like are dependant upon further testing linked with experience and feedback, but the framework for a successful system is provided and can be later extended to include other building types. COMPUTECH #2 can best be described as a complex arrangement of computer instructions that enables subsequent simple operation and the production of understandable results.

The pre-sketch plan design stage estimate relies on stored factors, costs and standard relationships for calculation of all elemental components. The information required from the user of the system is kept to a minimum so that flexibility for future design changes is controlled but not infringed. The philosophy of designing to a cost is the basis of the initial estimate, which utilises the technique of cost modelling to discover the optimum set of constraint variables given the particular known factors pertaining to the project. Comparisons using plan shape and number of storeys as fundamental components are made to illustrate the impact of nominated variables and improve the intuition of the user. Upon finalisation of the scheme a budgetary control statement can be prepared for the resultant design concept.

The elemental estimate/cost plan design stage estimate operates on the costing a design philosophy and accepts information pertaining to costs and areas from the user and assembles same into a traditional cost plan format. Facilities are provided to make changes to the inserted information including an indication of performance applied to both subdivision and total project aggregates. At the conclusion of all adjustments (if any) a comparison can be initiated between this information and that generated during the pre-sketch plan stage to obtain feedback on the suitability of standard data.

Although the subject matter covers only a small percentage of the total range of building types to which cost planning activities may pertain, the framework created can easily be extended at the pre-sketch plan level to suit any other form of standardised construction or even non-standardised construction. The elemental estimate/cost plan stage has universal suitability to any classification selected and generates costs, areas, percentages and the like in accordance with the established N.P.W.C. elemental definitions and the accepted methods of display.

The system flowcharts assist in understanding the processes involved and the manner in which they interrelate. These are contained in Appendix I and Appendix II.

Intention. The primary intention has been to completely analyse the subject matter described above and obtain, through associated research and testing, a useful and workable cost planning device. The system has to comply with a wide range of constraints including computer limitations, time, flexibility and the difficulties associated with correct interpretation of user-dependent data. While compromises are always necessary, the programme structure has lost little in the way of efficiency and direction. In fact, the previous constraints have often resulted in the discovery of a more advantageous method of approach that has, in turn, led to further optimisation of the overall system.

Since only about twenty percent of costs can be influenced after sketch plan documentation has commenced, the initial estimate or feasibility study has more significance than merely providing an approximate budget figure. Obviously it is necessary to arrive at an optimum design solution prior to preparation of drawings if all of the project is to be subject to improvement. The factors pertaining to plan shape, number of storeys and level of complexity (as predominantly used in the pre-sketch plan stage) are fundamental in the achievement of this aim.

The procedures used are structured so that the contents of the proposed scheme are known and individually identifiable while still allowing flexibility for future modification and improvement. Hence through techniques such as sensitivity analysis (testing minor variations), comparisons and trial and error a list of constraint variables are compiled and used as primary ingredients of the developing design each time the system is activated.

Pre-sketch plan estimating. The pre-sketch plan estimating system is designed to allow the preparation of a budgetary control statement given the minimum of outside information and the absence of any formalised scheme. During this process a number of constraint variables are identified as interacting, under normal conditions, to produce the total project cost. The costs per square metre, percentages of building cost, etc., can be compared for each of the available options generally in conjunction with a range of plan shape indicators between one and fifteen and number of storeys between one and three.

A final list of constraint variables can be collected and via an "immediate mode"[1] facility peripheral changes to same can be undertaken and the results reviewed. When satisfied with the displayed cost data, the budgetary control statement, in the format of a traditional cost plan summary sheet, is provided.

The information required by the programme pertains to the following specific areas:

1. Building price index figure (integrated reference file supplied)
2. Market conditions factor
3. Type of school (primary or secondary)
4. Number of pupils
5. Percent UCA[2] to GFA[3]
6. Design complexity

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[1] Immediate mode is the term used by Digital to identify the condition of instantaneous communication.

[2] UCA stands for unenclosed covered area as defined by the N.P.W.C. Cost Control Manual.

[3] GFA stands for gross floor area as defined by the N.P.W.C. Cost Control Manual.

7. Site area
8. Site slope
9. Locality index[1]
10. Foundation type
11. Construction type
12. Ventilation type
13. Roof type
14. Standard/quality of finish
15. Extent of alterations

Of this data the number of pupils and the design complexity are fundamental in determining the FECA[2] for the project. With the exception of those questions requiring specific figures the user is faced with a multiple-choice situation often incorporating a guide relating to average or normal conditions.

The available output options can be instigated in any order or any number of times and can be summarised as follows:

1. Elemental breakdown of all elements "01 SB SUBSTRUCTURE" to "14 CF CEILING FINISHES" inclusive providing costs per square metre and building cost

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[1]Locality index is a value assigned to a particular geographic area to take account of additional cost of transportation and work allowances.

[2]FECA stands for fully enclosed covered area as defined by the N.P.W.C. Cost Control Manual.

percentages for varying plan shapes and number of storeys

2. Total project costs for varying plan shapes and number of storeys

3. Total costs per square metre for varying plan shapes and number of storeys

4. Elemental breakdown of "05 RF ROOF" element for each roof type for varying plan shapes and number of storeys

5. Total costs per square metre for each construction type for varying plan shapes and number of storeys

6. Graphs indicating relationship between costs and plan shape for varying vertical scales

7. Immediate mode facility

8. Budgetary control statement for specific plan shape and percentage of each storey height

9. Revision of selected constraint variables

The philosophy of designing to a cost is the basis of this initial estimate, which utilises recognised methods of optimisation to improve the efficiency of a building's design before valuable time and effort is lost documenting a scheme that is inherently cost expensive. A computer is employed to enable more thorough investigation and overcome the restrictions currently imposed by insufficient time.

Elemental estimate/cost plan preparation. Once the documentation stage has begun, procedures are necessary to control costs and predict more accurately the final tender amount. Whereas the pre-sketch plan estimate is designed to predict a "ball park" figure within ten percent up or down of the successful tenderer's price as well as setting the parameters for an efficient scheme, the elemental estimate/cost plan is designed to control the course of development being pursued and forecast the cost to within five percent up or down. The latter operates on the costing a design philosophy and is capable of providing cost information for numerous subdivisional components in addition to that of total aggregates.

The elemental estimate/cost plan programme accepts information pertaining to costs and areas from the user and assembles same into the traditional N.P.W.C. form of display. Standard item descriptions and related unit rates can be employed to arrive at elemental total costs or these can be inserted separately. Any unit rates incorporated in subsequent calculations are derived from either escalated base figures, those previously entered in another estimate or a figure deemed applicable by the user.

Preliminaries are automatically spread over all built-up elemental costs in accordance with the percentage inserted at the outset. Facilities are provided to make any imaginable change to the data initially entered including the display of progressive subdivision and total percentage savings or extras. The cost plan can be reproduced as many times as desired until satisfied with the overall result.

Feedback, experience and reliability. In order to fully understand the reliability of the two estimating systems, experience through exhaustive testing is vital. To assist in this endeavour the user can activate a comparison that lists side by side the pre-sketch plan data and the cost plan data (including the percentage difference and identification of cost significant items) for the following:

1. Total cost
2. Quantity
3. Unit rate
4. Building cost percentage
5. Cost per square metre (of GFA)

Apart from indicating the extent to which the initial estimate can forecast the actual figures, it acts as a good check on the distribution of cost in the project and operates as a safeguard against accidental errors.

It is important to understand that, although an example run and four case studies have all produced encouraging results at the pre-sketch plan stage, the only method of objectively determining suitability of the various stored factors, costs and assumptions is via further testing. It may be thought that the initial estimate is capable of handling only typical and conventional school designs, but in fact any non-standard component can be incorporated into the cost by using the user-interactive features provided.

Cost versus plan shape index. Feedback to date has led to the discovery of a standard relationship between cost and plan shape that does not include size or number of storeys as influencing variables. It can be shown that costs increase by 0.56 percent for increase of 1 (one) in plan shape index (the indicator used for determining the plan complexity of the building). Thus the total cost of the building can be given by the formula:

$$C = Z(0.0056(P-1)+1)$$

where:

- C = total cost or cost per square metre for the project
- P = proposed plan shape index
- Z = total cost or cost per square metre for the project assuming optimum plan shape (ie. P = 1)

Of course this does not help to forecast the total cost itself as the value of "Z" requires extensive calculations, but it does provide an easy method of analysing the impact of plan shape changes at an early stage in the design process.

Critique

<u>General</u>. It is reasonable to assume that any post-sketch plan estimate that can consistently approximate the future tender amount within a margin of five percent up or down is justifiably reliable. Most budgets are flexible by at least this percentage and it is consequently a simple matter in hindsight to make the requisite modest alterations to an estimate so that it is equal to the successful tender. Unfortunately cost planning activities must operate prior to this stage and hence cannot utilise the benefits of hindsight when formulating a project's total cost. It must be made quite clear that where an estimate, however prepared, forecasts the cost to within one or two percent under traditional competitive tendering conditions, then luck as well as skill has played a part in the result.

The procedures contained in the pre-sketch plan design stage estimate appear to be adequate for forecasting within the wide limits of market pricing; any attempt to get much closer in these conditions is unlikely to be worthwhile. The initial estimate must operate at a crude level because no formal idea has been documented on paper and hence no real measurement can take place.

The exercise thus has a good deal in common with weather forecasting. The quantity surveyor is able to draw on a considerable body of past experience and can consider present trends, but even with computer assistance he is in no position to guarantee the result. He will often be right, but if any unusual circumstances manifest themselves he can still be badly wrong. Increasing the certainty of forecasting the project cost to an acceptable and consistent level (ten percent up or down for pre-sketch plan estimates and five percent up or down for subsequent cost plans) is the purpose of this cost planning package.

The pre-sketch plan estimate, however, has a greater significance than merely predicting the total cost. It is a means whereby the user can experiment with different variables that have cost importance and obtain quickly the impact of any particular combination on the total scheme. The number of storeys and the plan shape index are fundamental to the derived cost, though often their presence is ignored when conducting a preliminary analysis. The information provided gives the user valuable assistance in making decisions that are later incorporated in the actual design. Hence the designing to a cost philosophy can prevail if a budget cost figure can be reliably prepared based on a known and identifiable set of constraints.

The subsequent elemental estimates and/or cost plans provide a check on the accuracy of the initial estimate as well as giving an indication of the designer's success in adhering to the optimum or selected scheme. The philosophy of costing a design is the primary operation here and has merit in that the developed scheme can be made increasingly efficient given the availability of more detailed information.

The two components described above are compatible and vital to the success of the overall system. Their influence gives access to the optimisation of nearly one hundred percent (depending on site constraints) of the project's total value and allows all cost savings to be incorporated in the actual design. The limitations normally imposed by insufficient time are dissipated since the computer undertakes all of the routine and time consuming activities without requiring the attention or presence of the user.

Advantages. It is difficult to summarise the advantages of the cost planning system as most aspects of its operation can be interpretted as beneficial. However the major attributes that come initially to mind include:

1. Reduction in time (exclusive of measurement operations)

2. Greater exploration of possible alternative design solutions

3. Consistency of presentation and procedures

4. Automatic preparation of historical records

5. Simplicity of making adjustments including provision of meaningful objective feedback

6. Component optimisation via comparisons between different constraint variables

7. Sensitivity analysis mechanisms (immediate mode)

8. Maintenance of designing to a cost philosophy

9. Simple operation having all complexity contained in the programme instructions only

10. Flexibility of the designer not infringed

11. Nearly one hundred percent of project cost subject to optimisation

12. Easily understandable results

13. Accessible building price index reference file

14. Speed and accuracy of calculation

15. Options available for output

16. Improvement of user intuition

17. Small capital cost associated with purchase of hardware and software

18. Reliability of produced results subject to certain limitations

19. Full accompanying documentation (integrated commentary)

20. Future extension for other building types using existing framework

21. Suitability of elemental estimate/cost plan stage to any building category

22. Structured estimating system using stored unit rates, descriptions, etc.

23. Differential adjustment of unit rates by trade classification

24. Logical classification of programme filenames

25. Ability of programmes to be modified by the user to suit future requirements

26. Portability of software system

27. Benefits associated with computer introduction and experience including staff training

These advantages can be summarised into three primary categories, namely: (1) time savings; (2) cost savings, and (3) greater service to the client in terms of more efficient cost control. The use of computers is fundamental in each and allows the cost planning activities to be undertaken easily, whereas normal procedures would preclude such investigation.

Disadvantages. Whilst the advantages are difficult to summarise because of their abundance, the disadvantages are equally troublesome because of their rarity. The list is hence short, but nevertheless includes the following:

1. Limitations imposed by use of standard factors, costs and assumptions, some of which are highly subjective

2. Finite list of available and traditional construction types

3. Inherent problems associated with simplification

4. Lack of sufficient testing and optimisation over time

5. Size of computer memory capacity for both operation and file storage space

6. Stored costs obtained from only eight averaged examples

7. Difficulties in assessing the level of design efficiency as depicted by the design complexity constraint variable

8. Finite list of standard item descriptions

9. Price dilution of costs over time and associated need for re-estimation

10. Applicability to specific building category of schools in New South Wales

11. Specialisation of programmes to a particular computer system only

Again, the disadvantages can be compiled into two main components, namely: (1) limitations inherent with pre-sketch plan analysis, and (2) specialisation. The disadvantages have been reduced as much as possible at the expense of an inordinate amount of time--further improvement can only be achieved by more of the same.

Limitations. While elemental cost planning has made an outstanding contribution to the study, forecasting and control of building costs, it nevertheless suffers from a number of basic limitations which have prevented its further development. Difficulties lie with the standard list of elements since it is not possible to compare the cost performance of the same element on two different buildings, nor within one element to compare two different technical solutions concerning one building. In order to attempt this task, as the quantity surveyor is often asked to do, it is necessary to consider all kinds of extraneous matters, some of which are difficult to quantify.

The use of complex computer programmes that enable exhaustive calculation concerning the impact of interacting variables helps to overcome the above difficulty provided the data used is accurate and relevant. The costs which are being manipulated may conceivably bear no relation to fact; they are thus not really data in any scientific sense. It is a waste of time and money to use sophisticated methods to manipulate inaccurate data, as incapsulated by the phrase "garbage in means garbage out". In essence such processing is worse than useless because the fact that sophisticated analysis methods have been employed leads to attach some importance to the results. The original data would be interpretted as unreliable if it were presented in its unprocessed form.

Notwithstanding the above, the whole system suffers because, under conventional tendering conditions, there is no contractual commitment to the cost plan. The quantity surveyor has no responsibility for the tender amounts and the contractor has no interest in the cost plan. The methods employed to predict project costs should be viewed as internal controls that greatly increase the likelihood of obtaining a cost efficient design.

More specifically, other limitations are present and manifest themselves in the form of authenticity and reliability of stored cost data, maximum area/block used, stated assumptions for calculation of elemental areas, adjustment factors, use of fixed traditional construction types, applicability of building price index figures, range of plan shape index and storey height used and the maximum size of files imposed by the BASIC operating system. In a sense they are disadvantages, but more accurately they are conditions to which the system must comply; the difference being that the above cannot be successfully obviated. Other constraints include the method of presentation of reports and the specialisation associated with the software construction in terms of compatible hardware.

Conclusions

This computerised cost planning package is a prime example of a computer guidance system. It offers considerable advantages over traditional procedures of project cost control by increasing investigative power and accuracy yet significantly reducing time.

An initial and/or final budget may each take two to three days to complete by hand. No attempt is made at optimising the scheme since the procedures used are designed merely to set a cost limit based on historical data. The computer can duplicate the process of preparing an initial and/or final budget (incorporating a higher degree of reliability and flexibility) in significantly less time--about four minutes. Obviously a large number of alternatives and combinations can be analysed during the same time span occupied by a traditional budget estimate. In addition to setting a realistic cost limit, the computer facilitates efficient pursuit of optimisation via a powerful cost modelling framework.

Reductions in time are not so dramatic during the preparation of elemental estimates or cost plans largely because quantities of building work need to be measured from the developing drawings before the computer can be introduced. However, the time occupied by calculating and sorting information is reduced from about two days for a large school to a matter of seconds and estimating quantities is made considerably easier. Changes that would normally involve significant time in recalculating percentages, unit rates, costs per square metre and total costs are undertaken by the computer instantly.

For the above reasons, together with the others previously highlighted in this discussion, it is concluded that COMPUTECH #2 typifies the manner in which traditional cost control procedures can be streamlined. The philosophy of designing to a cost is allowed to flourish since the package is activated prior to the preparation of any formalised scheme.

An Integrated Computer-based Cost Plan and Bill of Quantities System

General

Constructive Computer Servives of Melbourne, Australia, has developed an integrated cost planning and bill of quantities computer package that operates on numerous popular micro-computers including IBM. It was designed by Rodney Nagel, a quantity surveyor, to specifically meet the needs of the Q.S. profession, to produce cost plans and bills of quantities quickly and to use the least amount of manual labour. This package, although only a storage system by previous definition, has sold remarkably well. Current owners have assisted in the preparation of this appraisal by highlighting the specific advantages and disadvantages so far discovered.

There are several computer storage systems directed at cost planning activities, but since they are generally similar in structure and operation they will not be separately identified. In addition, Rider Hunt & Partners, an Australian quantity surveying firm, has developed a highly sophisticated bill of quantities computer system called RIPAC that is without doubt the best in the world. They also wish to develop an integrated cost planning package but at present have not commenced its preparation. It is expected, however, that the likely product will be similar to the storage system described herein.

Detailed Summary

Cost planning package--COSTPACK. This package is a set of programmes combining the advantages of both word processing and electronic spreadsheets for producing cost plans and estimates. Basically information is entered much the same way as one writes it out on paper, the difference being it is typed onto a screen with all computations being carried out concurrently.

The screen display is configured into headed columns identified as follows:

1. Coding
2. Description
3. Unit

4. Quantity
5. Rate
6. Cost

The current element and project cost totals are permanently displayed in the bottom right-hand corner of the screen.

The description and unit rate are entered first. The dimensions are entered secondly, and as each is finalised it is displayed and extended by the computer and the running total is shown in the quantity column on the screen. If the rate has already been entered the running cost total is calculated and shown in the cost column. The new element and project costs are also updated and displayed as well as kept on file to be used later in a summary report.

Alterations to any quantity, rate or cost can be made at any time and the consequences of such action are displayed automatically and instantly. If an item's cost is changed and that item has a quantity, the rate is then recalculated and shown. As quantities and rates are systematically entered the corresponding running totals provide the estimator with a complete and up to date status on the formation of trends. For instance, it might become obvious as measurement proceeds that a quantity or cost is running too high or low.

Upon entering the last rate or dimension the estimate is complete. There is no need to have the information calculated, checked, compiled and typed as this is undertaken automatically by the computer. The estimate can hence be printed (once the gross floor area is entered) without determining the percentages of building cost, costs per square metre, unit rates, etc.

Various forms of presentation, each possessing different levels of information, can be requested. These include:

1. Summary only

2. Summary and: (a) elements with item costs only, (b) elements with unit, quantity, rate and costs only and (c) elements with everything printed including all dimensions

Previous estimates can also be reused, modified and reprinted with all extensions automatically recalculated simply by entering, changing, deleting and adding items or dimensions.

The impact of possible amendments can be explored by simply changing rates, quantities and descriptions until the desired mix of materials and workmanship and their impact on total cost are satisfactory. In addition, elements can be selectively updated by percentage increases or decreases. The operator simply types in a percentage (+/-) and the elements to which it applies. Naturally all elemental rates and totals are adjusted as well as the total project cost.

Bill of quantities package--BQPACK. The package is designed to be used by people with little knowledge of computers and software. The commands or prompts the programme generates total only seven, so staff training is kept to a minimum. The facilities embodied in BQPACK are:

1. Entering bill of quantities information
2. Checking and making alterations
3. Standard text
4. Printing bill of quantities
5. Tender estimates
6. Elemental bills of quantities

The only information that need be entered or checked is the description, unit, quantity and code (if required). The computer generates:

1. Page headings
2. Item numbering
3. Main heading continuations
4. Sub-heading continuations
5. Collection pages
6. Trade collection summaries

7. Page numbering

8. Formatting of code positioning, unit and quantity positioning and pagination

Any information can be altered at any time prior to final printing. It is at the final printing stage that the programme formats the information into its required layout.

References can be used to any other file containing information that can be used in the current project. An example of this facility is the reuse of standard specification clauses. This can be done by selecting either clause numbers or groups of lines from the applicable reference file. The need for the quantity surveyor and the typist to write or type repetitous material is eliminated. The programme searches the reference file and inserts the applicable lines into the final printing.

The bill of quantities can be printed in either a traditional format or a format whereby trade collections are generated at specific locations. This allows for requirements such as sectionalising the bill for progress claim evaluations and the like.

Tender estimates can be created by entering the rates for each item and reprinting. Rates from the builder's priced bill of quantities can be entered to arithmetically check cost extensions. When the bill of quantities is printed with rates included, all page totals, collections, etc. are calculated and displayed. In addition, items can be sorted according to elemental code and the totals applicable to each provided in a special summary.

Critique

From the viewpoint of a computer storage system, this integrated package has numerous advantages and exceptionally few identifiable disadvantages. In the wider context of guidance systems, however, it is obvious that this or any other storage system is virtually useless in assisting the approach of an optimum design solution. Since it is unfair to criticise a system for something that is undeniably beyond its scope of interest, the remainder of this section will deal specifically with matters relating to storage systems.

The major advantage is considered to be the manner in which information is manipulated and displayed. Speed, efficiency and ease of operation prevail throughout both COSTPACK and BQPACK components and all computer responses are "user-friendly". In particular, COSTPACK enables items of stored information to be changed simply by nominating the field in which they are contained (using keyboard arrows) and retyping the contents. All dependent calculations are instantly updated and the total project cost (displayed in the lower right-hand corner of the video screen) is altered to reflect the current condition.

Other advantages are more specific to the functioning of individual programme activities. Those that pertain to COSTPACK, the section which is more relevant to our investigation, are given below:

1. Entering dimensions of component quantities directly into the computer enables significant savings in time and improved accuracy to be achieved

2. Existing similar cost plans can be amended to form new documents in less time than that normally required

3. Instant assessment of cost and quantity totals is available

4. Flexibility of coding and printing activities enables a wide variety of special requirements to be fulfilled

5. Once the base information is inserted any component can be manipulated or modified using the editing commands

6. Integration with a bill of quantities system means that feedback can be assembled in elemental form using tender prices

7. The cost planning package is capable of

functioning as a bill of quantities system in its own right, subject to certain qualifications

8. Notes can be inserted to identify specific areas within dimensions

The disadvantages are trivial in comparison and are capable of being avoided as COSTPACK is further refined. They include:

1. Dimensions entered against items cannot be simultaneously examined to assist in measurement of subsequent related items without first obtaining a printed copy

2. Large descriptions are outlawed

3. The printed format does not strictly comply with standard N.P.W.C. setout and cannot be produced on cut sheets without an automatic paper feeder

4. COSTPACK cannot readily be used by unskilled staff (although BQPACK can)

5. Associated documentation is poor

Overall, the system is highly flexible and adaptable and has significant benefits to offer the quantity surveyor in order to improve profitability of cost plan preparation. The idea of an integrated bill of quantities and cost plan works exceptionally well.

