An investigative study of value engineering in the United States of America and its relationship to United Kingdom cost control procedures

by

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Abstract

The aim of this thesis is to make an investigative study of value engineering (VE) in the United States. The purpose is to establish if current United Kingdom cost control procedures could benefit from value engineering.

The study examined the system of value engineering that exists in the US, along with the design procedures within which it prevails. The examination was based on a survey, analysis of fifty-five completed VE studies and attendance at four VE workshops. A comparison of VE practice in the US was made with UK procedures to establish whether VE is supplementary to UK cost control. Any supplementary components were analysed for effective integration into UK systems. This analysis was based on examination of existing UK cost control, coupled with the opinions, obtained by interview, of twenty British professionals with VE experience either in the UK or USA.

The study produced the following conclusions,

1. Value engineering originally developed in manufacturing as a broad philosophy based on the technique of function analysis. Adapting value engineering for the construction industry in the USA distorted the technique of function analysis from its original principles.

2. Despite this, value engineering in the United States is effective in reducing construction cost by approximately 10%. However, this saving cannot be attributed to function analysis and is the result of other, broader, factors.

3. The practice of value engineering in the US offers only two components which do not exist in the UK cost planning system. First, VE is an autonomous approach and second it is carried out by an external team.

4. This autonomous approach by an external team is fraught with difficulties in the US. It is likely that these difficulties would also occur in the UK. In addition, British design procedures are not conducive to the application of US value engineering practice. Possibly as a result of this the majority of UK companies involved in VE have developed alternative systems. These systems appear to be based on an adaptation of American practice.

5. Function analysis could possibly be of benefit in the UK. The technique of function analysis however is largely a design orientated process that has no direct relationship to cost. The technique is not independent and it's successful implementation is influenced by other factors.

Declaration

No portion of the research referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other University or other Institution of learning.

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Chapter 1

Introduction

1. Introduction to subject matter

Design teams in both the United States and the United Kingdom, when designing a construction project, attempt to control its cost.

Reference to the University of Reading's (1979) report illustrates that US cost control contains a system of value engineering which does not exist in its UK counterpart. Since the 1979 report this aspect of cost control has developed strongly in the US, to the extent that the Department of Defence and the General Services Administration now require that value engineering be used on all of their construction contracts.

The last five years have witnessed the arrival of value engineering in the UK. The greetings extended to it have been mixed. Hartfield (1989) advocated VE as:

"a form of building appraisal that makes for faster, cheaper, better construction".

Eszenyi (1984) on the other hand doubted the validity of such claims:

"The ways in which the savings in question were achieved are seldom demonstrated/documented. You have to believe - or you may even doubt - the success without being able to check the results."

Kelly and Male (1990) although not doubting the validity of VE in the US raised the question that it may already exist in UK procedures:

"Professionals interviewed in the United Kingdom ... are unable to distinguish between value management and the current cost planning service".

They further questioned whether claims to VE success were merely:

"cost reduction exercises masquerading as value management".

The development of VE in the UK appears to be hindered by two factors. Firstly the British believe that VE is already inherent in existing cost control procedures. Secondly there is no evidence to date to prove that VE is effective in either reducing cost, or in reducing cost other than by traditional cost reduction techniques.

2. Objectives of the research

The objectives of this research are fourfold:

1) to define value engineering;

2) to test the effectiveness of the US system of VE as a means of reducing cost and to investigate if any reduction achieved is other than by traditional cost reduction methods;

3) to investigate whether US VE is additional to, or inherent in, current British cost control procedures; and

4) to determine how VE can be best employed in the UK.

3. Need for the research

The need for the research in the UK springs from three merging themes,

1) Clients who are unsure whether the use of value engineering substantiates payment of additional fees.

2) Design teams wary of VE being used to their detriment.

3) Quantity surveyors unsure if, and how, to include VE in their portfolio of services.

4. Research methodology

The research was carried out using the hypothetico-deductive method. Research methods are detailed in chapter 4.

5. Context of the study

This work is an investigation of value engineering in the United States and its relationship to United Kingdom cost control procedures. The scope of the study is limited to UK cost control procedures under the 'traditional' procurement method, that is, the system as laid down by the RIBA plan of work (1973). Cost control, as opposed to any other procedures, were selected as the basis of investigation because it was in this area that interest in VE appeared to be developing most strongly. This was highlighted by the RICS in their QS 2000 report (1990) which outlined value management as one of three core areas of future practice. Further, the more abundant cost control procedures that exist in the UK over its US counterpart are often argued to encompass VE procedures.

6. Guide to the thesis

The first stage of the thesis, contained in chapters 2 and 3, was to make a review of VE literature followed by a critique. This allowed precise definition of the problem statement and formulation of the research propositions. The research propositions consisted of five statements and a separate chapter is devoted to the examination of each statement. The overall picture presented by the research propositions begins, in chapters 5 and 6, with the investigation of VE practice and a measure of its output.

Chapter 7, makes a comparison of VE with UK cost control, highlighting those components that are supplementary to the former system.

Chapter 8 examines how well the supplementary components of VE would be received in the UK. Finally chapter 9 makes pilot investigation into the technique of function analysis.

7. Summary of main conclusions

The research drew the following major conclusions,

1. Value engineering originally developed in manufacturing as a broad philosophy based on the technique of function analysis. Adapting value engineering for the construction industry in the USA distorted the technique of function analysis from its original principles.

2. Despite this, value engineering in the United States is effective in reducing construction cost by approximately 10%. However, this saving cannot be attributed to function analysis and is the result of other broader, factors.

3. The practice of value engineering in the US offers only two components which do not exist in the UK cost planning system. First, VE is an autonomous approach and second it is carried out by an external team.

4. This autonomous approach by an external team is fraught with difficulties in the US. It is likely that these difficulties would also occur in the UK. In addition, British design procedures are not conducive to the application of US value engineering practice. Possibly as a result of this the majority of UK companies involved in VE have developed alternative systems. These systems appear to be based on an adaptation of American practice.

5. Function analysis could be of possible benefit in the UK. The technique of function analysis however is largely a design orientated process that has no direct relationship to cost. The technique is not independent and it's successful implementation is influenced by other factors.

Chapter 2

Value engineering literature

1. Introduction

Value engineering (VE) developed during World War II in the United States. Its roots lay in the search for alternative components, a shortage of which had developed as a result of the Second World War. Due to the war however, these alternative components were often equally unavailable. This led to a search not for alternative components but to a means of fulfilling the function of the component by an alternative method. It was later discovered that this process of function examination produced cheaper overall products without reducing quality and after the war the system was maintained as a means of removing unnecessary cost from products. The process of VE based on examination of function was therefore born. The element of function examination separated VE from traditional cost reduction techniques.

Up until the early sixties VE was confined to manufacturing and process industries. It was not until 1963 that it was introduced by the US Department of Defence into construction contracts. Value engineering later became a requirement of all construction contracts for the US Public Building Services, the Environmental Protection Agency and the Department of Transport.

This separate development of VE in the manufacturing and construction industries is reflected in the available value engineering texts. The first text, written in 1961, concentrated solely on manufacturing and it was not until 1972 that a text appeared based on VE in the construction industry.

The examination of VE literature in this chapter conforms to this manufacturing/construction divide. The years 1961 to 1972 deal with VE in manufacturing, whilst 1972 to present day examines the development of VE in construction.

2. VE in manufacturing, 1961 to 1972