Conclusions

In addition to the benefits previously described there is significant scope to add other packages to undertake related project control tasks. These include detailed comparison of a particular cost plan with previous projects, automatic storing of elemental costs per square metre for later use and post contract activities such as progress payment calculation.

Building Estimating and Costing System

General

A building estimating and costing system has been developed by an English company known as S D Micros Limited. The system has been designed to function on a number of popular personal micro-computers and is being marketed in several countries around the world. It has already sold well (over two hundred sold to date), especially among learning institutions such as colleges of further education and universities. The programmes that constitute this system are called ESTIMATE and COST PLAN/COST LIST. Together they represent an example of a computer guidance system.

Detailed Summary

Estimate system. The ESTIMATE package aims at assisting the preparation of building estimates at any stage during the design process. It has particular application at the feasibility or outline proposals stage when the design decisions possessing major cost effect are being made. Information required to carry out the estimate may be as brief or as detailed as the availability of data permits.

Elemental quantities for use in the estimate may be entered directly or generated by the computer from a mathematical cost model formulated for the building. If the latter alternative is selected certain items of data are required for calculations. They comprise:

1. Gross floor area
2. Number of storeys
3. Building envelope data including wall-to-floor ratio, shape index, width of building and floor-to-floor height
4. Window-to-wall ratio
5. Partition-to-floor ratio
6. Frame element area
7. Door-to-partition ratio
8. Floor finishes area
9. Ceiling finishes area

The programme displays default values against many of the questions and produces explanations on the screen about these values. It is also possible to request a simplistic graphical representation of the building shape.

It is the estimating of the elemental quantities where the greatest flexibility is offerred. The following methods are available:

1. The elemental unit rate is entered directly against each element

2. The elemental unit rate may be built up by pricing up to ten components within each element

3. A single grade between one and ten is selected for the whole building and the rate designated by that grade is applied to each element

4. Different grades are selected for each element rather than the whole building

5. A pre-selected pattern of grades relevant to a particular building type is applied to each element

6. A single rate cost analysis of a similar project is adjusted using historical information from "in house" sources or from a commercial cost service

7. A statistical analysis of all projects in the data bank (fifteen maximum allowed) is undertaken producing mean, trimmed mean, maximum, minimum and standard deviation for use in estimating calculated quantities

There are similar methods of rate selection for the mechanical and electrical elements with three addition facilities. An overall rate per square metre may be used, a lump sum or a lump sum using a pre-selected grade pattern.

The final stage before the estimate is produced allows the user to insert either lump sums or percentage adjustments for external works, contingencies, preliminaries and price and design risk. The estimate is then produced utilising a flexible building cost model with a full interactive adjustment facility. At every stage during production of estimates the user may adjust quantities, rates, lump sums or percentages to suit the identified requirements.

Once the user is satisfied with the compiled build-up for the estimate, data such as number of storeys, window-to-wall ratio, width of the building, etc., may be adjusted and the impact of those changes immediately seen. The number of options is infinite and, since the necessary financial and design restrictions can be collated before design commences, the saving in time, building cost and abortive design and costing work can be substantial.

Cost Plan/Cost List system. The COST PLAN and COST LIST programmes are designed to respectively undertake and present cost planning activities. They can be operated independently or in association with the ESTIMATE system and produce all information in a full elemental format.

The layout of the COST PLAN programme is such that all data held can be easily amended and improved as the design develops. The programme is structured to calculate and print data at three levels, namely:

1. Full cost plan format
2. Individual elements only
3. Unit rate build-up

Movement from level to level is automatic upon request from the user of the system.

The initial data used to produce the COST PLAN can be obtained from a data bank prepared by the ESTIMATE programme or may be entered directly. Information to produce cost checks on individual elements is assembled and stored in separate element data banks (maximum thirty allowed). The form of entry within these data banks can vary from items of description, quantity, unit and rate to notes with or without monetary values. Entries may also be treated as additions or omissions to previous data.

To assist in the preparation of elemental data a rate assistance routine can be activated which will permit the assembly of a rate from first principles using labour, material and plant base information. Revised cost plans and element data files may be later recalled from the data bank for alteration and improvement.

Special systems are provided in the programme for the block amendment of cost plan values. These comprise a routine to adjust for tender index movements which may affect the total cost and a system for revising the cost plan total to any desired figure. In this latter routine any or all of the unit rates can be reversed to meet the new figure entered.

COST LIST is used to undertake special formatting of data for purposes of presentation. The alternative printing layouts comprise:

1. Listing with quantities and/or rates rounded
2. Comparison between cost plan and latest cost check prepared
3. Comparison between cost plan and all cost checks on file
4. Composite presentation of two separate projects indicating total cost differences

A screen histogram display is provided to highlight element unit rates which appear high or low when compared to a pre-determined schedule of unit rates.

Critique

ESTIMATE and COST PLAN/COST LIST are collectively poor examples of a computer-based estimating and costing system for use in commercial situations. The reasons for this statement are essentially three-fold:

1. All computer-generated quantities are overly simplistic and do not accurately represent changes in building morphology

2. No investigative analysis takes place other than trial and error

3. All printed information is difficult to read and understand and lacks any form of flexibility

Technical knowledge is necessary to operate both ESTIMATE and COST PLAN/COST LIST, although the simplistic nature of the system is not difficult to learn. It is anticipated that this system has sold well to date primarily because of a lack of any real competition.

It is difficult to rationalise the list of data required by the ESTIMATE programme in order to calculate elemental quantities. Standard equations should be quite capable of arriving at floor and ceiling areas without having them entered directly. The width of the building is of no benefit to any configuration of plan shape other than square and/or rectangular designs and appears to have little practical use.

The ESTIMATE system makes no attempt to show the impact of lift services on alternative schemes. External works is essentially derived from a percentage of the total building cost and at no stage is the area of the site requested or incorporated in calculations for building height changes. Alterations to existing buildings are not specifically catered for where associated with new construction and such costs must be included as a lump sum under "abnormal work". Preliminaries and overheads cannot be automatically distributed over relevant elemental totals without inserting zero against this item and increasing all elemental unit rates manually.

The large number of estimating options still fail to guarantee production of an accurate end result due primarily to the large proportion of lump sums and percentages used. All options should ideally be integrated so that maximum flexibility is allowed. The type of detail chosen during estimating should at least be variable from item to item.

The major deficiency, however, is that no investigation at feasibility level is undertaken except through simplistic trial and error. At best the computer is used to indicate the effect of changes, but it is incapable of highlighting in which direction the optimum solution lies. Value for money is hence not likely to result.

COST PLAN/COST LIST suffers from poor formatting of information and the associated difficulties of effective communication. During cost plan preparation only the total project is considered since subdivisions are not allowed. At no stage is the content of the cost plan documented by descriptions of materials and construction methods other than of a rudimentary nature. Examination of summary sheets soon indicates that the elemental costs are not artificially adjusted in order to arrive at the correct overall total--hence column additions are usually incorrect.

Since the system was designed in Great Britain it has elemental subdivisions based on the B.C.I.S./R.I.C.S. "Standard Form of Cost Analysis". The usefulness of the ESTIMATE and COST PLAN/COST LIST systems in Australia has been effectively reduced by the N.P.W.C. guidelines now commonly employed in practice here.

Conclusions

This building estimating and costing system indicates how the advantages of a computer can be minimised substantially by poor design and over-simplification. The envisaged savings in time are obviated by the necessity to elaborate on all cost reports for the purposes of later submission. While the concept is theoretically sound, the practicalities of its use preclude the award of a favourable assessment.

Exploration and Strategic Cost Planning in Design

General

Peter Brandon is principal lecturer in design economics at Bristol Polytechnic and visiting fellow to the Welsh School of Architecture. The computer programme he developed, known as EXPLORA, arose from a project prepared as part of an MSc. submission to Bristol University that subsequently was awarded a commendation. The following discussion highlights the theories and practicalities of his research in the field of cost modelling, specifically in relation to this programme.

Detailed Summary

Approach. The approach taken by Brandon was to identify two basic stages prior to design which would allow determination of the parameters defining the design strategy. The first stage would be to analyse the brief in order to select the areas of cost exploration for various sets of elements of the building. A series of elemental cost models would be prepared which allow for the exploration of cost outside the context of a hypothesised design. From this cost exploration a base cost can be chosen and selected according to the design parameters identified by the design team.

The second stage is to adjust these base costs in a dynamic cost model according to the morphology of the building. A large number of hypothetical building solutions are postulated within the identified constraints and the base cost of each element is altered according to the effect of changes in building shape, height and location.

The building design problem is one of changing the environment. It is a complex problem involving choice from a considerable range of alternatives within a number of legal, geographical, financial and technical constraints. Some of the constraints are self evident such as planning restrictions, site boundaries and some legal impositions. In some projects the cost limit is clearly defined and may therefore form a neat boundary to the range of feasible solutions. In other cases the edge of the solution space is not so clear cut.

Obviously at the brief stage the data and state of knowledge concerning the building is usually limited and therefore the model must operate at a coarse level, but this should not hinder the comparison of cost relationships and the strategies determined from the results. In each elemental programme it should be possible to return and explore different configurations before a final choice is made. The results are then carried forward for use in the dynamic model.

The dynamic model. The object of the dynamic model is to explore costs for a given floor area according to changes in the morphology of a building. For this purpose it is necessary to find suitable descriptors for the building which would:

1. Allow flexibility for the designer when formulating the project scheme
2. Provide quantities for evaluation purposes within the dynamic model
3. Be simple and yet convey the essence of the strategy
4. Allow identification of the cost thresholds due to building form
5. Allow other constraints to be related to the descriptors for identification of the feasible solution space

The following parameters are identified by Brandon as being suitable descriptors of building form for use in the EXPLORA programme and compatible with elemental parameters:

1. The plan shape index whereby any plan shape of a building can be described by a rectangle having the same area and perimeter
2. The number of storeys
3. A boundary co-efficient which defines the

extent of the internal subdivision of floor area by expressing the perimeter of all rooms as a ratio with the gross floor area

4. The average storey height

5. The percentage of glazed area

6. A plan compactness parameter which is a function of the smallest circle in which the building plan can be enclosed

Programme operation. The design parameters need to be reduced to a space which can be explored and eventually mapped and contoured by a computer aided modular iteration process. Within the solution space will be the least cost solution which will form the point of reference for any alternative solution that may be postulated on grounds other than cost. It is then possible to assess value by comparison to this point.

Where the building consists of two or more readily identifiable shapes it is probably necessary to acknowledge this in the first stage of the strategic process and explore each building "block" in turn. This may also apply in buildings containing multiple functions requiring different quality standards.

Once the operator has fed into the computer each building form descriptor, the dynamic model calculates the cost of a series of buildings hypothesised by a modular search through the solution space defined by plan shape and number of storeys. Quantities for elemental total costs are computed for each configuration and costed according to the data provided by the elemental models bearing in mind the relevant cost thresholds.

The solution of least cost may occur, for example, at a plan shape of 1:1 and a height of six storeys in relation to the elemental and form parameters chosen. It is then possible to select any other configuration and identify the additional cost for the extra degree of external modelling to the building surface by the designer. The design team can assess from a graph of this nature whether it is worth the extra cost and make a decision accordingly.

Critique

Satisfaction of primary aim. It is a common problem in the cost control of building design that the professional team charged with the overall responsibility of providing value for money for the client find themselves with insufficient time to investigate the enormous number of potentially feasible solutions. The time constraint does not allow the design team to produce a series of hypotheses which can be tested in order that the best solution be chosen.

The design economist or quantity surveyor has a particular interest in the establishment of suitable cost constraints but he has a greater responsibility to the client and society to ensure that capital is spent in accordance with their objectives. New techniques are necessary for the design economist to provide positive cost advice which can form an integral aspect of the pre-design dialogue.

The system employed must overcome the problems of evaluation of a sketch design as advice of this nature is too late in the strategic thinking of the designer to be of more than limited use. By the time a sketch design is formulated the major decisions affecting management costs, structure, envelope and quality standard have been made and the ability to influence the remaining decisions is probably limited to twenty percent of the final cost. In life cycle cost terms the figure may be even higher.

The cost adviser must be aware of the boundaries posed by all constraints in order that he can contribute to a decision strategy that will fall within the range of feasible solutions and provide the best value for money. The aim is to provide sufficient information for intelligent decision making which will allow physical parameters to be identified that can be carried into the process of design thinking.

Limitations. At the present stage of development there is considerable work to create a useful range of elemental models, a suitable data base and a comprehensive dynamic model in which all cost thresholds are identified. Despite the fact that the approach has been developed in conjunction with architects, the model descriptors need testing in the field. This work will be undertaken with the co-operation of architectural students at local universities in the near future.

It is believed that a suitable framework has been created to explore and identify cost strategies for design. Further developments envisaged by Brandon include the provision of a cost-in-use map to be superimposed upon the initial cost contours to provide improved information and the plotting of elemental costs on graph plotters for clearer identification of changes in cost relationships. With the micro-computers now available it is possible to run models like EXPLORA and to use their potential to full advantage in providing suitable cost information for strategic cost planning.

Conclusions

Design cost modelling must surely be considered an exciting development. Not only does it offer the possibility of improved design solutions, but it also implies a crossing of the traditional professional boundaries. The latter improves communication exchange and hence must be to the benefit of the whole industry. Cost modelling is relatively new but would appear to possess the ability to improve early design decision making in a quantitative manner.

Cost modelling is complicated by the lack of techniques available for the incorporation of intangibles such as comfort or prestige that are often a major objective of any brief. It must be recognised that there will always be human and qualitative factors that will never lend themselves to measurement and functional representation. This does not negate cost modelling but it does demand insight on the part of its practitioners.

CHAPTER IV

FRAMEWORK FOR COMPLETE COMPUTER-GUIDED COST PLANNING PACKAGE

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Idea Development

The Problem Reiterated

The main difference between the designing to a cost and the costing a design philosophy is that the latter does not involve the appraisal of alternative solutions and hence makes no attempt at optimisation. The reason why it is used almost exclusively is not related to the merits of the respective philosophies but to several external factors.

The problem when analysed is a direct function of inherent time and cost constraints, thus rendering the implementation of a designing to a cost approach prohibitive. The alternative costing a design philosophy is utilised in lieu, but unfortunately fails to fulfil the overall objective of providing value for money. It is nevertheless beneficial in monitoring the project cost after formal documentation has commenced.

The lack of compatibility between pre-tender activities and those required during construction is also of concern. Coupled with the fact that present cost planning operations are not initiated until after sketch plan preparation, it is obvious that some reorganisation is required to the manner in which the building process is carried out.

In Chapter II the merits of both philosophies together with the cost planning tools and associated disciplines available for use were outlined. It was initially stated that the problem was not likely to be solved by revising traditional methods but rather through employment of time-minimisation tactics aimed at increasing investigative power at pre-design levels. With this in mind the course chosen necessitates computer assistance to succeed.

Chapter III hence dealt with assessments of existing computer-based systems currently available or under development in order to gain further experience in this area. All examples presented had direct impact on procedures likely to be incorporated in any devised framework aimed at actively solving the problem. The distinction drawn between storage and guidance systems was highlighted in the discussions of these respective examples and the latter was identified as suitable.

Actual problem solving has yet to commence, but the foundations upon which decisions can be made is now present. The objective of this chapter is to compile all available resources into a framework capable of eliminating the deficiencies identified to date while enabling both flexibility and practicability to flourish.

Suggested Solution

The intended strategy simply involves reducing time and related cost throughout the various project control processes. While the level of investigation needs to be dramatically increased to facilitate optimisation, present financial constraints imposed by business economics render this option unfeasible. The decision to adhere to traditional practice means that little improvement is possible without changing the manner in which existing activities are implemented.

Given that increased investigation is the key objective, redesigned implementation the key issue and time-minimisation the key strategy, it becomes clear that computer assistance is mandatory. Only the computer has the ability to repetitively analyse a wide range of alternatives with the efficiency and speed capable of improving profitability. The inherent accuracy and consistency produced by the computer is a welcomed advantage, but the maintenance of the designing to a cost philosophy through continual supervision and guidance is undeniably the major benefit.

The suggested solution is thus defined as the creation of requisite instructions for the purpose of enabling traditional procedures of project cost control to be integrated with the computer. The employment of current techniques is an indication of their suitability and relevance to any future cost planning direction.

The resulting computer guidance system shall pertain to any building type and shall operate between the stages of conception and tender. By making the system easy to use and understand it is hoped to encourage its use amongst architectural and building disciplines in addition to that of quantity surveying. This will constitute the first step in resurrecting the flow of information between members of the design team and will create a data base that has the potential to link actual construction with the design process.

System Identification

The envisaged computer guidance system shall take the form of a complex mathematical cost model that can be used to decrease current time expenditure and allow design and cost optimisation to be achieved simultaneously. The purpose of establishing the guidelines for an efficient model lie in the intention to use this framework to develop a commercially viable computer-based cost planning package suitable for the real world.

The system shall be identified by the acronym "COSTPLANNER"[1], derived as follows:

C omputer-aided
O ptimisation
S ystem using
T ime-minimisation
P rocedures of
L ogistical
A ppraisal and
N etworking to
N ecessitate
E fficient
R eporting

The terms used above help to reinforce the concepts of optimisation and time-minimisation which are intrinsic components of the devised system.

A Tentative Specification

Essential Elements

Before a detailed specification can be compiled for COSTPLANNER it is necessary to identify and discuss the essential elements to be included. The majority of elements were highlighted by the examination of existing computer storage and guidance systems, though others were derived from experience and intuition. Collectively they

[1] COSTPLANNER is a trade mark of Computerelation Pty. Limited.

will set the boundaries for the development of a framework capable of rectifying current deficiencies.

The general specification for the COSTPLANNER cost model may therefore be outlined as:

1. The mechanics of cost generation are to be "transparent" so that cost consequences can be traced through all inter-relationships

2. The user must be allowed to interogate the results in great detail

3. The model should facilitate a dynamic decision making process

4. The costing mechanism is to be highly flexible and adaptable to the most innovative design solution

5. Cost information is not to interrupt the "flow" of design

6. The model must link the user to a central data base

7. The model should relate a proposed design to previous comparable projects and indicate the variability of that relationship

8. Assistance is to be given in solution generation

9. Information is to be presented in a consistent and familiar form

10. The system must be easy to use and must significantly reduce time

11. Flexibility and practicability must be encouraged

12. Feedback to the data base is to be mandatory

13. Previous investigations must be able to be updated

14. Traditional methods of project cost control must be incorporated into the model

Cost has been classified as a poorly understood sub-system to design[1]. As such, existing cost models have been evaluated in relation to several guidelines which proposedly judge the potential of a costing system to meet the various requirements of the design activity. The failure of many diverse approaches to date suggests that cost output is constrained in some respect by the way in which costs are generated. An appraisal of the cost generation process indicates that:

1. The cost data produced is context dependent and inherently inaccurate

2. Cost relationships are never completely manifest but implicit in the process as a whole

The above then leads to the suggestion that cost models which assume absolute/static cost relationships are over-simplifying the problem. However, by progressively

[1] Brandon ed., Building Cost Techniques: New Directions, p. 203.

breaking down costs into smaller and smaller components the likelihood of significant error is minimised.

A Realistic Scenario

There are numerous applications in project cost control activities to which computer guidance systems offer potential improvement. It is impossible, however, to attempt to solve all current deficiencies with one homogeneous system. It is suggested that the three principle stages of design, tender and construction will form the basis of a computer guidance trilogy. Each will interlink and share a common data base but each will operate efficiently in its own right.

The tender stage will involve a flexible bill of quantities production system having a range of different printing layouts and code subdivisions. Amongst other things it will supply information obtained from an analysis of the successful tenderer's priced bill of quantities for each project. The construction stage will tackle progress claim valuation, variations, rise and fall calculations, cash flows and the preparation of informative reports. The design stage is the subject of this thesis and an explanation of its content follows.

In practice, design is divided into three fundamental activities. First, a concept is generated to satisfy the particular constraints set out in the client's brief. Second, sketch drawings translate that imaginary concept into a definitive scheme in order to facilitate interpretation by persons other than the designer. Third, drawings are gradually developed until the point is reached where they are suitable for tender and/or construction.

Any serious attempt at creating a useful system during the design stage of a building's life must include these three components. More importantly, however, information must be consistent between concept and tender and all costs used therein should be built-up in the same way. Theoretically a single idea should be progressively expanded to the point where all available detail is included.

The COSTPLANNER computer guidance system should be compatible with the specific needs of the industry. The majority of present cost planning activities are prepared in accordance with the N.P.W.C. guidelines and hence are composed of elemental and sub-elemental components. In addition, various types of reports are preferred and/or necessary either to suit different projects or different stages in the design process. Both of these requirements need to be fully supported.

A realistic scenario therefore demands multiple staging of estimates in varying levels of detail, future integration with related systems, N.P.W.C. guideline compatibility and versatile report preparation. The essential elements previously outlined need to be successfully merged into this overall concept. The manner in which this process is undertaken shall comprise the remainder of this chapter.

Selection of Computer Hardware and Software

Hardware

COSTPLANNER ideally needs to be designed for a small inexpensive personal computer attached to a letter quality printer and medium size storage facility. The choice of hardware should be based on the most popular brand available in Australia at the present time so that the likelihood of the computer being already present in the offices of potential users is maximised.

The IBM PC personal computer is suggested as the optimum choice. Although there are more efficient computers available, this one is the market leader and is compatible with a wide range of software in all aspects of business operation. It should be remembered that software written for the PC is usually upwardly compatible with future versions of hardware as technological improvements are introduced.

The computer must incorporate at least ten million bytes (10 mb) of permanent disk storage and at least one portable "floppy disk" drive. A single high resolution colour or monochrome video screen is desirable, but if necessary a number of terminals may be interlinked so that computing time is shared amongst different tasks. It is not likely that any advantage will be forthcoming from having two or more terminals operating on the same project at the same time, and hence this capability is not a specific consideration.

A fast yet high quality printer is obviously essential. It must be capable of accepting instructions from a word processor and must be capable of underlining. Continuous paper and cut sheets (with or without automatic feed) must also be accepted. Proportional spacing is a desirable function for preparation of letters and reports but is not mandatory for COSTPLANNER. An NEC type daisy wheel printer is recommended.

The cost of the complete hardware system is in the order of ten thousand dollars ($10,000 Aust). This does not constitute a big investment and when coupled with the benefits of having a word processing, filing and accounting system in the professional office will not form any disincentive to the introduction of computer guidance software.

<u>Software</u>

There are two types of software to be considered here. First, the operating system for an IBM PC can be either MS/Dos or CP/M. The former is more powerful and more common and is hence recommended for use. The final choice, however, will be a matter for a professional software consultant to determine. Second, the system software can be written in a number of high level languages including BASIC, Pascal, C, etc., but the most suitable one is known as D BASE III. All these languages represent extremely complex examples of programming technology capable of performing data management activities efficiently and economically.

The cost of progressing the software from the theory described herein to a functioning system is currently in the order of sixty thousand dollars ($60,000 Aust). However the likely cost of purchase is envisaged to be approximately two thousand five hundred dollars ($2,500 Aust) and would include a protected copy of the software system, full documentation and maintenance. COSTPLANNER would be marketed exclusive of cost information, thus enabling each user to assess costs individually and hence every system would be intrinsically different.

Costs are based on the best estimate possible at this stage. They have been included for no other reason than to illustrate the benefit of computer guidance technology in relation to expenditure. It is thus possible to show the relationship of purchase price to efficiency gains and hence provide the foundation for a case aimed at justifying computer implementation.

System Overview

Concept

Appendix III illustrates the devised flowchart for the computer guidance system COSTPLANNER. The individual programmes shall utilise combinations of wordprocessing, electronic spreadsheet and on-screen editing technology. Significant use is made of directional arrows on the computer keyboard to select options and move to various parts of the screen displays.

COSTPLANNER enables the designing to a cost philosophy to be integrated into the control system for every project. It is important to realise that the computer has the capability to generate a full elemental budget before any documentation has begun. Thorough investigative facilities enable influencing parameters to be identified and the optimum values calculated. Dynamic programming techniques are necessary to assemble all information in order that preparation of sketch plan drawings may be commenced.

A project envisaged to be single storey of a complex shape can be converted to multi-storey of a simple shape at command; ten separate blocks can be changed to three larger clusters with ease; the structure can be instantly altered from brickwork to concrete frame to steel frame and so on. Preliminaries percentage, locality index, market conditions, etc., can be modified at any time and all variances in cost are reflected in the current project value which is continually displayed. Value analysis, cost-benefit analysis and life cycle costing are all supported by COSTPLANNER.

The National Public Works Conference guidelines, definitions and elements are incorporated without modification in this cost planning system. Reports are prepared directly by the computer at various stages in the design process in standard N.P.W.C. format. Estimates can be converted instantly between elemental and sub-elemental levels and traditional trade subdivision.

Implementation

COSTPLANNER operates at three stages, or "modes". These are known as feasibility, sketch/interim design and tender document. Control can be switched at any time between these modes resulting in the production of estimates and reports at varying levels of detail. The modes are designed to equate with normal cost planning requirements during the development of a design concept.

No matter which mode is originally selected, insertion of specific base information is mandatory. This data is classified as "variables" and comprises the name of the project, location, date current, tender date, site area and number of identifiable blocks. Thence for each block it is necessary to nominate the duplication factor, fully enclosed covered area (FECA), unenclosed covered area (UCA), plan shape index, number of storeys above and below ground and boundary co-efficient. Naturally any inserted data can be changed at any time.

The feasibility mode is initiated before any sketch plans are commenced. Once the variables are entered it is possible for the computer to calculate all elemental quantities. This is undertaken using standard equations with reference to a set of assumptions classified as "constants". The latter comprise default values that are subject to modification as may be seen fit. Preliminaries costs are based on dual percentages for building work and services which may be spread over each element or shown separately.

Having calculated the elemental quantities it is necessary to place costs against them. At feasibility level this is undertaken by placing percentages and/or affirmative responses against standard construction types.

Costs updated from stored historical records are displayed against each construction type for approval. Total element and project costs are accumulated and displayed continually as the estimate progresses. This procedure is undertaken for each block or the total project if all blocks are of the same construction.

During the feasibility mode it is necessary to investigate alternative solutions for the purpose of identifying the optimum scheme. The topics available for investigation comprise plan shape (low rise buildings), number of storeys (high rise buildings), value analysis/cost-benefit analysis, life cycle costs, previous project comparison, reconciliation and cost check. Up to nine alternative schemes can be examined separately and later appraised to select the one which provides the best value for money. Investigations are not trial and error but are structured to identify the optimum parameters.

The sketch design mode (hereinafter held to include an interim design mode if applicable) when selected allows the estimate to be prepared in more detail. Computer-generated quantities are overlaid with actual measurements taken from sketch plan drawings. The estimate is undertaken at a level equivalent to sub-element classification using updated unit rates from previously stored historical records. Dimensions can be inserted into the computer for quantity calculations or total values may be entered directly.

The tender document mode when selected enables corresponding drawing detail to be incorporated into the estimate. Standard item descriptions are measured and priced in a similar manner to an abbreviated bill of quantities for each identified block. Whereas the feasibility and sketch design estimates can only be produced using two letter coding, this estimate allows either two or four letter generation or special codes upon command. It is also possible to measure a sketch design cost plan at this level and then revert back to a previous stage for presentation. Previous completed cost plans can be amended to further improve efficiency and reduce time.

A wide range of printing options is provided that conform to standard N.P.W.C. requirements. These include summary only, feasibility report, draft cost plan (showing all dimensions) and cost plans displaying either descriptions and quantities only, descriptions and costs only or descriptions, quantities and costs each in two or four letter or special code subdivision. All investigations and user selections can also be produced. The printed output is compiled into a fully paginated report suitable for immediate dispatch.

The main structural advantage of utilising the computer to prepare cost plans is the ease with which changes can be made. It is possible to change any information directly on the video screen, to reassess variables and constants and insert items not contained in standard description lists. All data is correctly calculated and the possibility of human error is confined only to user-dependent information. It is also important to note that feedback from each tender document cost plan is automatically stored at a sub-elemental level for future use in a sketch design cost plan.

Three policies are maintained throughout COSTPLANNER. First, all aspects of the system must allow flexibility and practicability to flourish and consequently the system is easy to use and understand. Second, information generated by the computer is progressively overriden as more detail becomes available, but it is never possible for the computer to substitute the original values back again. Third, default values are provided wherever appropriate and only affirmative responses need to be entered. The benefit of these policies assists the general strategy of time-minimisation.

It is suggested that the production of a detailed feasibility report is reduced for a medium-sized project from about three manweeks to one day. The results obtained from the computer are also more likely to be a true appraisal and are guaranteed to identify the optimum solution. Manual means are generally confined to trial and error--hence arrival at the optimum solution is pure chance.

It is suggested that sketch design and tender document estimates (exclusive of measurement operations) are also significantly reduced in preparation time. Measurement still constitutes the major activity but all calculation, manipulation and presentation is automatically carried out and estimating activities are rapidly accelerated. Again accuracy and reliability are improved well above manual procedures.

Detailed Discussion of Complete Computer-guided Cost Planning Package

How the System Works

File structure. COSTPLANNER requires a main storage disk with 10 mb minimum of available capacity for use as file working space. All project specific data files are contained on this disk for the life of each job involvement, after which floppy disks contain the only record. A minimum of three and a maximum of twelve floppy disks are required for each project. The first contains all cost summaries and investigative information, the second contains protected copies of all final reports, while the remaining disks are used for each identified subdivision. Together they form a complete file set.

Screen displays and printing layouts. The COSTPLANNER system is designed to produce a wide variety of information on both the video screen and printer. Colours are utilised to highlight different components of the screen displays and to improve correct interpretation. Screen displays consist of "menu" selections, required information and other user instructions. Printing layouts are designed to construct and present investigations, feasibility reports, cost plans and cost statements in a hard copy form. Nevertheless all screen displays can be printed and all reports can be shown on the screen (in a special draft form) for editing purposes.

Refer to Appendix IV for detailed format and content of the major screen displays and printing layouts. Hypothetical data is used as an illustration of typical inputs and outputs and the manner in which they interrelate. Underlining in screen displays generally represents either default options or information required and would appear as inverse lettering on the video screen. This section shall further attempt to describe how the system works by reference to each major display and layout in sequence.

Title screen display. All project specific data files are recorded on the main storage disk and optionally backed up on removable floppy disks as before mentioned. Hence when the system is started either a set of formatted blank disks or current data disks need to be on hand. The commencement procedure involves entering the current date and a special security password. Satisfactory completion of this requirement results in generation of the title screen display. A few seconds later the first menu selection is presented.

Main menu screen display. The main menu deals with the structural responsibilities of file manipulation and maintenance. The available options are:

1. Continue--returns control to the inner menu (see later)

2. Obtain--retrieves existing file set from main storage disk and loads data into memory

3. New--creates new file set and name on main storage disk

4. Save--stores complete file set on floppy disks (information is automatically recorded on the main storage disk during COSTPLANNER operation)

5. Transfer--copies individual files from either main storage disk to floppy, floppy to main storage disk or floppy to floppy

6. Rename--changes current name of file set on main storage disk

7. Update--retrieves file set from floppy disks and records on main storage disk under new name

8. Exit--returns control to main operating system

(file set should be backed up on floppy disks first using "save" command)

In addition to the above file handling options the main menu is the only device through which the estimate mode can be selected. The three choices are feasibility, sketch design and tender document. Provision for two separate cost plans at sketch design stage is included to facilitate preparation of an interim design cost plan should it be required. The mode may be changed at any time by returning to the main menu. The current mode is continually displayed in the top right-hand corner of the video screen.

Inner menu screen display. Unlike the main menu, the inner menu is concerned with specific choices of programme direction. The options are:

1. Variables--used to enter base information for project and is mandatory to be selected first (see later)

2. Constants--contains all important assumptions and standard relationships (see later)

3. Construction--allows selection of construction types for feasibility mode and standard desriptions, quantities and costs for sketch design and tender document modes (sec later)

4. Investigation--transfers control to investigation sub-menu (see later)

5. Display cost summary--presents the total and subdivision summary sheets on the screen for review (changes to costs and quantitites on screen not permitted)

6. Print report--transfers control to the print report sub-menu (see later)

7. Compile feedback--for use only after tender document mode has been completed; assembles sub-elemental unit rates for benefit of subsequent sketch design estimates (costs are reverted to base date and may be printed out separately according to job name or as averages of all stored records at any selected building indice)

8. Building indices--stores all building indices for both Public Works and N.CAP2/A.B.S. indice systems (latter used for internal adjustment of cost data) from base date to present date and contains the mechanisms to enter new figures, amend existing figures, retrieve information for a particular date and predict future trends (indices may be displayed on screen or printed as permanent records)

9. Base costs--all costs stored in the programme are at base date value; costs can be entered, reviewed and updated singularly or according to trade classification (stored costs pertain to feasibility construction choices, sketch design categories and all standard descriptions)

10. Set printer--instructs user how to enable a specific type of printer to be used by COSTPLANNER; in addition contains standard assumptions on form length (70 lines), character spacing (12 characters per inch) and the

company identification intended for inclusion in the report

11. Main menu--returns control to the main menu

Once the construction option has been completed the current project cost is continually displayed in the bottom right-hand corner of the video screen. All subsequent alterations to the project are instantly reflected in cost terms by the resulting change in value of this amount.

Investigation sub-menu screen display. This menu applies to any selected mode for most options. However it is of primary use during the feasibility stage before drawings are commenced and is charged with the responsibility of identifying the optimum constraint variables relevant to the project. The options are:

1. Plan shape (low rise)--compares plan shape index (1-22) to number of storeys (1-8) and displays the average cost increase per plan shape increment (see later)

2. Number of storeys (high rise)--compares number of storeys (1-45) to plan shape index (1-4.5) and indicates the points at which lift/plant staging has been assumed (see later)

3. Value analysis/cost-benefit analysis--enables performance criteria to be determined and weighted and then used in connection with forty standard design criteria to determine the net benefit of the current scheme (see

later)

4. Life cycle costs--enables base information to be inserted and then calculates discounted maintenance costs, renovation costs, replacement costs and energy costs for up to forty years for any component including the whole building (see later)

5. Solution appraisal--facilitates the recording of up to nine different alternatives (feasibility mode only) and displays the results for each in terms of capital cost, value assessment, life cycle cost and problem count as well as providing the average figures; the best alternative can be selected and further work can then proceed using that scheme (see later)

6. Previous project comparison--compares current scheme with any single project previously compiled by COSTPLANNER for total cost, unit rate, quantity, cost per square metre and building cost percentage for the total project only; requires insertion of the first floppy disk in a previous file set to function (see later)

7. Reconciliation--compares feasibility report to sketch design/tender document cost plan, sketch design cost plan to interim design cost plan (if any) and sketch design/interim design cost plan to tender document cost plan, reconciling all differences (see later)

8. Cost check--prepares up to nine cost statement summaries during the development of the project's design stating all elemental savings and extras (see later)

<u>Print report sub-menu screen display</u>. The type of output can be selected using this sub-menu within the confines of the current mode. The feasibility mode is restricted to the first two options whereas the sketch design and tender document modes utilise all options except the second. However, cost information is downwardly compatible--that is, a tender document estimate can be compiled into a sketch design or feasibility report and a sketch design estimate can be compiled into a feasibility report by simply changing the current mode. The available options for printing are:

1. Summary only--prints the summary sheets for the total project and all subdivisions (see later)

2. Feasibility report--produces a paginated report that includes the summary sheets and a breakdown of costs into elements complete with brief descriptions; investigation results are optional (see later)

3. Draft cost plan--produces a draft copy of the cost plan complete with all dimensions; is designed for internal use only (see later)

4. Cost plan (descriptions and quantities only)--prints a complete paginated cost plan including descriptions and quantities but excluding costs and unit rates; investigation results are optional (see later)

5. Cost plan (descriptions and costs only)--prints a complete paginated cost plan including descriptions and costs but excluding quantities and unit

rates; investigation results are optional (see later)

6. Cost plan (descriptions, quantities and costs)--prints a complete paginated cost plan including descriptions, quantities, costs and unit rates; investigation results are optional (see later)

All feasibility reports and sketch design cost plans are produced in two letter code format without choice. Tender document cost plans, however, can be compiled into either two letter, four letter or special code subdivision upon command. The latter also can be produced completely devoid of all cost information for the purpose of tendering.

All printed reports and cost plans are prepared on cut sheets--therefore COSTPLANNER makes use of automatic cut sheet feeders or alternatively waits for each new sheet to be entered manually into the printer before transmitting that page of information. Naturally all output is correctly formatted according to the standard page length and repetitive headings and footings. The exception to the above is the draft cost plan, which is dumped to the printer in a continuous format.

Investigations and screen displays are printed by inserting a special control command at any time when the layout/display is on the video screen. Since they are generally not page numbered they can be included separately at the end of the final report as desired. Another special control command stores a protected copy of each final report on the main storage disk.

Variables screen display. This display enables the fundamental project information to be inserted by the user. Only upper case responses are accepted within the identified limits. All entries can be changed at any subsequent occasion. Information is checked where possible and any relevant error messages are shown in the top left-hand corner of the video screen. The variables required are:

1. Name of project

2. Location

3. Date current (the date to which all base costs are escalated)

4. Tender date (projected date for further cost escalation)

5. Site area (including land not utilised)

6. Number of identifiable blocks (if no subdivision is required, enter "1"; if the project is to be segregated into a number of smaller units or a number of different functions, then insert that number)

For each identifiable block the following is also required:

1. Duplication factor (the number of times the contained information is duplicated; hence fifty identical units are measured only once and the total can be easily changed to suit available funding)

2. F.E.C.A. (fully enclosed covered area)

3. U.C.A. (unenclosed covered area)

4. Plan shape index (a measure of shape complexity)

5. Number of storeys above ground

6. Number of storeys below ground

7. Boundary co-efficient (a measure of the relationship between internal room perimeter and the fully enclosed covered area)

Constants screen display. A number of standard assumptions are stored in the programme for use as default values. These can be overriden at any time to suit the particular circumstances involved. Only the first five constants are used in estimates other than feasibility level. The constants consist of:

1. Preliminaries % (building percentage applies to all elements except ventilation, evaporative cooling, air conditioning, electric light and power, communications, transportation systems, special services, centralised energy system, external electric light and power, external communications, external special services and special provisions)

2. Preliminaries % (services percentage including attendance applies to the above exempted elements excluding special provisions)

3. Design risk allowance (added to building percentage only)

4. Market index

5. Locality index

6. Average storey height

7. Average ceiling height

8. Lift/plant stages (number of individual segments in a high rise building for lifts and air conditioning)

9. Cost increase/floor (including basement floors--ground level used as base factor)

10. Site slope factor (multiplying factor to adjust for increased substructure cost)

11. Quality of finish factor (multiplying factor to adjust for low or high finish requirements; applies to finishing elements only)

12. Staircase area (percentage of staircase area to net upper floor area)

13. Eaves overhang area (percentage of eaves overhang area to net roof area)

14. Window area (percentage of window area to net external wall area)

15. External door area (percentage of external door area to net external wall area)

16. Internal screen area (percentage of internal

screen area to net internal wall area)

17. Internal door area (percentage of internal door area to net internal wall area)

18. Contingency allowances (special provisions element)

<u>Construction screen display</u>. Initially a list of all possible subdivisions is presented to enable the required names to be placed against COSTPLANNER's descriptions. An asterisk (*) shows which subdivisions have had the construction phase completed. Depending on the current mode further information is expected.

In feasibility mode COSTPLANNER has already calculated each elemental quantity according to standard equations, variables and constants. A list of standard composite construction types is displayed in order that percentages and/or affirmative responses can be placed against them. If the total project is selected for this purpose then all subdivisions are based on identical responses. Individual subdivisions may otherwise be inserted separately or the above procedure followed and indivdual subdivisions edited at another time. See later for more information.

In sketch design mode the estimate form is set out in identical fashion to the final document except that all possible items (sub-elements) are shown and all unit rates are net. Each subdivision must be estimated separately. The quantities need to be entered but the net unit rates are obtained from averaged figures of all previous projects. The latter can also be modified if considered inappropriate. The elemental and total costs increase as each quantity is inserted. No other items are permitted to be included.

In tender document mode the fixed list of sketch design items is replaced by a variable list of standard descriptions. Each subdivision again must be estimated separately. Each applicable description has a quantity placed against it by the user. An escalated net unit rate is shown as a guide which may be accepted or modified. Descriptions can be altered using the word processing power of COSTPLANNER and completely new descriptions can be entered. The use of standard descriptions help to reduce time and save typing.

Both sketch design and tender document estimates support the inclusion of dimensions. Hence no separate calculating activities are necessary and all computations are automatically correct. See later for further information.

Value analysis/cost-benefit analysis screen display. This screen display requests a maximum of six performance criteria and their weighting percentage.

Default values are shown but may be changed to suit specific project intentions. These criteria are derived from an analysis of the project's function conducted manually.

Life cycle costs screen display. The purpose here is to obtain the necessary information to conduct a life cycle cost analysis. Any building component can be the subject of the analysis and each one completed is separately stored. However only a component called "whole building" will be used for solution appraisal. The following is required:

1. Component name
2. Life cycle period
3. Maintenance period
4. Renovation period
5. Replacement period
6. Current cost of maintenance
7. Current cost of renovation
8. Current cost of replacement
9. Associated annual energy cost
10. Expected interest rate
11. Expected inflation rate

The discounting rate used is given by the difference between the expected interest rate and the expected inflation rate.

Standard printing format. A standard printing format is used for presentation of feasibility reports, cost plans, investigations and statements. Sixty-four lines are used for each formatted page but only fifty lines contain variable text. The remainder constitute headings and footings.

The heading contains the name of the project, its location, the type of information (main summary, elemental summary, cost breakdown, investigation, reconciliation, cost check or blank for screen displays) and the subdivision under scrutiny (total project for all screen displays and investigations except reconciliation and cost checks). The footing contains the name of the company, its title and the relevant page number. Reconciliation and cost statements are individually page numbered. All other investigations and screen displays have the page number replaced with "Appendix".

Main cost plan summary layout (sheet 1). The main cost plan summary is used for the total project and each subdivision. It is automatically prepared with the exception of several items. These are inserted manually during the "display cost summary" option, and consist of:

1. Building type code
2. Job reference
3. Current building price index

4. Client

5. Unenclosed covered area cost weighting

6. Useable floor area

7. Net rentable area (default based on eighty percent of gross floor area above ground level to facilitate lift calculations)

8. Current project budget

9. Type of contract

10. Time for completion (in months)

11. Shape description

12. Special factors

13. Drawing reference

Any of these items may be left blank or typed in using either upper or lower case as allowed.

<u>Main cost plan summary layout (sheet 2)</u>. This summary is used once only for the total project. It is automatically prepared except for sundry expenses such as loose furniture and equipment, professional fees and supervision cost (others allowed) which may be entered during the "display cost summary" option. Escalation costs are shown only if tender date and time for completion have been entered.

<u>Main cost plan summary layout (sheet 3)</u>. This summary is used for each subdivision as well as the total project, but for subdivisions the summary is left blank

below the level of building cost. Note that preliminaries are either included or shown as three separate amounts--one total cost and two proportioned amounts.

Elemental summary layout. This summary is used for each subdivision as well as the total project, although the latter also includes a list of each external element and its cost. Note that when calculating total percentages and costs per square metre, the total project figures are progressively broken down and hence a certain amount of rounding must take place at lower levels to maintain correct additions.

Construction cost estimating layout. The manner in which feasibility reports are estimated requires further explanation. As each element is displayed in turn, the user is expected to enter various responses and costs. All quantities are calculated by the computer but may be changed to take account of innovative or otherwise unusual designs. Information required consists of either percentage values depicting extent or a simple "Y" indicating inclusion.

Escalated unit rates are shown on the screen for each percentage-type item. These costs are obtained from base figures stored in the programme--they are not averages. If rates are not relevant to a particular project concept they may be changed. As soon as a percentage value is inserted that item is valued by multiplying the elemental area, inserted percentage and net unit rate together and adding for preliminaries (if applicable), locality index and market condition factors. Cost loadings for multi-storey buildings are also taken into account. Affirmative-type items where applicable need to be priced as lump sums including all on-costs.

The feasibility estimate continues in this manner for each element. Items not contained in the standard lists may be added using word processing functions or existing items may be altered. As corrections are made it should be remembered, however, that the feasibility report compiles the relevant choices into sentences automatically. See later for further information.

Feasibility report layout. Material shown in the construction cost estimating layout is used to prepare the feasibility report. In addition to all title and summary sheets, COSTPLANNER lists out each element for each subdivision and states the constructional components incorporated therein. The layout conforms to established N.P.W.C. requirements including calculation of building cost percentages, costs per square metre, quantities, unit rates and total costs.

The priced construction types are automatically compiled into readable descriptions without need for editing. They are printed within a space governed by forty-three characters from the left-hand margin. Formatting ensures that elements and headings are not adversely split over pages.

Refer to Appendix V for a complete list of all standard feasibility descriptions. Note that in two cases additional information is provided by COSTPLANNER. Where floors are required below ground level a quantity of basement excavation is calculated as a pricing aid. Similarly for multi-storey buildings over three floors the likely number of passenger lifts in each selected height zone is stated.

Cost plan layout. The sketch design estimate is prepared by measuring applicable sub-elemental quantities according to N.P.W.C. definitions and inserting them against the relevant descriptions. Net unit rates obtained from compiled feedback of previous tender document cost plans are automatically multiplied with these inserted quantities as well as the selected preliminaries allowance, locality index and market condition factors to give the total cost. The only difference between the estimating and cost plan layouts is that in the latter case all unit rates are gross figures.

The above procedure of entering sub-elemental quantities is a pre-requisite of the tender document mode assuming that either four letter coding or feedback compilation is envisaged. Otherwise this estimate form follows a similar path to that previously described. However, additional descriptions can be entered under the appropriate sub-elemental headings and existing descriptions modified.

The tender document mode can be printed in one of three ways. Two letter, four letter or special codes can be nominated from the print report sub-menu. Samples of each layout indicate the manner in which descriptions are sorted and arranged. Refer again to Appendix V for a list of standard tender document descriptions for the substructure element. Note also the default codes used for normal trade subdivision which can be altered to suit any other type of coding.

Although short descriptions have been shown for the tender document mode, a length of two hundred and fifty five characters for each description is allowed (approximately seven lines). All lines after the first are indented two spaces for reasons of clarity.

All quantities calculated by the computer during feasibility mode are displayed until they have been overriden. Cost loadings and other selected constants (except preliminaries, design risk allowance, locality index and market conditions) are not incorporated into sketch design or tender document estimates.

Draft cost plan layout. A draft cost plan can be prepared during sketch design or tender document modes to list all entered dimensions and show all calculations. Unit rates are displayed as net figures although total costs include all selected percentage loadings.

Dimensions are entered at the discretion of the user. A maximum of five items of information are allowed. These comprise:

1. Location notes (any characters accepted)
2. Number off (for example: 2/2/4/)
3. First dimension to two decimal places
4. Second dimension to two decimal places
5. Third dimension to two decimal places

All three dimensions must be inserted. Where only one or two dimensions are necessary zeros must be entered for the remainder. In order to save time, any previous dimension is considered constant until a new figure is entered. The computer types all constant dimensions by itself and adds zeros to reach two decimal places.

Plan shape investigation layout (low rise). This layout compares plan shape to number of storeys for low rise projects. Since the floor areas are constant throughout, all cost variances are a function of elemental equations and cost loadings. A plan shape of "one" indicates a square building. As the plan shape increases so does the external perimeter, thus resulting in larger external wall quantities. This also increases elements such as windows and external doors but decreases internal walls, internal screens and internal doors. Wall finishes may be correspondingly increased or decreased.

Number of storeys investigation layout (high rise). This layout is calculated and displayed in a similar manner to the plan shape investigation. There are two limitations placed on building height. These comprise the area of the site and the area of the ground floor after space for lift shafts has been deducted. In the example quoted a scheme incorporating less than seven floors will not fit on the site. Should the area of the building have resulted in lift shafts occupying more than fifty percent of the ground floor F.E.C.A., then those schemes would also not be shown.

Value analysis investigation layout. Performance criteria is compared to a fixed set of design criteria to determine the relative value of the scheme. Crosses are placed in the spaces provided where performance criteria have been satisfied. All calculations are undertaken automatically. Results less than or equal to ten points for each design criteria are automatically highlighted by an asterisk to indicate possible deficiencies. Definitions of standard terms are not necessary since it is the user's perception of them that is most important.

Life cycle cost investigation layout. This layout is based on the data entered during the screen display. Various discounting rates can be tried to determine the likely accuracy of predicted costs. A maximum of forty years is imposed since predictions in excess of this period are too unstable to be useful.

Solution appraisal investigation layout. When this layout is displayed on the video screen, the first alternative is highlighted together with the latest results. The alternative number can be changed by moving the inverse coloured block to another location. Any further investigation results will be recorded under this new heading.

Up to nine separate alternative schemes can be appraised at any one time. If a previous alternative is shown to be the best it can be rechosen. All information generated at the time that investigation was completed will be reinstated for further development.

Each life cycle cost study undertaken is also shown in summarised form. Any component of the project can be individually analysed in this manner, though only an identification of "whole building" will be used in the main appraisal.

Project comparison investigation layout. Any current alternative can be compared to a previous project using this function. The first disk in a corresponding file set must be entered so that information can be obtained. A display at the start also compares such data as preliminaries, locality index and market condition factors. Escalation to the required date is automatic. The data used from a previous project is the latest recorded, and hence may be at feasibility, sketch design or tender document level.

Reconciliation statement layout (sheet 1). This layout is used for the total project only. Its purpose is to reconcile all differences between each cost plan type depending on the current mode. Options are:

1. In feasibility mode the feasibility report is compared against the sketch design cost plan (where the latter has not been prepared it is automatically replaced with the tender document cost plan)

2. In sketch design mode the sketch design cost plan is compared against the interim design cost plan (if any)

3. In tender document mode the sketch design cost plan is compared against the tender document cost plan

(where an interim design cost plan has been prepared it is used in lieu of the sketch design cost plan)

The layout is automatically prepared except for comments relating to reasons for movement in floor areas.

Reconciliation statement layout (sheet 2). This layout is essentially the same as the previous one and is used for subdivisions only except where no subdivisions are present.

Reconciliation statement layout (sheet 3). The costs contained in each cost plan are compared on an elemental basis. The increase and/or decrease that has resulted is automatically calculated. Unlimited space is provided to manually enter the reasons for movement in displayed costs. This layout is not prepared for the total project unless no subdivisions are involved.

Cost statement summary layout. A maximum of nine cost statements are allowed for the purpose of reporting or "cost checking" on changes in elemental value. The previous project cost shown may be obtained from the latest cost statement or cost plan as applicable. All amendments and remarks need to be inserted manually.

Standard Equations

Refer to Table 8 for a listing of all standard equations for use by COSTPLANNER during the feasibility mode only.

Elemental areas. During the feasibility mode a number of standard equations are used to automatically calculate elemental areas. The equations combine information from both variables and constants screen displays. Through this technique it is possible for COSTPLANNER to examine alternative schemes quickly and identify the optimum set of constraints.

Lift calculations. Numerous assumptions are made in order to conduct lift calculations but these are not subject to change. The reason for this is primarily because they are not important enough to warrant inclusion in the constants screen display. Lift calculations are used merely to establish the likely number of passenger lifts in each height stage to facilitate pricing, to show the effect of lifts on other elemental quantities and as a cost significant component in height comparisons.

The sizing and estimating of lifts is a specialist field. Estimates are usually undertaken free of charge upon presentation of a concept design. However, it is still essential that COSTPLANNER be able to assess the

TABLE 8

LIST OF STANDARD EQUATIONS
FOR FEASIBILITY MODE

<u>Elemental Areas</u>

Substructure (SB)	=	$\frac{\text{building area}}{\text{no. of storeys}}$
Columns (CL)	=	UF + SC + RF
Upper Floors (UF)	=	building area - SB - SC
Staircases (SC)	=	(building area - SB) x constant
Roof (RF)	=	SB x constant
External Walls (EW)	=	(ext per x no. of storeys x av storey height) - WW - ED
Windows (WW)	=	(ext per x no. of storeys x av storey height) x constant
External Doors (ED)	=	(ext per x av storey height) x constant
Length of Internal Walls (L)	=	$\frac{\text{boundary co-efficient/100 x F.E.C.A.}}{2}$
Internal Walls (NW)	=	((L - ext per x no. of storeys) x av storey height) - NS - ND
Internal Screens (NS)	=	(L - ext per x no. of storeys) x av ceiling height x constant
Internal Doors (ND)	=	(L - ext per x no. of storeys) x av ceiling height x constant
Wall Finishes (WF)	=	2 x NW + EW
Floor Finishes (FF)	=	G.F.A. - SC - (3 x no. of lifts stage 3 x floors served + 2 x no. of lifts stage 2 x floors served + no. of lifts stage 1 x x floors served) x 8
Ceiling Finishes (CF)	=	FF
Sanitary Fixtures (SF)	=	equal to quantity inserted

TABLE 8 - Continued

Sanitary Plumbing (PD) = based on SF + 10% for floor wastes

Other Elements where applicable = F.E.C.A.

Lift Calculations (*lift stages to be calculated individually)

No. of persons/ 5 min peak (LD) = $\dfrac{\text{net rentable area} \times 0.125}{10\ \text{m2 per person}}$

Probable stops (PS)* = $S - S\left(\dfrac{S - 1}{S}\right)^{P}$

where S = floors served
P = no. of persons/lift (80% of 20)

Round trip time (RTT)* = 22.5 sec + (9.5 sec x PS) + (no. of floors travelled x av storey height x 2 / lift speed)

5 min handling capacity (HC)* = $\dfrac{\text{no. of persons/lift} \times 300\ \text{sec}}{\text{RTT}}$

No. of lifts (N)* = LD / HC

If (RTT / N) > 30 then add 1 and repeat until <= 30 seconds*

Other Equations

Building area (BA) = F.E.C.A. + U.C.A. + (ext per x 0.30 x no. of storeys)

Boundary co-efficient (BC) = $\dfrac{\text{perimeter of all rooms} \times 100}{\text{F.E.C.A. above ground}}$

Plan shape index (P) = $\dfrac{G + SQR((G \times G) - (16 \times R))}{G - SQR((G \times G) - (16 \times R))}$

where G = external perimeter
R = F.E.C.A.

External perimeter (G) = $2 \times (P + 1) \times SQR\left(\dfrac{R}{P}\right)$

likely impact of lifts on a particular design. To do this realistically before a design has been formulated requires the use of a number of assumptions. These are:

1. Lift load based on 1 person/10 m2 of net rentable area using an expected incoming peak of 12.5% of the total population in five minutes duration

2. Round trip time comprising 22.5 seconds at lobby and 9.5 seconds per upper floor stop

3. Lift car capacity of 20 people filled to no more than 80%

4. Choice of three maximum height stages using lifts at 3 m/sec in first stage, 4 m/sec in second stage and 6 m/sec in third stage (height stages refer to zoning of floors into groups to improve service)

5. Lifts only allowed where building over 3 floors

6. Lift waiting time not to exceed 30 seconds

Other equations. It is not intended to cover material more easily obtained from the N.P.W.C. Cost Control Manual. Hence equations for gross floor area, area efficiency, cost efficiency, wall/floor area ratio, p.o.p. ratio, cost weightings, etc., are not repeated here. Nevertheless there remains several other equations of crucial importance to the functioning of COSTPLANNER.

Included amongst these equations is the basis for plan shape index. By solving for external perimeter an equation is created that enables the perimeter at ground level to be calculated for any selected plan shape index. Hence elemental areas such as external walls, windows and external doors are obtainable and internal walls, internal screens, internal doors and wall finishes derivative.

Time-minimisation

The key strategy of the COSTPLANNER computer guidance system is time-minimisation. The various procedures described earlier reflect this strategy in every aspect. Since cost is directly proportional to time, any savings in time can be immediately translated into monetary terms.

Quantification of envisaged operating speed is difficult because no real data is available as yet. However, experience with the COMPUTECH #2 computer guidance system enables some analogies to be drawn. The following areas are seen as contributing to time-minimisation:

1. Feasibility mode investigations
2. Estimating methods at all levels
3. Ability to change level of estimate between feasibility, sketch design and tender document modes
4. Use of standard descriptions
5. Use of default values (assumed inputs)

wherever possible

6. Ease with which changes can be made including distribution of on-costs

7. Editing of information directly on video screen

8. Facility for entering dimensions and having calculations completed and checked automatically

9. Computer-generated elemental quantities at feasibility level

10. Updating previous similar cost plans

11. Automatic compilation of feedback for sketch design mode

12. Ability to change printing layout and coding subdivision instantly

13. No need for current activities such as preparing hand draft, calculating costs and percentages, typing and general checking

14. Simplicity, flexibility and practicability

It is suggested that significant real time savings result from these items. By applying average charge-out rates to the difference in time between current and envisaged cost planning activities it is possible to show that preparation cost can be reduced by approximately fifty percent.

The feasibility stage is likely to involve a reduction in time of approximately ninety-three percent. In addition, the resulting investigation will be of increased scope, more accurate and will guarantee to identify the optimum constraint variables. Due to normal time limitations in design work and documentation feasibility investigations are seldom carried out.

The sketch design stage still involves measurement of actual quantities from drawings. However, no draft needs to be prepared and all dimensions can be entered directly into the computer if desired. Nevertheless a saving of approximately forty-five percent is likely since preparation and compilation of the cost plan is greatly increased. Estimating activities are also significantly enhanced.

The tender document stage involves a likely saving for preparation and compilation of the cost plan of approximately thirty-four percent. Measurement of quantities is the major activity, but is made more efficient by the use of standard descriptions. For large projects it may not be possible for one person to measure and enter all the dimensions into the computer, but it is possible to supply each member of the cost planning team with a printed list of all standard descriptions. This list can have quantities added and be otherwise modified in such a way that a typist can complete the cost plan draft.

Refer to Table 9 for calculation of time and cost savings using COSTPLANNER. Estimates given are based on a

TABLE 9

CALCULATION OF TIME AND COST SAVINGS USING DEVISED COMPUTER GUIDANCE SYSTEM

TIME STUDY:	Current Time		Envisaged Time	
Feasibility Stage				
Measuring and preparing draft	10 days		0 days	
Estimating and calculating	4 days		1 day	
Final typing/checking	1 day	15 days	0 days	1 day
Sketch Design Stage				
Measuring and preparing draft	15 days		10 days	
Estimating and calculating	3 days		1 day	
Final typing/checking	2 days	20 days	0 days	11 days
Tender Document Stage				
Measuring and preparing draft	27 days		21 days	
Estimating and calculating	5 days		2 days	
Typing and checking	3 days	35 days	0 days	23 days
Total Time		70 days		35 days

TABLE 9 - Continued

COST STUDY:	Current Cost	Envisaged Cost	Saving
Feasibility Stage	$ 6,000	$ 400	$ 5,600 (93%)
Sketch Design Stage	$ 8,000	$ 4,400	$ 3,600 (45%)
Tender Document Stage	$14,000	$ 9,200	$ 4,800 (34%)
Total Cost	$28,000	$14,000	$14,000 (50%)

FEE PAYMENT:	Public Works Department Fee Scale	A.I.Q.S. Fee Scale
Feasibility Stage	time basis[1] ($5,000)	time basis ($6,000)
Sketch Design Stage) Tender Document Stage)	0.30%-0.40%[2] ($12,000-$16,000)	0.50% ($20,000)

PROFITABILITY:	Current Cost	Envisaged Cost
N.P.W.C. Fee Scale (Government Work)	- $7,000-$11,000 (25%-39% loss)	+ $3,000-$7,000 (18%-33% profit)
A.I.Q.S. Fee Scale (Private Work)	- $ 2,000 (7% loss)	+ $ 12,000 (46% profit)

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[1]Hourly rate for time basis calculations equals basic annual salary divided by 1505 and multiplied by either 2.10 (NPWC) or 2.50 average (AIQS).

[2]Actual percentage is dependant upon the category of building as defined in both fee scales.

medium-sized project valued at five million dollars with eighty percent of cost identified as building work. It is assumed that a team of people measure quantities simultaneously in the tender document stage and only minimal reuse of measurements is anticipated. Time occupied by programme operation exclusive of staff presence is ignored.

Table 9 also displays the time taken to prepare each type of cost plan, the cost attributable to same (based on a rate of fifty dollars per hour), the savings possible through use of COSTPLANNER and the relationship between the cost of preparation and the main recommended fee scales. From this data it can be seen that cost planning is presently not a profitable activity for the cost consultant. COSTPLANNER, however, can result in avoidance of a loss relative to either fee allowance while significantly increasing investigative power and accuracy.

At present it would appear that cost consultants indulge in taking "short-cuts" to reduce the preparation cost of cost planning to within close proximity to whichever fee allowance is used. Some doubt may also be lodged at the saving in time and cost at the feasibility stage because at present feasibility reports are not prepared anyway. Unfortunately providing a poorer service to the client is not a valid argument to discredit the suggested savings that COSTPLANNER can produce.

The Importance of Estimating

Estimating is the key activity in cost planning. If it is effective, taking account of all the factors which influence and generate costs and of all aspects of capital and revenue, then cost planning can achieve its objectives. Without good estimating cost planning is a frail and ineffective on-cost.

Studies[1] have shown that optimum estimating performance is reached by measuring and pricing approximately one hundred equally valued items of work. The more even the distribution of cost amongst the items, the more accurate the total estimate will be for those items. As the number of items is increased so the overall accuracy increases, but at a diminishing rate. The effort expended in pricing more than about one hundred items of work is not rewarded by any significant increase in accuracy.

Estimating methods range in practice from a single cost per square metre rate taken from one previous project to resource use and associated costs based on contractors' estimating procedures. The mean deviation of estimates from actual tenders range from eighteen percent to

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[1] Construction Cost Data Base Second and Third Annual Reports. Reports produced on behalf of P.S.A. by the University of Reading, Department of Construction Management, P.S.A. Library, 1981.

five-and-a-half percent respectively[1]. However, in the situation where a contractor makes an average error of five percent in his tenders, the cost consultant or quantity surveyor cannot predict these tenders which on average fall within five percent except by chance.

Notwithstanding the above it is anticipated that the feasibility stage used in COSTPLANNER should be capable of producing estimates having a mean deviation from actual tender amounts of nine percent. Sketch design estimates should approach six percent as the compiled data base increases in size and diversity. Tender document estimates should achieve the minimum of five-and-a-half percent deviation and should be no less accurate than a priced bill of quantities. The maximum error in a tender document cost plan using a tender error of five percent is hence likely to be about ten percent on average above or below the lowest tender. Deviations outside this range are unlikely to occur.

Elemental base costs for use in the feasibility stage of COSTPLANNER should be obtained by averaging a number of previous projects of different types. In the sketch design stage costs are automatically derived from averaging all previous tender document estimates. Cost information for use in the tender document stage should be

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[1] Ibid.

gathered from the priced bill of quantities of each successful tenderer for a number of previous projects.

The presence of a central data base within the building industry tied directly to individual computerised estimating systems would be of great benefit in the collection of base costs, although not essential. However, present methods of producing and using cost data taken from a small number of bills of quantities are neither sufficiently flexible in use nor capable of supporting accurate cost estimating.

CHAPTER V

CONCLUSION

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Summary

Project cost control is a process in which various design strategies are evaluated in monetary terms for the purpose of identifying value for money, establishing a realistic budget for future design and construction and ensuring that such allowance is not arbitrarily exceeded. During the pre-tender period the activity is known as cost planning. Its usefulness is summarised by the following extract[1]:

> Cost planning is a system of procedures and techniques used by quantity surveyors. Its purpose is to ensure that clients are provided with value for money on their projects; that clients and designers are aware of the cost consequences of their proposals; that if they so choose, clients may establish budgets for their projects; and the designers are given advice which enables them to arrive at practical and balanced designs within budget. It helps to ensure that clients can realise their expected profits and benefits and that their financial requirements stay within anticipated limits. . . Therefore cost planning monitors and helps direct design and organisation decisions in order to achieve the client's cost objectives.

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[1] Department of Construction Management, University of Reading, Cost Planning and Computers, (Southampton: Hobbs Printers, 1981), p. 6.

Current project cost control processes in Australia fail to adequately research and examine alternative design solutions due primarily to the imposition of time and cost constraints. While traditional philosophies of cost planning are basically sound, their implementation is concerned more with controlling the cost of a given design than any serious attempt at investigation and optimisation of the concept before drawings are commenced. New procedures are required to facilitate use of designing to a cost techniques and hence to guarantee that value for money is recognised in practice as the principle objective of cost control activities.

The new methods of implementation necessitate computer assistance to succeed. Only the computer possesses the speed and accuracy to research design alternatives both efficiently and extensively. It also has the benefit of being able to guide cost planning activities and ensure that the potential of the designing to a cost philosophy is fully exploited.

The assistance described above can be in the form of computer guidance systems or computer storage systems--the latter being a subset of the former. While storage systems have great benefit to the control of cost for a given design, only guidance systems are capable of investigation and optimisation. The key to reducing time but increasing examination of design alternatives clearly lies in the employment of established cost planning practices continually supervised by an extensive computer-based guidance system.

Appraisal of existing cost planning approaches involving computer usage is mandatory to ensure that further development is undertaken at the leading edge of technology. Essential elements can be identified for inclusion within the new system and a tentative specification can be prepared. The result is encompassed in the framework for a powerful computer guidance system known simply as COSTPLANNER.

Minimising preparation time and related cost during project control activities is the key strategy of COSTPLANNER. It is achieved primarily by streamlining existing practices through computer involvement and capitalising upon repetitive tasks better handled by a machine. The cost consultant is hence free to consider the overall direction being pursued rather than the detail involved therein.

COSTPLANNER operates at three levels--feasibility, sketch design and tender document--which equate with the normal sequence of design evolution. Within each level extensive use is made of N.P.W.C. elements and sub-elements and the manner in which they are commonly presented. Life cycle costing, value analysis and cost-benefit analysis are all fully supported and integrated within each cost plan type.

It is envisaged that COSTPLANNER will result in savings in preparation time on average sized projects of approximately ninety-three percent at feasibility level, forty-five percent at sketch design level and thirty-four percent at tender document level. An overall saving of approximately fifty percent is possible if the complete cost planning process is followed. When compared against the recommended fee scales for government and private work it is shown that full cost planning activities can be undertaken without the likelihood of incurring a loss.

The purchase price of COSTPLANNER together with all the computer hardware necessary for its operation can be justified by the profit received from each full cost control assignment. If existing recommended fee scales are used, a large proportion of the total system cost can be recuperated on each occasion. In addition to providing the client with maximum value for money, for the first time cost planning has been converted into a profitable and rewarding exercise.

Costing a Design Versus Designing to a Cost

The two mainstream philosophies of cost planning are costing a design and designing to a cost. The former involves estimating and thence controlling the value of a given design whereas the latter involves creating a scheme to comply with a pre-determined budget allocation. Costing a design is used almost exclusively in Australia at the present time.

The advantage that is possessed by the designing to a cost philosophy involves the mechanisms to search for and identify the optimum constraint variables that are capable of guaranteeing value for money. Hence design options can be individually appraised prior to commencement of drawings in order to select a building configuration within available funding limits. Attempts at optimisation after drawings have been started is of little practical benefit.

While advocation of designing to a cost is fine in theory, there remain reasons that have precluded its use to date. These are:

1. The manner in which the industry is structured results in cost advice not being sort until sketch plans have been completed

2. Government bodies support the N.P.W.C. guidelines pertaining to designing to a cost but fail to implement them

3. There is a general consensus that architects do not want to be given design advice or have any other limitation imposed upon them

4. Full or partial cost planning studies result in a loss against recommended fee allowances--methods are hence employed to reduce preparation cost not increase it

The latter is an economic consideration and is hence the most significant; the remainder are structural problems.

Assuming that none of these restrictions are likely to inadvertently change overnight, a strategy is required to make designing to a cost common practice. Such a strategy would comprise:

1. Quantity surveyors and other cost consultants need to demonstrate to clients that significant savings can be made through pursuit of feasibility investigations before valuable time is spent documenting a scheme that is inherently cost expensive

2. Governments should insist on full implementation of N.P.W.C. guidelines for all government funded projects as an example to the rest of the industry

3. It is proposed that architects are interested in cost advice provided it does not lock them into a set scheme--by identifying the optimum constraint variables[1] no design restriction is created

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[1]There is no discernible reason why the optimum set of constraint variables needs to be incorporated into a particular design anyway. Architectural decisions can also result in value for money in the same way as cost decisions, and the two should be considered on their merits for each project.

4. Time and related cost can be reduced by fifty percent through use of the COSTPLANNER computer guidance system (raising the fee payment would achieve the same profitability but thorough investigation can not take place without computer assistance--there are just too many variables and interdependencies to be analysed manually)

Implementation of designing to a cost procedures is hence a real possibility, but in the meantime COSTPLANNER still provides the opportunity for savings during preparation of normal cost plan documents. While COSTPLANNER can operate under either condition it fails to provide value for money to the client unless cost advice can occur at a very early stage.

Application of Computer Guidance Systems to Project Cost Control

Business communications and information handling are moving into a new era. The change has been called the information revolution. Its impact will be as dramatic and as inevitable as the agricultural and industrial revolutions were in their time. Quantity surveyors together with other members of the building industry will have no choice but to adopt the faster and more accurate methods used throughout the world of business.

Several attempts have already been made to improve current practice through the introduction of computers. In the field of cost planning such attempts can be categorised as either guidance or storage systems. Research has demonstrated that there are suprisingly few guidance and storage systems available at present either in Australia or overseas. This situation exemplifies the lack of advancement that has occurred and the noticable failure to keep pace with new technology.

At present the ultimate combination of computer-based systems for quantity surveyors is seen as comprising three parts. The main component is COSTPLANNER, which is subsequently integrated with a bill of quantities preparation system ("SURVEYOR") and a post-contract package ("CONSTRUCTOR").

The bill of quantities system must enable printing in a wide variety of forms, accept N.P.W.C. two and four letter coding and enable unit rates to be entered and totalled. Compilation of an elemental summary from this information and direct contribution to special data bases is also necessary. The post-contract package must enable sections of either the bill of quantities or the tender document cost plan to be given a percentage complete. All summaries associated with progress payments, variations, rise and fall calculations, cash flows, etc., will require automatic preparation.

Bill of quantities and post-contract systems are a useful inclusion. Nevertheless, a detailed cost plan operating in conjunction with a computer guidance system is seen as an efficient mechanism of budgeting, controlling, tendering and administrating certain building projects, obviating the need for a traditional bill of quantities. The main opposition to this event centres around the present fee allowances of cost planning compared to bills of quantities and the possible reduction in work content for the quantity surveying profession.

COSTPLANNER is suitable for use among quantity surveyors, building contractors, developers, project managers and others interested in cost and economy. The benefit to quantity surveyors in particular is obvious and the savings that shall result are real. In addition, architects may find use from the feasibility stage given that accurate cost information had been provided and entered into the system. Perseverance with manual cost control implementation typifies poor business management.

Advantages and Disadvantages of Selected Cost Plan Framework

COSTPLANNER has many attributes that benefit both the user of the system and the project client. In fact every aspect of its design can be interpretted as an advantage. There are no discernible drawbacks evident at this stage. The system arguably has the potential to be the ultimate cost control package after further feedback and testing has occurred. Its advantages presently include but are not limited to:

1. Designing to a cost philosophy facilitated--investigative procedures research and identify optimum constraint variables (eg. all "variables" and "constants" described in COSTPLANNER) at feasibility stage and set a realistic budget amount within which the final design can comply

2. Support of N.P.W.C. elements and sub-elements and the accepted methods of display--all estimating procedures and printing options are structured to suit standard elemental subdivisions, leading to consistency in presentation and reliability in compiled feedback

3. Cost plan "modes" equate with the actual design process--feasibility, sketch design and tender document modes may be chosen in sequence or in any order as appropriate at any time to best facilitate the particular task at hand

4. Flexibility--COSTPLANNER allows great flexibility in all aspects of investigation, estimating and presentation and is designed to suit the particular requirements of the system user

5. Practicability--the procedures are essentially simple to understand and logical to follow, thus rendering the system easy to use by both skilled and unskilled staff

6. Accuracy--the consistency of estimate preparation together with the automatic compilation of feedback result in increased accuracy at all levels when carried out with computer supervision

7. Ease with which changes are possible--since all data is stored in the computer it can be easily changed at any time using powerful options contained in the programme structure

8. Time-minimisation--time is reduced significantly at feasibility level since the computer calculates all investigation results without measurement from drawings, and reduced to a lesser extent at sketch design and tender document levels since all measurement is enhanced, standard descriptions used, estimating simplified and printing automatically completed

9. Increased investigation--manual procedures of investigation just cannot compete with the speed, reliability, consistency and thoroughness of COSTPLANNER nor can manual procedures realistically identify the optimum constraint variables other than by chance

10. Role of designer not infringed--feasibility investigations can identify information such as optimum plan shape (perimeter), number of storeys and construction type, but can essentially enable quick assessment of design options for discussion by the design team; the design hence remains largely unrestricted

11. Achievement of value for money--pursuit of designing to a cost techniques leads to value for money

when cost and design are treated with equal importance (the optimum value for money usually does not equal minimum cost)

12. Improvement of information flow--the speed of COSTPLANNER and the transportability of data means that feedback to all members of the design team is enhanced

13. Link with actual construction--a detailed tender document cost plan is capable of being used for tendering and administration and hence enables the estimate to more closely resemble the actual tender amount since they both relate to the same base information

14. Creation of data base--COSTPLANNER automatically compiles feedback from tender document cost plans for use in the sketch design mode, but in the future auxiliary packages will transfer cost information from priced bills of quantities for direct use in cost planning activities

15. Profitability of cost planning--under existing recommended fee scales COSTPLANNER can convert almost certain loss into profit through reduction of time intensive procedures

16. Cost--the purchase price of both hardware and software is relatively low and can be easily offset against envisaged profit

17. Software compatibility--although COSTPLANNER will only operate on one type of computer (in theory), it is the most popular personal computer available in Australia today and is already present in many professional

offices because of its usefulness in word processing, accounting, job costing and record keeping

The Problem in Retrospect

The initial statement made in this thesis suggested that cost control of building design is justified if cost is equated with form and function and is recognised as a design limitation. The inclusion of cost within the design process enables the concept of maximum value for money to be achieved given that such action is conducted early. Using the feasibility mode, COSTPLANNER is most capable of providing quick and reliable feedback before drawings are commenced to enable design decisions to be made based on fact.

Cost control processes at present are aimed at estimating and monitoring the value of a given design, and for this reason the potential of such processes is not being fully exploited. COSTPLANNER enables the theory of traditional procedures to be used expediently under the continual supervision of a powerful computer guidance system. In addition to increased investigation and accuracy, time and related preparation cost are significantly reduced.

The designing to a cost philosophy is currently substituted for the more popular costing a design approach.

COSTPLANNER aims to turn this situation around by creating a realistic budget amount before sketch designs are prepared. The budget is not an average of results from other projects but is based on an identifiable list of factors known to contribute to overall cost. The progress of drawings can then be monitored, advice given on developing trends and requisite action initiated.

The client's interest is not satisfactorily protected using the costing a design approach and some doubt can be raised regarding fulfilment of contractual obligations in this regard. COSTPLANNER has the necessary mechanisms to conduct life cycle cost, value analysis and cost-benefit analysis studies in addition to normal estimating requirements. Coupled with full support of N.P.W.C. guidelines and recommendations a significant increase in control is forthcoming.

Cost control during the design process currently has no continuation into the construction phase, resulting in duplication of work on behalf of those charged with post-contract activities. The structure of COSTPLANNER lends itself as a medium for progress claim evaluation, cash flows and the like given that the cost plan is used as an actual tender document. In this case all detail of materials, workmanship and extent of work needs to be included in the specification where it belongs.

The design team is collectively charged with the responsibility, whether explicit or implicit, of providing the client with value for money. However, little sharing of resources takes place among disciplines due primarily to difficulties in communication. Computers have the ability to rapidly transfer vast amounts of information and COSTPLANNER has been engineered to take full advantage of this technology.

The existence of a common data base for the entire industry will assist estimating accuracy at all stages in the design process. COSTPLANNER maintains its own data base structured around N.P.W.C. sub-elemental coding. Thus sketch design cost plans are prepared on the basis of average figures from all previous tender document estimates. Four letter coding is used to obviate the problem of specific building types and their cost implications by breaking down the overall scheme into a number of self-contained items.

Problems associated with co-operation and market competitiveness are responsible for restricting the flow of cost information within the industry. This results in a lack of accuracy in future estimates. COSTPLANNER can improve this situation by sharing information on each project, especially between the architect, the quantity surveyor and the successful tenderer.

Concluding Remarks

There is little more that can be said to reinforce the plea for introduction of computer guidance systems into all aspects of project cost control. The advantages associated with implementation should now be obvious and the problems shown to be in evidence solved. Designing to a cost is the path to follow and only computer-based systems have the power to capitalise upon its inherent strengths.

This investigative study of computer guidance systems for project cost control has focused on three main topics. First, traditional methods were explained in sufficient detail to form a foundation for later decision making. Second, computer-based systems currently available were used to illustrate the level at which research in this field had aspired. Third, the solution to the problems of cost control were solved by the design and documentation of the computer guidance system COSTPLANNER.

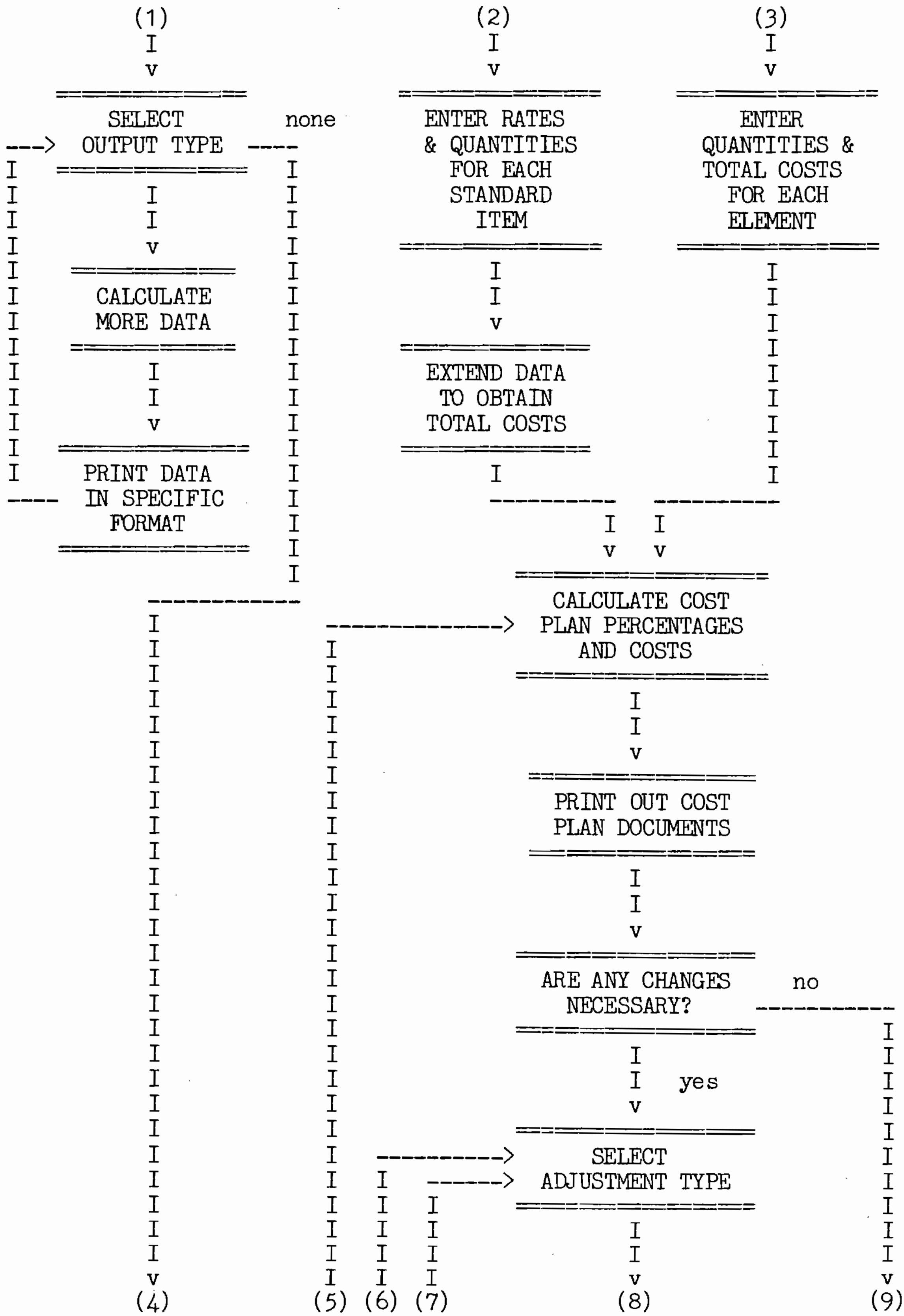
Funding of the further development of COSTPLANNER will ensure that it is available to all members of the building industry. The guesswork will be taken out of cost planning and replaced with well-established techniques capable of fulfilling the primary objective of guaranteeing value for money to the client. COSTPLANNER is the means that will allow the N.P.W.C. guidelines to be utilised as they were originally intended and as a result the reliability of future cost planning activities will be significantly increased. It is simply the next step in the cost control evolution. []

APPENDICES

APPENDIX I

FLOWCHART ILLUSTRATING SEQUENCE OF ACTIVITIES FOR "COMPUTECH #2" COST PLANNING SYSTEM

```
                              ========
                                START
                              ========
                                  I
                                  I
                                  v
                        ================            ===========
                        SELECT BUILDING    other       FUTURE
                             TYPE        --------->  EXTENSION
                        ================            ===========
                                  I
                                  I   schools
                                  v
                        ================
                        SELECT ESTIMATE
                              TYPE
                        ================
                                  I
                                  I
                                  v
===========             =================
  INDICE     <--------- INPUT CONSTRAINT
PROGRAMME    --------->    VARIABLES
===========             =================
          pre-sketch plan  I  I   cost plan
     --------------------     -----------
     I                                 I
     v                                 v
===============                 ==============
CALCULATE AND                   INSERT EXTRA
STORE ESTIMATE                  INFORMATION
 INFORMATION                    ==============
===============            unit rates   I   I   totals only
     I                        ---------     ---------
     I                        I                     I
     v                        v                     v
    (1)                      (2)                   (3)
```


(1)
(2)
(3)
SELECT OUTPUT TYPE
none
ENTER RATES & QUANTITIES FOR EACH STANDARD ITEM
ENTER QUANTITIES & TOTAL COSTS FOR EACH ELEMENT
CALCULATE MORE DATA
EXTEND DATA TO OBTAIN TOTAL COSTS
PRINT DATA IN SPECIFIC FORMAT
CALCULATE COST PLAN PERCENTAGES AND COSTS
PRINT OUT COST PLAN DOCUMENTS
ARE ANY CHANGES NECESSARY?
no
yes
SELECT ADJUSTMENT TYPE
(4)
(5)
(6)
(7)
(8)
(9)

```
(4)           (5) (6) (7)              (8)                  (9)
 I             I   I   I                I                    I
 I             I   I   I                v                    I
 I             I   I   I        ===============              I
 I             I   I   I             ENTER                   I
 I             I   I   I        ADJUSTMENT CODE              I
 I             I   I   I        ===============              I
 I             I   I   I                I                    I
 I             I   I   I                I                    I
 I             I   I   I                v                    I
 I             I   I   I       ==================            I
 I             I   I   I         ENTER NEW UNIT              I
 I             I   I   I         RATE, QUANTITY              I
 I             I   I   I         AND/OR COST AND             I
 I             I   I   I        ALTER STORED DATA            I
 I             I   I   I       ==================            I
 I             I   I   I                I                    I
 I             I   I   I                I                    I
 I             I   I   I                v                    I
 I             I   I   I          ==============             I
 I             I   I   I             ARE ANY                 I
 I             I   I   ---------   MORE CHANGES              I
 I             I   I      yes       NECESSARY?               I
 I             I   I              ==============             I
 I             I   I                    I                    I
 I             I   I                    I   no               I
 I             I   I                    v                    I
 I             I   I             ===============             I
 I             I   I      no      IS IMMEDIATE               I
 I             ----(-----------   MODE FACILITY              I
 I                 I                REQUIRED?                I
 I                 I             ===============             I
 I                 I                    I                    I
 I                 I                    I   yes              I
 I                 I                    v                    I
 I                 I                  ======                 I
 I                 I                   STOP                  I
 I                 I                  ======                 I
 I                 I                                         I
 I                 I                    ----------------------
 I                 I                    I
 I                 I                    v
 I                 I          ================
 I                 I          IS A COMPARISON       no
 I                 I          WITH PRE-SKETCH  -------------
 I                 I          PLAN REQUIRED?               I
 I                 I          ================             I
 I                 I                    I                  I
 I                 I                    I   yes            I
 v                 I                    v                  v
(10)              (11)                 (12)               (13)
```

```
(10)              (11)                (12)                 (13)
  I                 I                   I                    I
  I                 I                   v                    I
  I                 I            ================            I
  I                 I              ENTER MORE                I
  I                 I              INFORMATION               I
  I                 I            ================            I
  I                 I                   I                    I
  I                 I                   I                    I
  I                 I                   v                    I
  I                 I           ===================          I
  I                 I             CALCULATE AND              I
  I                 I             STORE ESTIMATE             I
  I                 I              INFORMATION               I
  I                 I           ===================          I
  I                 I                   I                    I
  I                 I                   I                    I
  I                 I                   v                    I
  I                 I         ======================         I
  I                 I           PRINT COMPARISON             I
  I                 I           IN TABULATED FORM            I
  I                 I         ======================         I
  I                 I                   I                    I
  I                 I                   I                    I
  I                 I                   v                    I
  I                 I            =================           I
  I                 I      yes       ARE ANY                 I
  I                 -------------- MORE CHANGES              I
  I                                 NECESSARY?               I
  I                              =================           I
  I                                     I   no               I
  I                       ----------------                   I
  ----------------------  I   --------------------------------
                      I   I   I
                      v   v   v
                 ====================
                   LIST CONSTRAINT
                   VARIABLES USED
                 ====================
                          I
                          I
                          v
                       ========
                         END
                       ========
```

APPENDIX II

FLOWCHART ILLUSTRATING RELATIONSHIPS BETWEEN "COMPUTECH #2" OPERATING PROGRAMMES

The following summary of the operating programmes lists the filename[1] assigned to each together with a brief statement pertaining to the primary function(s). It is provided as a legend to the flowchart contained hereinafter.

"PROGXX". This sub-programme is also referred to as the building price index reference file and is activated from "PROG02".

"PROG01". This is the introductory programme that enables selection of the required building type and estimate type and would be in common with any future set of programmes written for another category of building.

"PROG02". All of the constraint variables are entered here for both types of estimate and in addition this programme contains the link to the integrated building price index reference file.

"PROG03". This programme undertakes the majority of calculations necessary during the pre-sketch plan and comparison output modes and contains all the standard factors, assumptions and costs.

---

[1]Filename is the general term used to describe the name that computers use to identify a specific programme contained in memory or on a storage device.

"PROG04". In this programme some of the types of pre-sketch plan output alternatives are contained as well as the means for selecting same.

"PROG05". In addition to harbouring the immediate mode facility for the pre-sketch plan stage, this programme also contains the remainder of output functions and the termination point.

"PROG06". This programme consists of additional input information for the cost plan stage followed by the calculation section of method 2 of cost plan generation.

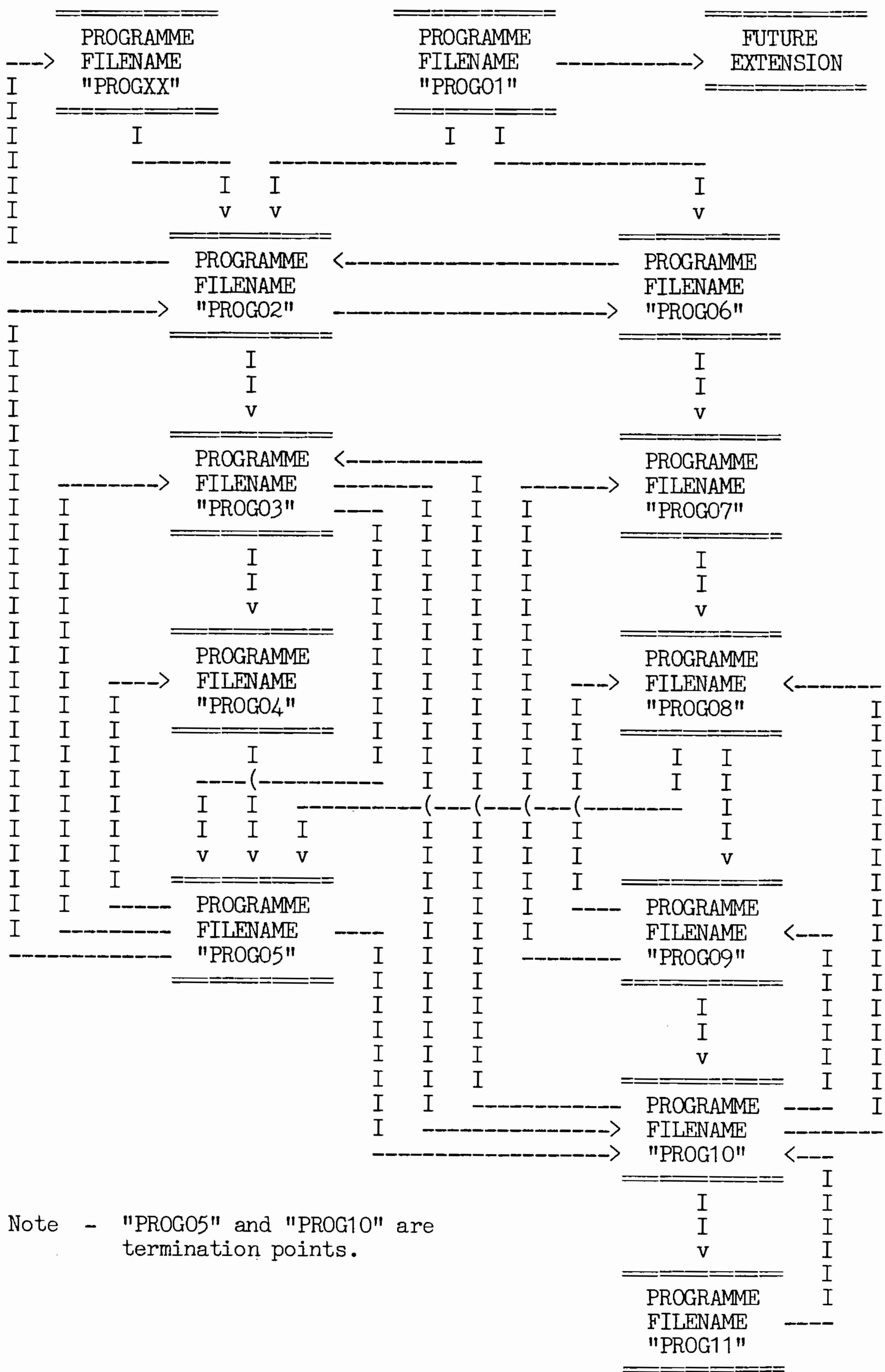
"PROG07". Calculations for method 1 of cost plan generation including access to standard item descriptions as well as additions of subdivisional components, percentages, etc., for both methods are contained here.

"PROG08". During this programme all of the required output for the cost plan and pre-sketch plan summary is produced.

"PROG09". This is the adjustment section of the cost plan stage which also acts as mediator to "PROG07", "PROG08" and "PROG10" and contains the immediate mode facility for the second stage.

"PROG10". All calculations for the comparison phase as well as summary calculations at a pre-sketch plan stage are made here. The programme also contains the termination point for the cost plan estimate.

"PROG11". This is the standard output programme for the comparison of pre-sketch plan and cost plan figures.

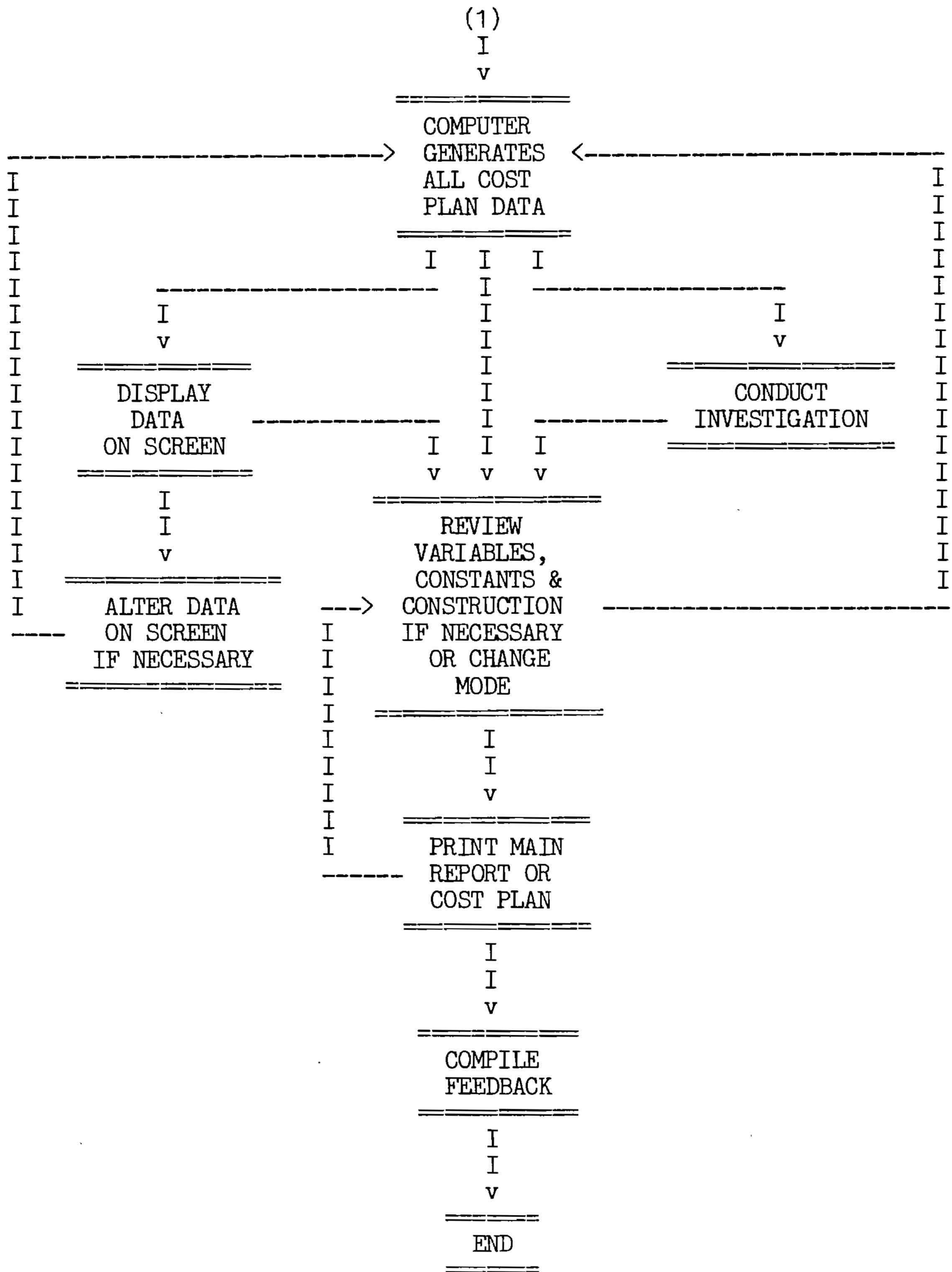


Note - "PROG05" and "PROG10" are termination points.

APPENDIX III

FLOWCHART ILLUSTRATING SEQUENCE OF MAJOR OPERATIONS FOR FRAMEWORK "COSTPLANNER"

```
                              =======
                               START
                              =======
                                 I
                                 I
                                 v
                              ========
                               SELECT
                                MODE
                              ========
                               I   I
         ---------------------      ---------------------
         I                                              I
         v                                              I
  ==============                                        v
   ADJUST BASE                                     ===========
  COSTS, REVIEW                                       ENTER
    BUILDING     ----------------------------->     VARIABLES
   INDICES OR                                      ===========
   SET PRINTER                                          I
  ==============                                        I
                                                        I
                               -------------------------
                               I
                               v
                          =============
                             SELECT
                          CONSTRUCTION
                             TYPES
                          AND ESTIMATE
                             COSTS
                          =============
                               I
                               I
                               v
                              (1)
```


(1)
COMPUTER GENERATES ALL COST PLAN DATA
DISPLAY DATA ON SCREEN
CONDUCT INVESTIGATION
ALTER DATA ON SCREEN IF NECESSARY
REVIEW VARIABLES, CONSTANTS & CONSTRUCTION IF NECESSARY OR CHANGE MODE
PRINT MAIN REPORT OR COST PLAN
COMPILE FEEDBACK
END

APPENDIX IV

SCREEN DISPLAYS AND PRINTING LAYOUTS FOR FRAMEWORK "COSTPLANNER"

Title Screen Display

Welcome to the ultimate cost planning system . . . . .

```
[][][][][][][]
[]
[]
[]
[]  [][][][][][][]
[]  []          []
[][][][][][][]  []
    []          []
    [][][][][][][]
    []
    []                  COSTPLANNER  Computer Guidance System
    []                               Version 1.0 (IBM PC)
```

Main Menu Screen Display

M A I N M E N U

```
Options     -    Continue
                 Obtain
                 New
                 Save
                 Transfer
                 Rename
                 Update
                 Exit

Modes       -    Feasibility
                 Sketch Design / Interim Design
                 Tender Document

[   up arrow      move cursor up       ]
[   down arrow    move cursor down     ]
[   Cntrl-M       change mode          ]
[   <RET>         select               ]

>>> Enter Filename: ________          <ESC>  exit
```

Inner Menu Screen Display

```
                                   Current Mode:  FEASIBILITY

                      I N N E R   M E N U

Options     -    Variables
                 Constants
                 Construction
                 Investigation
                 Display Cost Summary
                 Print Report
                 Compile Feedback
                 Building Indices
                 Base Costs
                 Set Printer
                 Main Menu

[   up arrow      move cursor up       ]
[   down arrow    move cursor down     ]
[   <RET>         select               ]

                                   Current Project Cost:  $14,436,083
```

Investigation Sub-menu Screen Display

```
                              Current Mode:  FEASIBILITY

                        I N V E S T I G A T I O N
                              S U B - M E N U
                        =========================

   Options      -     Plan Shape (Low Rise)
                      Number of Storeys (High Rise)
                      Value Analysis / Cost-benefit Analysis
                      Life Cycle Costs
                      Solution Appraisal
                      Previous Project Comparison
                      Reconciliation
                      Cost Check

[    up arrow      move cursor up        ]
[    down arrow    move cursor down      ]
[    <RET>         select                ]
[    <ESC>         inner menu            ]

                              Current Project Cost:  $14,436,083
```

Print Report Sub-menu Screen Display

```
                              Current Mode:  FEASIBILITY

                 P R I N T   R E P O R T   S U B - M E N U
                 =========================================

   Options      -     Summary Only
                      Feasibility Report
                      Draft Cost Plan
                      Cost Plan (Descriptions and Quantities Only)
                      Cost Plan (Descriptions and Costs Only)
                      Cost Plan (Descriptions, Quantities and Costs)

   Coding       -     Two Letter Codes
                      Four Letter Codes
                      Special Codes

[    up arrow      move cursor up        ]
[    down arrow    move cursor down      ]
[    Cntrl-C       change coding         ]
[    <RET>         select                ]
[    <ESC>         inner menu            ]

                              Current Project Cost:  $14,436,083
```

Variables Screen Display

Current Mode: FEASIBILITY

VARIABLES

Name of Project:	COMMONWEALTH BANK PREMISES	
Location:	GEORGE STREET, SYDNEY	
Date Current:	01/04/84	Tender Date: __/__/__
Site Area (m2):	2544	
Number of Identifiable Blocks (1-10 Only):		1
Total -	Duplication Factor	1
	F.E.C.A. (m2):	16285
	U.C.A. (m2):	380
	Plan Shape Index:	1.5
	Number of Storeys - Above Ground:	11
	- Below Ground:	3
	Boundary Co-efficient (%):	21

[up arrow move cursor up]
[down arrow move cursor down]
[<RET> select]
[<ESC> inner menu]

Current Project Cost: $14,436,083

Constants Screen Display

Current Mode: FEASIBILITY

CONSTANTS

Preliminaries % (building)	12.5	Site Slope Factor	1
Preliminaries % (services)	5	Quality of Finish Factor	1
Design Risk Allowance (%)	5	Staircase Area (%)	4
Market Index (base 100)	100	Eaves Overhang Area (%)	5
Locality Index (base 100)	100	Window Area (%)	20
Average Storey Height (m)	3.5	External Door Area (%)	6
Average Ceiling Height (m)	2.7	Internal Screen Area (%)	10
Lift/Plant Stages (No.)	1	Internal Door Area (%)	8
Cost Increase/Floor (%)	0.5	Contingency Allowances (%)	5

[up arrow move cursor up]
[down arrow move cursor down]
[<RET> select]
[<ESC> inner menu]

Current Project Cost: $14,436,083

Construction Screen Display

Current Mode: FEASIBILITY

C O N S T R U C T I O N

Total Project:	*	TOTAL PROJECT
Block A:		BLOCK A
Block B:		BLOCK B
Block C:		BLOCK C
Block D:		BLOCK D
Block E:		BLOCK E
Block F:		BLOCK F
Block G:		BLOCK G
Block H:		BLOCK H
Block I:		BLOCK I
Block J:		BLOCK J

[up arrow move cursor up]
[down arrow move cursor down]
[<RET> select]
[<ESC> inner menu]

Current Project Cost: $14,436,083

Value Analysis/Cost-benefit Analysis Screen Display

Current Mode: FEASIBILITY

V A L U E A N A L Y S I S / C O S T -
B E N E F I T A N A L Y S I S

Performance Criteria		Weighting %
A:	Low Capital Cost	40
B:	Low Running Cost	30
C:	Good Return on Investment	5
D:	Architectural/Engineering Significance	0
E:	Activity Maximisation	10
F:	Community Improvement	15

[up arrow move cursor up]
[down arrow move cursor down]
[<RET> select]
[<ESC> inner menu]

Current Project Cost: $14,436,083

Life Cycle Costs Screen Display

Current Mode: FEASIBILITY

L I F E C Y C L E C O S T S

Component Name:	WHOLE BUILDING
Life Cycle Period (Years):	40 [Max 40 years]
Maintenance Period (Years):	0.5
Renovation Period (Years):	5
Replacement Period (Years):	20
Current Cost of Maintenance ($):	5000
Current Cost of Renovation ($):	750000
Current Cost of Replacement ($):	15000000
Associated Annual Energy Cost ($):	125000
Expected Interest Rate (%):	15
Expected Inflation Rate (%):	10

```
[    up arrow      move cursor up       ]
[    down arrow    move cursor down     ]
[    <RET>         select               ]
[    <ESC>         inner menu           ]
```

Current Project Cost: $14,436,083

Standard Printing Format

```
<blank>
<blank>
<blank>
COMMONWEALTH BANK PREMISES                                  SUMMARY
GEORGE STREET, SYDNEY                                 TOTAL PROJECT
-------------------------------------------------------------------
<blank>
<blank>
<blank>
<blank>
. . . . . . . . . . . <50 lines of variable text> . . . . . . . . . .
<blank>
<blank>
<blank>
-------------------------------------------------------------------
COMQUANT PTY. LIMITED.                                    PAGE:   1
QUANTITY SURVEYORS AND COST CONSULTANTS
<blank>
<blank>
<blank>
```

Main Cost Plan Summary Layout (Sheet 1)

N. P. W. C. / A. I. Q. S. C O S T P L A N S U M M A R Y	S I N G L E / M U L T I P L E B U I L D I N G P R O J E C T

Building Type Code	Project/Building	Job Ref.
OFFICE BUILDING	COMMONWEALTH BANK PREMISES	8404/1

		Date	B.P.I.
Location GEORGE STREET, SYDNEY			
Client COMMONWEALTH BANK	Current	01/04/84	484.6F
	Tender	/ /	-
	Locality Index		100

P H Y S I C A L — C O S T / O T H E R   F A C T O R S

	Full Area m2	Area %	Cost Weight	Current Cost	Cost/m2 $	Cost $
F.E.C.A.	16,285	97.7	100	FECA Cost	857.84	13969877
U.C.A.	380	2.3	40	UCA Cost	346.18	131548
G.F.A.	16,665	100.0	Building Rate/Cost		846.17	14101425

			Current	Tender
Usable Floor Area	10,754 m2			
Net Rentable Area	10,860 m2			
Building Area	17,249 m2	Project Cost	14436083	
Area Efficiency	65.17 %	Project Budget	-	
Cost Efficiency	65.42 %			
No. of Storeys	3B+11 No	Gross Project Cost	-	
Building Height	39 m	Antic Total Commit	-	
Floor/Floor Height	3.5 m			
Wall/Floor Area Ratio	0.42 :1	Type of Contract	RISE AND FALL	
P.O.P. Ratio	86.98 %	Time for Completion	24 MONTHS	

Shape Description:

Commercial office building complex comprising insitu concrete floors and columns, brick infill walls, suspended ceilings, internal partitions and carpet. External paving and landscaping.

Special Factors:

Inner city location.

Drawing Reference:

Concept sketches only.

Main Cost Plan Summary Layout (Sheet 2)

S U M M A R Y   O F   C O S T

GFA m2	Buildings	Cost/m2	Cost
16,665	TOTAL PROJECT	846.17	14,101,425
	BUILDING COST (B.C.) $	846.17	14,101,425
Code	Element Group		
30	Centralised Energy System	-	-
31	Alterations	-	-
32-36	Siteworks	12.85	214,188
37-44	External Services	2.73	45,470
45	External Alterations	-	-
00	Proportion of Preliminaries	-	-
	NET PROJECT COST (N.P.C.) $	861.75	14,361,083
46	Special Provisions		
	Allowance for Contract Contingencies	4.50	75,000
	Foundation/Rock Contingencies	-	-
	PROJECT COST - CURRENT DATE $	866.25	14,436,083
	Escalation to Tender Date		
	PROJECT COST - TENDER DATE $		
		Current	Tender
	Loose Furniture and Equipment		
	Professional Fees		
	Supervision Costs		
	GROSS PROJECT COST (G.P.C.) $		
	Escalation during Contract Period	-	
	ANTICIPATED TOTAL COMMITMENT $		

Main Cost Plan Summary Layout (Sheet 3)

SUMMARY OF COST

Code	Element Group	% BC	Cost/m2	Cost
00	Preliminaries ($ INCLUDED)	-	-	-
01	Substructure	4.93	41.72	695,264
02-11	Superstructure	49.14	415.81	6,929,573
12-14	Finishes	9.18	77.69	1,294,704
15-16	Fittings	2.12	17.92	298,567
17-29	Services	34.63	293.03	4,883,317
00	Proportion of Preliminaries	-	-	-
	BUILDING COST (B.C.) $	100.00	846.17	14,101,425
Code	Element Group			
30	Centralised Energy System		-	-
31	Alterations		-	-
32-36	Siteworks		12.85	214,188
37-44	External Services		2.73	45,470
45	External Alterations		-	-
00	Proportion of Preliminaries		-	-
	NET PROJECT COST (N.P.C.) $		861.75	14,361,083
46	Special Provisions			
	Allowance for Contract Contingencies		4.50	75,000
	Foundation/Rock Contingencies		-	-
	PROJECT COST - CURRENT DATE $		866.25	14,436,083
	Escalation to Tender Date			
	PROJECT COST - TENDER DATE $			
			Current	Tender
	Loose Furniture and Equipment			
	Professional Fees			
	Supervision Costs			
	GROSS PROJECT COST (G.P.C.) $			
	Escalation during Contract Period		-	
	ANTICIPATED TOTAL COMMITMENT $			

Elemental Summary Layout

Code	Element	% BC	Cost/m2	Quantity	Unit Rate	Cost
01SB	SUBSTRUCTURE	4.93	41.72	1232 m2	564.34	695264
	SUPERSTRUCTURE					
02CL	Columns	2.20	18.58	17311 m2	17.89	309635
03UF	Upper Floors	19.33	163.61	15376 m2	177.32	2726495
04SC	Staircases	1.31	11.05	641 m2	287.28	184148
05RF	Roof	2.94	24.90	1294 m2	320.81	415125
06EW	External Walls	8.80	74.44	5712 m2	217.18	1240543
07WW	Windows	7.18	60.78	1070 m2	946.63	1012899
08ED	External Doors	0.15	1.30	29 m2	747.00	21663
09NW	Internal Walls	5.45	46.13	2221 m2	346.13	768756
10NS	Internal Screens	0.82	6.92	199 m2	579.53	115327
11ND	Internal Doors	0.96	8.10	160 m2	843.64	134982
	SUPERSTRUCTURE	49.14	415.81	-	-	6929573
	FINISHES					
12WF	Wall Finishes	1.95	16.49	10154 m2	27.06	274806
13FF	Floor Finishes	3.76	31.87	15464 m2	34.35	531114
14CF	Ceiling Finishes	3.47	29.33	15464 m2	31.61	488784
	FINISHES	9.18	77.69	-	-	1294704
	FITTINGS					
15FT	Fitments	1.31	11.08	-	-	184598
16SE	Special Equipment	0.81	6.84	-	-	113969
	FITTINGS	2.12	17.92	-	-	298567
	SERVICES					
17SF	Sanitary Fixtures	0.50	4.20	244 No	286.86	69993
18PD	Sanitary Plumbing	0.31	2.63	854 Fu	51.32	43831
19WS	Water Supply	0.35	2.95	16285 m2	3.02	49162
20GS	Gas Service	-	-	-	-	-
21SH	Space Heating	-	-	-	-	-
22VE	Ventilation	0.82	6.93	16285 m2	7.09	115488
23EC	Evaporative Cooling	-	-	-	-	-
24AC	Air Conditioning	12.43	105.20	16285 m2	107.65	1753158
25FP	Fire Protection	3.37	28.51	16285 m2	29.18	475119
26LP	Electric Light & Power	7.37	62.34	16285 m2	63.79	1038866
27CM	Communications	0.22	1.87	16285 m2	1.91	31164
28TS	Transportation Systems	8.51	72.04	-	-	1200506
29SS	Special Services	0.75	6.36	-	-	106030
	SERVICES	34.63	293.03	-	-	4883317

Construction Cost Estimating Layout

<Sample Feasibility>

OOPR PRELIMINARIES	-	-	-
Included in rates (Y/N)	Y		
Preliminaries, profit and overheads (DEFAULT)	N		

01SB SUBSTRUCTURE	1232 m2	564.34	695264
Substructure consisting of:			
piers, beams and pads with concrete slab	100	91.64	127210
strip footings with concrete slab		87.57	
concrete raft slab with thickenings		86.32	
concrete raft slab with piers		89.90	
piers and beams with timber floor		98.11	
strip footings with timber floor		93.05	
Basement excavation (Y/N) [12499 m3 allowed]	Y	-	568054
Swimming pool (Y/N)		-	

02CL COLUMNS	17311 m2	17.89	309635
Columns consisting of:			
insitu concrete	100	15.05	309635
precast concrete		23.95	
structural steel		13.15	
structural timber		9.90	

03UF UPPER FLOORS	15376 m2	177.32	2726495
Upper floors consisting of:			
insitu concrete	100	141.40	2543190
precast concrete		220.56	
structural steel		99.09	
structural timber		91.88	

<construction cost estimating continues in this manner>

Feasibility Report Layout

<Sample Feasibility>

PRELIMINARIES

OOPR	PRELIMINARIES	-	-	-	-	-

Included in rates.

SUBSTRUCTURE

01SB	SUBSTRUCTURE	4.93	41.72	1232 m2	564.34	695264

Substructure consisting of piers, beams and pads with concrete slab. Basement excavation.

SUPERSTRUCTURE

02CL	COLUMNS	2.20	18.58	17311 m2	17.89	309635

Columns consisting of insitu concrete.

03UF	UPPER FLOORS	19.33	163.61	15376 m2	177.32	2726495

Upper floors consisting of insitu concrete. Sunhoods.

04SC	STAIRCASES	1.31	11.05	641 m2	287.28	184148

Structure consisting of insitu concrete. Finish consisting of granolithic topping and terrazzo.

05RF	ROOF	2.94	24.90	1294 m2	320.81	415125

Structure consisting of insitu concrete and structural steel. Finish consisting of metal deck sheeting and waterproof membrane with gravel over. Parapet walls. Internal stormwater drainage.

06EW	EXTERNAL WALLS	8.80	74.44	5712 m2	217.18	1240543

Structure consisting of insitu concrete and cavity brick. Finish consisting of exposed aggregate and face brick.

07WW	WINDOWS	7.18	60.78	1070 m2	946.63	1012899

Windows consisting of glazed anodised aluminium frame. Double glazing. Reflective glass. Sunhoods.

08ED	EXTERNAL DOORS	0.15	1.30	29 m2	747.00	21663

External doors consisting of glazed aluminium frame, fire rated solid timber and roller shutters.

09NW	INTERNAL WALLS	5.45	46.13	2221 m2	346.13	768756

Internal walls consisting of insitu concrete and stud framing.

10NS	INTERNAL SCREENS	0.82	6.92	199 m2	579.53	115327

Internal screens consisting of demountable partitions, toilet cubicle partitions and glazed aluminium frame.

11ND	INTERNAL DOORS	0.96	8.10	160 m2	843.64	134982

Internal doors consisting of glazed aluminium frame, solid timber, fire rated solid timber and toilet doors.

F I N I S H E S

12WF	WALL FINISHES	1.95	16.49	10154 m2	27.06	274806

Wall finishes consisting of ceramic tiles, cement render and plasterboard.

<feasibility report continues in this manner>

Cost Plan Layout

<Sample Sketch Design>

S U B S T R U C T U R E

01SB SUBSTRUCTURE	4.93	41.72	1232 m2	564.34	695264
Basement excavation.			12980 m3	43.76	568054
Foundation excavation.			1232 m2	4.43	5460
Column pads and pedestals.			1232 m2	20.56	25330
Piles and piers.			160 m	73.06	11690
Ground slabs.			1232 m2	68.77	84730

S U P E R S T R U C T U R E

02CL COLUMNS	2.20	18.58	17311 m2	17.89	309635
Reinforced concrete columns (11-25 floors).			17311 m2	17.89	309635
03UF UPPER FLOORS	19.33	163.61	15376 m2	177.32	2726495
Insitu slab and beam construction.			15376 m2	177.32	2726495
04SC STAIRCASES	1.31	11.05	641 m2	287.28	184148
Flight construction.			410 m2	226.42	92832
Flight tread and riser finishes.			410 m2	50.13	20554
Flight soffit finishes.			410 m2	21.62	8864
Landing construction.			275 m2	138.70	38143
Landing coverings.			275 m2	35.00	9625
Landing soffit finishes.			275 m2	15.00	4125
Balustrades.			336 m	29.78	10005
05RF ROOF	2.94	24.90	1294 m2	320.81	415125
Concrete roof construction.			1294 m2	183.45	237387
Metal framed roof construction.			311 m2	115.40	35890
Covering (non-trafficable).			1294 m2	41.33	53485
Parapets and balustrades.			139 m	477.80	66414
Downpipes and fittings.			523 m	33.28	17405
Internal stormwater drainage.			76 m	59.79	4544

<cost plan continues in this manner>

<Sample Tender Document Two Letter Coding>

S U B S T R U C T U R E

01SB	SUBSTRUCTURE	4.93	41.72	1232 m2	564.34	695264

Excavate for basement.	12980 m3	42.50	551650
Excavate for pads.	56 m3	25.00	1400
Excavate for 600 diam. piers.	160 m	11.50	1840
Planking and strutting.	1552 m2	12.00	18624
Concrete in piers.	46 m3	105.00	4830
Concrete in pads.	56 m3	105.00	5880
Concrete in ground slabs.	191 m3	110.00	21010
Formwork to side of pads.	93 m2	30.00	2790
Formwork to edge of slab.	42 m2	30.00	1260
Bar reinforcement in footings.	24.0 t	980.00	23520
Bar reinforcement in ground floor.	50.0 t	980.00	49000
100 thick fine crushed rock basecourse.	1345 m2	6.00	8070
0.20 thick polythene sheeting.	1387 m2	2.50	3468
Termite treatment.	1240 m2	1.55	1922

S U P E R S T R U C T U R E

02CL	COLUMNS	2.20	18.58	17311 m2	17.89	309635

Concrete in columns.	433 m3	105.00	45465
Formwork to side of columns.	4336 m2	39.00	169110
Bar reinforcement in columns.	97.0 t	980.00	95060

03UF	UPPER FLOORS	19.33	163.61	15376 m2	177.32	2726495

Concrete in upper floors.	3675 m3	120.00	441000
Concrete in beams.	1748 m3	125.00	218500
Formwork to soffit of slab.	15376 m2	35.00	538160
Formwork to side and soffit of beams.	11648 m2	45.00	524160
Formwork to edge of slab.	455 m2	45.00	20475
Formwork to step in slab.	990 m	12.50	12375
Rebate in edge of slab.	1807 m	15.00	27105
Bar reinforcement in upper floors.	964.0 t	980.00	944720

04SC	STAIRCASES	1.31	11.05	641 m2	287.28	184148

<cost plan continues in this manner>

<Sample Tender Document Four Letter Coding>

S U B S T R U C T U R E					
01SB SUBSTRUCTURE	4.93	41.72	1232 m2	564.34	695264
SBXB			12980 m3	43.76	568054
Excavate for basement.			12980 m3	42.50	551650
Planking and strutting.			1367 m2	12.00	16404
SBXF			1232 m2	4.43	5460
Excavate for pads.			56 m3	25.00	1400
Excavate for 600 diam. piers.			160 m	11.50	1840
Planking and strutting.			185 m2	12.00	2220
SBCP			1232 m2	20.56	25330
Concrete in pads.			56 m3	105.00	5880
Formwork to edges of pads.			93 m2	30.00	2790
Bar reinforcement in footings.			17.0 t	980.00	16660
SBPR			160 m	72.45	11690
Concrete in piers.			46 m3	105.00	4830
Bar reinforcement in footings.			7.0 t	980.00	6860
SBGS			1232 m2	68.77	84730
Concrete in ground slabs.			191 m3	110.00	21010
Formwork to edge of slab.			42 m2	30.00	1260
Bar reinforcement in ground floor.			50.0 t	980.00	49000
100 thick fine crushed rock basecourse.			1345 m2	6.00	8070
0.20 thick polythene sheeting.			1387 m2	2.50	3468
Termite treatment.			1240 m2	1.55	1922
S U P E R S T R U C T U R E					
02CL COLUMNS	2.20	18.58	17311 m2	17.89	309635
CLER			17311 m2	17.89	309635
Concrete in columns.			433 m3	105.00	45465
Formwork to side of columns.			4336 m2	39.00	169110
Bar reinforcement in columns.			97.0 t	980.00	95060

<cost plan continues in this manner>

<Sample Tender Document Special Coding>

EXCAVATION				
	4.08	34.53	-	-	575436

Excavate for basement.	12980 m3	42.50	551650
Excavate for pads.	56 m3	25.00	1400
Excavate for 600 diam. piers.	160 m	11.50	1840
Planking and strutting.	1552 m2	12.00	18624
Termite treatment.	1240 m2	1.55	1922

CONCRETING					
	24.00	203.08	-	-	3384273

Concrete in piers.	46 m3	105.00	4830
Concrete in pads.	56 m3	105.00	5880
Concrete in ground slabs.	191 m3	110.00	21010
Concrete in columns.	433 m3	105.00	45465
Concrete in upper floors.	3675 m3	120.00	441000
Concrete in stair flights and landings.	137 m3	130.00	17810
Concrete in roof slab.	283 m3	120.00	33960
Concrete in beams.	1883 m3	125.00	235375
Formwork to side of pads.	93 m2	30.00	2790
Formwork to edge of slab.	42 m2	30.00	1260
Formwork to side of columns.	4336 m2	39.00	169110
Formwork to soffit of stairs.	685 m2	35.00	23975
Formwork to soffit of slab.	15376 m2	35.00	538160
Formwork to side and soffit of beams.	11648 m2	45.00	524160
Formwork to edge of slab.	455 m2	45.00	20475
Formwork to step in slab.	990 m	12.50	12375
Formwork to stair strings.	336 m	15.00	5040
Formwork to stair risers.	1358 m	12.50	16975
Rebate in edge of slab.	1807 m	15.00	27105
Bar reinforcement in footings.	24.0 t	980.00	23520
Bar reinforcement in ground floor.	50.0 t	980.00	49000
Bar reinforcement in columns.	97.0 t	980.00	95060
Bar reinforcement in upper floors and beams.	964.0 t	980.00	944720
Bar reinforcement in stairs.	41.0 t	980.00	40180
Bar reinforcement in roof slab and beams.	75.0 t	980.00	73500
100 thick fine crushed rock basecourse.	1345 m2	6.00	8070
0.20 thick polythene sheeting.	1387 m2	2.50	3468

<cost plan continues in this manner>

Draft Cost Plan Layout

<Sample Tender Document>

S U B S T R U C T U R E									
01SB SUBSTRUCTURE			4.93	41.72		1232 m2	564.34		695264
SBXB						12980 m3	43.76		568054
Excavate for basement.						12980 m3	37.78		551650
[basement	1/	32.00	38.50	10.50	=	12936.00		]	
[	2/	32.00	0.60	0.52	=	19.97		]	
[	2/	38.50	0.60	0.52	=	24.02		]	
[						--------		]	
[						12979.99		]	
Planking and strutting.						1367 m2	10.67		16404
[as exc.	2/	32.00	11.02		=	705.28		]	
[	2/	38.50	11.02		=	848.54		]	
[adj bldg	1/	32.00	5.85		=		187.20	]	
[						--------	--------	]	
[						1553.82	187.20	]	
[						187.20		]	
[						--------		]	
[						1366.62		]	
SBXF						1232 m2	4.43		5460
Excavate for pads.						56 m3	22.22		1400
[cols	64/	1.20	1.20	0.60	=	55.30		]	
[						--------		]	
[						55.30		]	
Excavate for 600 diam. piers.						160 m	10.22		1840
[under pad	64/	2.50			=	160.00		]	
[						--------		]	
[						160.00		]	
Planking and strutting.						185 m2	10.67		2220
[as exc.	2/2/64/	1.20	0.60		=	184.32		]	
[						--------		]	
[						184.32		]	

<draft cost plan continues in this manner>

Plan Shape Investigation Layout (Low Rise)

Cost $ x1000	Number of Storeys							
	1	2	3	4	5	6	7	8
Plan Shape Index								
1	-	-	-	-	-	-	13903	13998
1.5	-	-	-	-	-	-	13941	14036
2	-	-	-	-	-	-	13978	14074
2.5	-	-	-	-	-	-	14016	14111
3	-	-	-	-	-	-	14053	14149
3.5	-	-	-	-	-	-	14091	14187
4	-	-	-	-	-	-	14128	14225
4.5	-	-	-	-	-	-	14166	14263
5	-	-	-	-	-	-	14203	14300
5.5	-	-	-	-	-	-	14241	14338
6	-	-	-	-	-	-	14278	14376
6.5	-	-	-	-	-	-	14314	14414
7	-	-	-	-	-	-	14353	14452
7.5	-	-	-	-	-	-	14391	14489
8	-	-	-	-	-	-	14429	14527
8.5	-	-	-	-	-	-	14466	14565
9	-	-	-	-	-	-	14504	14603
9.5	-	-	-	-	-	-	14541	14641
10	-	-	-	-	-	-	14579	14678
10.5	-	-	-	-	-	-	14616	14716
11	-	-	-	-	-	-	14654	14754
11.5	-	-	-	-	-	-	14691	14792
12	-	-	-	-	-	-	14729	14829
12.5	-	-	-	-	-	-	14766	14867
13	-	-	-	-	-	-	14804	14905
13.5	-	-	-	-	-	-	14841	14943
14	-	-	-	-	-	-	14879	14981
14.5	-	-	-	-	-	-	14917	15018
15	-	-	-	-	-	-	14954	15056
15.5	-	-	-	-	-	-	14992	15094
16	-	-	-	-	-	-	15029	15132
16.5	-	-	-	-	-	-	15067	15170
17	-	-	-	-	-	-	15104	15207
17.5	-	-	-	-	-	-	15142	15245
18	-	-	-	-	-	-	15179	15283
18.5	-	-	-	-	-	-	15217	15321
19	-	-	-	-	-	-	15254	15359
19.5	-	-	-	-	-	-	15292	15396
20	-	-	-	-	-	-	15329	15434
20.5	-	-	-	-	-	-	15367	15472
21	-	-	-	-	-	-	15405	15510
21.5	-	-	-	-	-	-	15442	15548
22	-	-	-	-	-	-	15480	15585
Av Incr	-	-	-	-	-	-	0.27%	0.27%

Number of Storeys Investigation Layout (High Rise)

Cost $ x1000		Plan Shape Index						
	1	1.5	2	2.5	3	3.5	4	4.5
No. of Storeys <<<* indicates lift/plant stages>>>								
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
7	13903	13941	13978	14016	14053	14091	14128	14166
8	13998	14036	14074	14111	14149	14187	14225	14263
9	14082	14120	14158	14196	14234	14272	14310	14348
10	14157	14195	14233	14272	14310	14348	14386	14425
11	14225	14263	14302	14340	14379	14417	14455	14494
12	14287	14326	14364	14403	14441	14480	14518	14557
13	14344	14383	14421	14460	14499	14538	14576	14615
14	14397	14436	14475	14514	14553	14592	14630	14669
15 *	14445	14484	14523	14562	14601	14640	14679	14718
16	14535	14574	14613	14653	14692	14731	14770	14810
17	14621	14660	14700	14739	14779	14818	14858	14897
18	14702	14742	14781	14821	14861	14900	14940	14980
19	14779	14819	14859	14899	14939	14979	15018	15058
20	14853	14893	14933	14973	15013	15054	15094	15134
21	14924	14964	15005	15045	15085	15125	15166	15206
22	14992	15032	15073	15113	15154	15194	15235	15275
23	15057	15098	15138	15179	15220	15260	15301	15342
24	15119	15160	15201	15241	15282	15323	15364	15405
25	15180	15221	15262	15303	15344	15385	15426	15467
26	15238	15279	15320	15361	15403	15444	15485	15526
27	15295	15336	15378	15419	15460	15501	15543	15584
28	15349	15390	15432	15473	15515	15556	15598	15639
29	15402	15444	15485	15527	15568	15610	15652	15693
30 *	15454	15496	15537	15579	15621	15663	15704	15746
31	15528	15570	15612	15654	15696	15738	15780	15821
32	15601	15643	15685	15727	15769	15812	15854	15896
33	15672	15714	15757	15799	15841	15884	15926	15968
34	15741	15784	15826	15869	15911	15954	15996	16039
35	15809	15852	15894	15937	15980	16022	16065	16107
36	15875	15918	15961	16004	16064	16089	16132	16175
37	15939	15982	16025	16068	16111	16154	16197	16240
38	16002	16045	16088	16132	16175	16218	16261	16304
39	16063	16106	16150	16193	16236	16280	16323	16367
40	16124	16168	16211	16255	16298	16342	16385	16429
41	16183	16227	16270	16314	16358	16401	16445	16489
42	16240	16284	16328	16372	16415	16459	16503	16547
43	16297	16341	16385	16429	16473	16517	16561	16605
44	16353	16397	16441	16485	16530	16574	16618	16662
45 *	16407	16451	16496	16540	16584	16628	16673	16717

Value Analysis Investigation Layout

		Performance Criteria A	B	C	D	E	F	Score (Max 100)	
Design Criteria									
A1	STRUCTURAL								
A1.01	Form	[X]	[X]	[X]	[ ]	[ ]	[X]	90	
A1.02	Structural Design	[X]	[ ]	[X]	[ ]	[ ]	[ ]	45	
A1.03	Construction System	[X]	[ ]	[X]	[ ]	[ ]	[ ]	45	
A1.04	Regulations Compliance	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
A1.05	Weatherproofing	[ ]	[X]	[ ]	[ ]	[ ]	[ ]	30	
A1.06	Material Selection	[X]	[X]	[X]	[ ]	[ ]	[X]	90	
A1.07	Prefabrication	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
A1.08	Ventilation	[X]	[X]	[X]	[ ]	[X]	[ ]	85	
A1.09	Fire Safety	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
A1.10	Innovation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
A2	PHYSIOLOGICAL								
A2.01	Function	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
A2.02	Designer Requirements	[X]	[X]	[X]	[ ]	[X]	[X]	100	
A2.03	Cost	[X]	[X]	[X]	[ ]	[X]	[ ]	85	
A2.04	Time Constraints	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
A2.05	Maintenance	[X]	[X]	[X]	[ ]	[ ]	[ ]	75	
A2.06	Energy Conservation	[ ]	[X]	[X]	[ ]	[ ]	[ ]	35	
A2.07	Owner/User Benefits	[ ]	[X]	[X]	[ ]	[X]	[ ]	45	
A2.08	Planning	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
A2.09	Flexibility	[X]	[ ]	[ ]	[ ]	[X]	[X]	65	
A2.10	Durability	[X]	[X]	[X]	[ ]	[ ]	[X]	90	
B1	ENVIRONMENTAL								
B1.01	Site Characteristics	[X]	[ ]	[X]	[ ]	[X]	[X]	70	
B1.02	Orientation	[ ]	[X]	[X]	[ ]	[ ]	[X]	50	
B1.03	Site Climate	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
B1.04	Sun Control	[ ]	[X]	[X]	[ ]	[X]	[X]	60	
B1.05	Wind Movement	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
B1.06	Heat Exchange	[ ]	[X]	[X]	[ ]	[ ]	[ ]	35	
B1.07	Daylighting	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
B1.08	Traffic Flow	[ ]	[ ]	[ ]	[ ]	[ ]	[X]	15	
B1.09	View Maximisation	[ ]	[ ]	[X]	[ ]	[X]	[ ]	15	
B1.10	Internal Climate	[ ]	[X]	[ ]	[ ]	[X]	[ ]	40	
B2	PSYCHOLOGICAL								
B2.01	External Appearance	[ ]	[ ]	[X]	[ ]	[ ]	[X]	20	
B2.02	Internal Appearance	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
B2.03	Shapes and Colours	[ ]	[ ]	[ ]	[X]	[ ]	[X]	15	
B2.04	Detailing	[ ]	[ ]	[ ]	[X]	[ ]	[X]	15	
B2.05	Impact on Surroundings	[ ]	[ ]	[ ]	[X]	[ ]	[X]	15	
B2.06	Internal Spatial Flow	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
B2.07	Induced Responses	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	0	*
B2.08	Int/Ext Relationship	[ ]	[ ]	[ ]	[ ]	[X]	[ ]	10	*
B2.09	Prestige	[X]	[ ]	[X]	[ ]	[ ]	[X]	60	
B2.10	Comfort	[X]	[ ]	[ ]	[ ]	[X]	[ ]	50	

TOTAL WEIGHTED SCORE (MAX POSSIBLE 4000): 1410

Life Cycle Cost Investigation Layout

Component Name: WHOLE BUILDING

Year	Maintenance Cost	Renovation Cost	Replacement Cost	Energy Cost
1	10,000			125,000
2	9,070			113,379
3	8,638			107,980
4	8,227			102,838
5		587,645		97,941
6	7,642			93,277
7	7,107			88,835
8	6,768			84,605
9	6,446			80,576
10		460,435		76,739
11	5,847			73,085
12	5,568			69,605
13	5,303			66,290
14	5,051			63,133
15		360,763		60,127
16	4,581			57,264
17	4,363			54,537
18	4,155			51,940
19	3,957			49,467
20			5,653,342	47,111
21	3,589			44,868
22	3,418			42,731
23	3,256			40,696
24	3,101			38,758
25		221,477		36,913
26	2,812			35,155
27	2,678			33,481
28	2,551			31,887
29	2,429			30,368
30		173,533		28,922
31	2,204			27,545
32	2,099			26,233
33	1,999			24,984
34	1,904			23,794
35		135,968		22,661
36	1,727			21,582
37	1,644			20,554
38	1,566			19,576
39	1,491			18,643
40			2,130,685	17,756
TOTAL	141,191	1,939,821	7,784,027	2,150,836

TOTAL LIFE CYCLE COST: $12,015,875

Solution Appraisal Investigation Layout

	Performance Statistics			
	Capital Cost	Value Assessment	Life Cycle Cost	Problem Count
Alternative 1	$14,436,083	1410 points	$12,015,875	14
Alternative 2				
Alternative 3				
Alternative 4				
Alternative 5				
Alternative 6				
Alternative 7				
Alternative 8				
Alternative 9				
AVERAGE:	$14,436,083	1410 points	$12,015,875	14

Life Cycle Cost Summary:

WHOLE BUILDING	$12,015,875

Project Comparison Investigation Layout

Code	Element	Previous Project	Current Project	Reduction Percent	Addition Percent
<<<Total Cost>>>					
01SB	SUBSTRUCTURE	500754	695264		38.84
	SUPERSTRUCTURE				
02CL	Columns	444000	309635	43.39	
03UF	Upper Floors	2355000	2726495		15.77
04SC	Staircases	105750	184148		74.14
05RF	Roof	420555	415125	1.31	
06EW	External Walls	1354805	1240543	9.21	
07WW	Windows	779665	1012899		29.91
08ED	External Doors	26400	21663	21.87	
09NW	Internal Walls	800580	768756	4.14	
10NS	Internal Screens	175680	115327	52.33	
11ND	Internal Doors	180525	134982	33.74	
	SUPERSTRUCTURE	6642960	6929573		4.31
	FINISHES				
12WF	Wall Finishes	290995	274806	5.89	
13FF	Floor Finishes	465000	531114		14.22
14CF	Ceiling Finishes	391050	488784		24.99
	FINISHES	1147045	1294704		12.87
	FITTINGS				
15FT	Fitments	91500	184598		101.75
16SE	Special Equipment	126890	113969	11.34	
	FITTINGS	218390	298567		36.71
	SERVICES				
17SF	Sanitary Fixtures	70885	69993	1.27	
18PD	Sanitary Plumbing	50645	43831	15.55	
19WS	Water Supply	50980	49162	3.70	
20GS	Gas Service	45000	-	100.00	
21SH	Space Heating	65750	-	100.00	
22VE	Ventilation	40955	115488		181.99
23EC	Evaporative Cooling	-	-	-	-
24AC	Air Conditioning	2550875	1753158	45.50	
25FP	Fire Protection	472110	475119		0.64
26LP	Electric Light & Power	986605	1038866		5.30
27CM	Communications	32995	31164	5.88	
28TS	Transportation Systems	1160000	1200506		3.49
29SS	Special Services	-	106030		100.00
	SERVICES	5526800	4883317	13.18	

Reconciliation Statement Layout (Sheet 1)

N. P. W. C. / A. I. Q. S.
R E C O N C I L I A T I O N   S T A T E M E N T   S U M M A R Y

Project/Building	Job Ref.	Date
COMMONWEALTH BANK PREMISES	8404/1	01/04/84

Reconciliation between:	Sketch Design	Cost Plan
and:	Tender Document	Cost Plan

	S.D.C.P.	T.D.C.P.	REASONS FOR MOVEMENT
F.E.C.A.	15,998 m2	16,285 m2	Increased by 287 m2 as a result of additional car spaces
U.C.A.	380 m2	380 m2	No change
G.F.A.	16,378 m2	16,665 m2	Increaed by 287 m2
Current Date	01/01/84	01/04/84	
Current B.P.I.	477.0F	484.6F	
Tender Date	/ /	/ /	
Tender B.P.I.			

Buildings	Cost $	Cost $
TOTAL PROJECT	13,665,850	14,101,425
BUILDING COST (B.C.) $	13,665,850	14,101,425
Elements 30 to 46	319,675	334,658
PROJECT COST - CURRENT DATE $	13,985,525	14,436,083
Escalation to Tender Date		
PROJECT COST - TENDER DATE $		

Reconciliation Statement Layout (Sheet 2)

N. P. W. C. / A. I. Q. S.
R E C O N C I L I A T I O N S T A T E M E N T S U M M A R Y

Project/Building	Job Ref.	Date
TOTAL PROJECT	8404/1	01/04/84

Reconciliation between:	Sketch Design	Cost Plan
and:	Tender Document	Cost Plan

	S.D.C.P.	T.D.C.P.	REASONS FOR MOVEMENT
F.E.C.A.	15,998 m2	16,285 m2	Increased by 287 m2 as a result of additional car spaces
U.C.A.	380 m2	380 m2	No change
G.F.A.	16,378 m2	16,665 m2	Increaed by 287 m2
Current Date	01/01/84	01/04/84	
Current B.P.I.	477.0F	484.6F	
Tender Date	/ /	/ /	
Tender B.P.I.			

Code	Element Group	Cost $	Cost $
00	Preliminaries	-	-
01	Substructure	684,335	695,264
02-11	Superstructure	6,755,005	6,929,573
12-14	Finishes	1,251,772	1,294,704
15-16	Fittings	283,500	298,567
17-29	Services	4,691,238	4,883,317
00	Proportion of Preliminaries	-	-
BUILDING COST (B.C.) $		13,665,850	14,101,425
Elements 30 to 46		319,675	334,658
PROJECT COST - CURRENT DATE $		13,985,525	14,436,083
Escalation to Tender Date			
PROJECT COST - TENDER DATE $			

Reconcilation Statement Layout (Sheet 3)

N. P. W. C. / A. I. Q. S.
R E C O N C I L I A T I O N   S T A T E M E N T

CODE	S.D.C.P. $	T.D.C.P. $	INCREASE $	DECREASE $	REASONS FOR MOVEMENT OTHER THAN B.P.I.
01 SB	684,335	695,264	10,929	-	Additional basement floor area
02 CL	304,780	309,636	4,856	-	No change
03 UF	2,683,734	2,726,494	42,760	-	No change
04 SC	181,260	184,148	2,888	-	No change
05 RF	408,615	415,125	6,510	-	No change
06 EW	1,221,088	1,240,543	19,455	-	No change
07 WW	1,019,318	1,012,899	-	6,419	Window sills changed to Tasmanian Oak
08 ED	21,323	21,663	340	-	No change
09 NW	685,617	768,756	83,139	-	Redesigned toilet and cleaner areas to typical floors
10 NS	116,405	115,327	-	1,078	Toilet partition extent and finish increased
11 ND	132,865	134,982	2,117	-	No change
12 WF	305,534	274,806	-	30,728	Minor changes to extent; H&R Johnson "Waringa" wall tiles in lieu of imported Italian tiles
13 FF	484,315	531,114	46,799	-	Extent reduced; new skirting detail
14 CF	461,923	488,784	26,861	-	Plasterboard sheet changed to 10 thick
		C/F	246,654	38,225	

Cost Statement Summary Layout

N. P. W. C. / A. I. Q. S.
C O S T   S T A T E M E N T   S U M M A R Y   Statement No. 2

Project/Building	Job Ref.	Date
COMMONWEALTH BANK PREMISES TOTAL PROJECT	8404/1	01/04/84

Current Date	01/04/84	Previous Project Cost as	
Current B.P.I.	484.6F	per Statement No. 1	14,200,651
Tender Date	/ /		
Tender B.P.I.		Deduct Savings	135,750
Locality Index	100		
			14,064,901
F.E.C.A.	16,285 m2		
U.C.A.	380 m2	Add Extras	371,182
G.F.A.	16,665 m2	REVISED PROJECT COST	14,436,083

Remarks:

Minor changes to typical floor layouts and basement plant areas. Redesign of toilet areas generally. Soap dispenser system added. Finishes quality reduced.

Amendments	Elements Affected	Elemental Savings	Elemental Extras
Redesign toilet and cleaner areas to typical floors	NW/NS/WF/FF/CF	66,555	13,996
Tasmanian Oak window sill in lieu of marble	WW	12,500	-
H&R Johnson "Waringa" wall tiles in lieu of imported Italian tiles	WF	45,775	-
Soap dispenser system	SS	-	95,000
Hand driers in lieu of paper towel dispensers	FT/SE	-	68,000
	C/F	124,830	176,996

APPENDIX V

LIST OF STANDARD CONSTRUCTION TYPES AVAILABLE FOR FRAMEWORK "COSTPLANNER"

Feasibility Mode

OOPR PRELIMINARIES

Included in rates (Y/N)	Y
Preliminaries, profit and overheads (DEFAULT)	N

01SB SUBSTRUCTURE

Substructure consisting of:

piers, beams and pads with concrete slab	100
strip footings with concrete slab	
concrete raft slab with thickenings	
concrete raft slab with piers	
piers and beams with timber floor	
strip footings with timber floor	

Basement excavation (Y/N) [_______m3 allowed]	Y
Swimming pool (Y/N)	

02CL COLUMNS

Columns consisting of:

insitu concrete	100
precast concrete	
structural steel	
structural timber	

03UF UPPER FLOORS

Upper floors consisting of:	
insitu concrete	100
precast concrete	
structural steel	
structural timber	
Computer floor (%)	
Integral sunhoods (Y/N)	Y

04SC STAIRCASES

Structure consisting of:	
insitu concrete	100
precast concrete	
structural steel	
structural timber	
Finish consisting of:	
off-form concrete	
cement topping	
granolithic topping	90
marble tiles	
terrazzo	10
carpet	
vinyl	
Handrails (Y/N)	
Balustrades (Y/N)	Y
Spiral staircases (Y/N)	

05RF ROOF

Structure consisting of:	
insitu concrete	80
precast concrete	
structural steel	20
structural timber	
gangnail timber trusses	
large span timber trusses	
structural steel trusses	

Finishes consisting of:

metal deck sheeting	20
concrete tiles	
terracotta tiles	
stone chip tiles	
waterproof membrane with concrete over	
waterproof membrane with quarry tiles over	
waterproof membrane with gravel over	80

Parapet walls (Y/N)	Y
Balustrades (Y/N)	
Eaves lining (Y/N)	
Downpipes and gutters (Y/N)	
Internal stormwater drainage (Y/N)	Y
Skylights (Y/N)	

Add for: raking exceeding 30 degrees (%)

06EW EXTERNAL WALLS

Structure consisting of:

insitu concrete	75
precast concrete	
cavity brick	
solid block	25
brick veneer	
stud framing	
steel framing	
curtain walling	
glazed aluminium frame	
glazed plastic coated steel frame	
glazed timber frame	
frameless glazing	

Finish consisting of:

off-form concrete	
exposed aggregate	75
face brick	25
face block	
timber boarding	
metal cladding	
infill panels	

Add for: paint (%)

07WW WINDOWS

Windows consisting of:

glazed anodised aluminium frame	100
glazed plastic coated steel frame	
glazed timber frame	
Double glazing (%)	100
Reflective glass (%)	100
Sunshading (%)	100

08ED EXTERNAL DOORS

External doors consisting of:

glazed aluminium frame	75
glazed plastic coated steel frame	
glazed timber frame	
solid timber	
fire rated solid timber	20
roller shutters	5

09NW INTERNAL WALLS

Internal walls consisting of:

insitu concrete	50
precast concrete	
solid brick	
solid block	
stud framing	50
steel framing	

10NS INTERNAL SCREENS

Internal screens consisting of:

glazed timber frame	
demountable partitions	20
toilet cubicle partitions	30
frameless glazing	
glazed aluminium frame	50
glazed plastic coated steel frame	
operable wall panels	

Handrails (Y/N)

Balustrades (Y/N)

11ND INTERNAL DOORS

Internal doors consisting of:

glazed aluminium frame	20
glazed plastic coated steel frame	
glazed timber frame	
solid timber	20
fire rated solid timber	50
folding accordian	
toilet doors	10

12WF WALL FINISHES

Wall finishes consisting of:

off-form concrete	
face brickwork	
painted blockwork	
ceramic tiles	20
cement render	60
plasterboard	20
timber boarding	
exposed aggregate	

13FF FLOOR FINISHES

Floor finishes consisting of:

finished as laid concrete	
cement topping	
granolithic topping	
marble tiles	10
terrazzo	
carpet	60
vinyl	10
ceramic tiles	20
quarry tiles	
slate	
sprung timber	
exposed aggregate	
rubber	
brick paving	
special concrete finish	

14CF CEILING FINISHES

Ceiling finishes consisting of:

off-form concrete	
plasterboard	
timber boarding	
plywood	
suspended plasterboard	10
suspended acoustic tiles	70
suspended woodwool tiles	
ripple iron	
textured coating	20
linear aluminium	

Add for: raking exceeding 30 degrees (%)

15FT FITMENTS

Take delivery and fix furniture (Y/N)	Y
Bench cupboards (Y/N)	Y
Storage wall units (Y/N)	
Shelving (Y/N)	Y
Counters (Y/N)	Y
Mirrors (Y/N)	Y
Pin-up boards (Y/N)	
Signs (Y/N)	Y

16SE SPECIAL EQUIPMENT

Food preparation equipment (Y/N)	
Hospital equipment (Y/N)	
Bank safe (Y/N)	Y

17SF SANITARY FIXTURES

>>> Enter quantity (No)	244

Sanitary fixtures consisting of:

toilet suites	30
hand basins	5
vanity basins	30
urinals	15
cleaner's sinks	10
sinks and drainers	10
runnel sinks	
wash troughs	

18PD SANITARY PLUMBING

Sanitary plumbing consisting of:

copper pipework and fittings	
UPVC pipework and fittings	100
cast iron pipework and fittings	

Drainage consisting of:

VCP pipework and fittings	
UPVC pipework and fittings	100

Sewer pits (Y/N)

Plaster arrestor pits (Y/N)

19WS WATER SUPPLY

Copper cold water reticulation (Y/N)	Y
Copper hot water reticulation (Y/N)	Y
Cocks and faucets (Y/N)	Y
Hot water heaters (Y/N)	Y
Boiling water units (Y/N)	Y

20GS GAS SERVICE

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Copper reticulation and fittings (Y/N)

Cocks and valves (Y/N)

21SH SPACE HEATING

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Space heating consisting of:

unitary heaters
reticulated steam system
hot water system
hot oil system
warm air system

22VE VENTILATION

Consultant's estimate (Y/N) Y
Builder's profit, overheads and attendance

Ventilation consisting of:

mechanical ventilators
non-mechanical roof ventilators
ducted systems

Exhaust fans (Y/N)

23EC EVAPORATIVE COOLING

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Evaporative coolers and reticulation (Y/N)

24AC AIR CONDITIONING

Consultant's estimate (Y/N) Y
Builder's profit, overheads and attendance

Package air conditioners (Y/N)

Ducted system including plant (Y/N)

Plenum system including plant (Y/N)

25FP FIRE PROTECTION

Copper fire hose reel service (Y/N)	Y
Copper hydrant service (Y/N)	Y
Copper sprinkler service (Y/N)	Y
Fire extinguishers (Y/N)	Y
Automatic fire detection and alarm system (Y/N)	Y

26LP ELECTRIC LIGHT & POWER

Consultant's estimate (Y/N) Y
Builder's profit, overheads and attendance

Reticulation lighting and power outlets (Y/N)

Distribution boards (Y/N)

27CM COMMUNICATIONS

Consultant's estimate (Y/N) Y
Builder's profit, overheads and attendance

Telephone system (Y/N)

Public address system (Y/N)

Closed circuit TV (Y/N)

28TS TRANSPORTATION SYSTEMS

Consultant's estimate (Y/N) Y
Builder's profit, overheads and attendance

Passenger lifts (Y/N) [__ No. allowed stage 1]
[__ No. allowed stage 2]
[__ No. allowed stage 3]

Goods lifts (Y/N)

Hoists and conveyor system (Y/N)

Escalators (Y/N)

Monorail beams (Y/N)

29SS SPECIAL SERVICES

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Staircase pressurisation system (Y/N)

Security system (Y/N)

Waste disposal system (Y/N)

Lightning protection (Y/N)

Cool rooms (Y/N)

30CE CENTRALISED ENERGY SYSTEM

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Central plant and reticulation (Y/N)

Building works (Y/N)

31AR ALTERATIONS

Renovation and redecoration (Y/N)

Demolitions (Y/N)

SITE WORKS

Site area consisting of:

roads, footpaths and paved areas	50
outbuildings and covered ways	
landscaping	50
resurfacing paved and grassed areas	
unaltered site	

32XP SITE PREPARATION

Site clearance (Y/N)	Y
Bulk excavation and filling (Y/N)	Y

Retaining walls (Y/N)

Site demolitions (Y/N)

Underpinning (Y/N)

33XR ROADS, FOOTPATHS AND PAVED AREAS

Paved areas consisting of:

bituminous roadways	10
concrete footpaths	
brick paving on sand	90
brick paving on concrete	
Kerbs and gutters (Y/N)	Y
Crossover (Y/N)	
Bollards (Y/N)	

34XN BOUNDARY WALLS, FENCING AND GATES

Chain wire fence (Y/N)	
Hardwood paling fence (Y/N)	
Masonry walls (Y/N)	Y
Gates (Y/N)	

35XB OUTBUILDINGS AND COVERED WAYS

Covered ways (%)

Shed (%)

Cottage (%)

Bridge link (Y/N)

36XL LANDSCAPING AND IMPROVEMENTS

Landscaping and improvements consisting of:	
turfing mass planting light planting	100
Seating (Y/N)	Y
Fountains (Y/N)	
Flagpoles (Y/N)	Y
Swimming pool (Y/N)	

37XK EXTERNAL STORMWATER DRAINAGE

Stormwater drainage consisting of:	
VCP and RCP pipes and fittings UPVC and RCP pipes and fittings	100
Subsoil drainage (Y/N)	Y
Sumps and pits (Y/N)	Y
Headwalls (Y/N)	
Connect to main (Y/N)	Y

38XD EXTERNAL SEWER DRAINAGE

Sewer drainage consisting of:	
VCP and RCP pipes and fittings UPVC and RCP pipes and fittings	100
Inspection pits (Y/N)	Y
Boundary trap (Y/N)	
Septic tanks (Y/N)	
Absorption trenches (Y/N)	
Grease arrestor (Y/N)	
Connect to main (Y/N)	Y

39XW EXTERNAL WATER SUPPLY

Copper cold water reticulation (Y/N)	Y
Water meter (Y/N)	Y
Hose cocks (Y/N)	Y
Connect to main (Y/N)	Y

40XG EXTERNAL GAS

Consultant's estimate (Y/N) Builder's profit, overheads and attendance	
Copper reticulation (Y/N)	
Connect to main (Y/N)	

41XF EXTERNAL FIRE PROTECTION

Copper fire hose service (Y/N)	Y
Copper hydrant service (Y/N)	Y
Booster valve (Y/N)	Y

42XE EXTERNAL ELECTRIC LIGHT & POWER

Consultant's estimate (Y/N) Builder's profit, overheads and attendance	Y
Consumer's mains (Y/N)	
External lighting (Y/N)	
Main switchboard (Y/N)	
Sub-station equipment (Y/N)	
Connect to main (Y/N)	

43XC EXTERNAL COMMUNICATIONS

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Telephone mains (Y/N)

Public address system (Y/N)

44XS EXTERNAL SPECIAL SERVICES

Consultant's estimate (Y/N)
Builder's profit, overheads and attendance

Security system (Y/N)

45XX EXTERNAL ALTERATIONS AND RENOVATIONS

External alterations consisting of:

- resurfacing paved areas
- resurfacing grassed areas

Renovation and redecoration (Y/N)

Demolitions (Y/N)

46YY SPECIAL PROVISIONS

Rock excavation (Y/N) Y

Contract contingency (Y/N)

Sketch Design/Tender Document Mode

The following is a sample list of standard construction components used during either sketch design or tender document modes to arrive at elemental costs. In order to illustrate the hierarchy involved, both sketch design and tender document components are integrated--the latter is indented. Sub-elemental and default special codes are provided but example quantities, unit rates and total costs are not shown for clarity.

01SB SUBSTRUCTURE

SBXB	Basement excavation. (m3)
<A>	Excavate for basement. (m3)
<A>	Planking and strutting. (m2)
SBXS	Swimming pool excavation. (m3)
<A>	Excavate for swimming pool. (m3)
<A>	Planking and strutting. (m2)
SBXF	Foundation excavation. (m2)
<A>	Excavate for slabs and thickenings. (m3)
<A>	Excavate for footing beams. (m3)
<A>	Excavate for strip footings. (m3)
<A>	Excavate for pads. (m3)
<A>	Excavate for 600 diam. piers. (m)
<A>	Planking and strutting. (m2)
SBCP	Column pads and pedestals. (m2)
<B>	Concrete in pads. (m3)
<B>	Formwork to edges of pads. (m2)
<B>	Bar reinforcement in footings. (t)
SBPR	Piles and piers. (m)
<B>	Concrete in piers. (m3)
<B>	Bar reinforcement in footings. (t)
SBCS	Caisson piles and piers. (m)
<B>	Concrete piles. (m)
SBSF	Strip footings. (m2)
<B>	Concrete in strip footings. (m3)
<B>	Formwork to sides of strip footings. (m2)
<B>	Bar reinforcement in footings. (t)
<B>	Fabric reinforcement in footings. (m2)
SBFB	Foundation beams. (m2)
<B>	Concrete in footing beams. (m3)
<B>	Formwork to sides of footing beams. (m2)
<B>	Bar reinforcement in footings. (t)
<B>	Fabric reinforcement in footings. (m2)

SBWG Walling. (m2)
<B> Concrete in walls. (m3)
<B> Formwork to sides of walls. (m2)
<B> Bar reinforcement in walls. (t)
<B> Fabric reinforcement in walls. (m2)
<B> 0.20 thick polythene sheeting. (m2)

SBDA Drop aprons and earth stops. (m2)
<B> Concrete in drop aprons. (m3)
<B> Formwork to sides of drop aprons. (m2)
<B> Bar reinforcement in drop aprons. (t)
<B> Fabric reinforcement in drop aprons. (m2)
<B> 0.20 thick polythene sheeting. (m2)

SBFN External finishes. (m2)
<J> Exposed aggregate. (m2)

SBGS Ground slabs. (m2)
<B> Concrete in ground slabs. (m3)
<B> Formwork to edge of slabs. (m2)
<B> Bar reinforcement in ground floor. (t)
<B> Fabric reinforcement in ground floor. (m2)
<B> 100 thick fine crushed rock basecourse. (m2)
<B> 0.20 thick polythene sheeting. (m2)
<A> Termite treatment. (m2)

SBSS Suspended slabs. (m2)
<B> Concrete in suspended slabs. (m3)
<B> Formwork to edge of slabs. (m2)
<B> Bar reinforcement in ground floor. (t)
<B> Fabric reinforcement in ground floor. (m2)
<B> 100 thick fine crushed rock basecourse. (m2)
<B> 0.20 thick polythene sheeting. (m2)
<A> Termite treatment. (m2)

SBTF Timber framed floors. (m2)
<A> Excavate for isolated piers. (m3)
<C> Brick piers. (m3)
<F> 100x75 hardwood bearers. (m)
<F> 100x50 hardwood joists. (m)
<F> T&G hardwood flooring. (m2)

SBES Open entrance steps and ramps. (m2)
<B> Concrete in entrance steps and ramps. (m2)
<B> Formwork to edge of steps and ramps. (m2)
<B> Formwork to step risers. (m)
<B> Bar reinforcement in ground floor. (t)
<B> Fabric reinforcement in ground floor. (m2)
<J> Exposed aggregate. (m2)

SBSD Subsoil drainage. (m)
<N> 90 diam. agricultural pipe. (m)
<N> 900x900x600 inspection pit. (No.)

SBST Service tunnels. (m)
<A> Excavate for service tunnels. (m3)
<A> Planking and strutting. (m2)
<B> Concrete in service tunnel slabs. (m3)
<B> Concrete in service tunnel walls. (m3)
<B> Formwork to soffit of slabs. (m2)
<B> Formwork to sides of walls. (m2)
<B> Bar reinforcement in service tunnels. (t)
<B> Fabric reinforcement in service tunnels. (m2)
<B> 0.20 thick polythene sheeting. (m2)

SBDB Ducts, bases and miscellaneous pits. (-)
<N> 900x900x600 inspection pit. (No.)

SBSP Swimming pools. (m2)
<B> Concrete in swimming pool base. (m3)
<B> Concrete in swimming pool walls. (m3)
<B> Formwork to side of walls. (m2)
<B> Bar reinforcement in swimming pool. (t)
<B> Fabric reinforcement in swimming pool. (m2)

SBNE Not elsewhere included in SB. (%)

<construction components continue in this manner>

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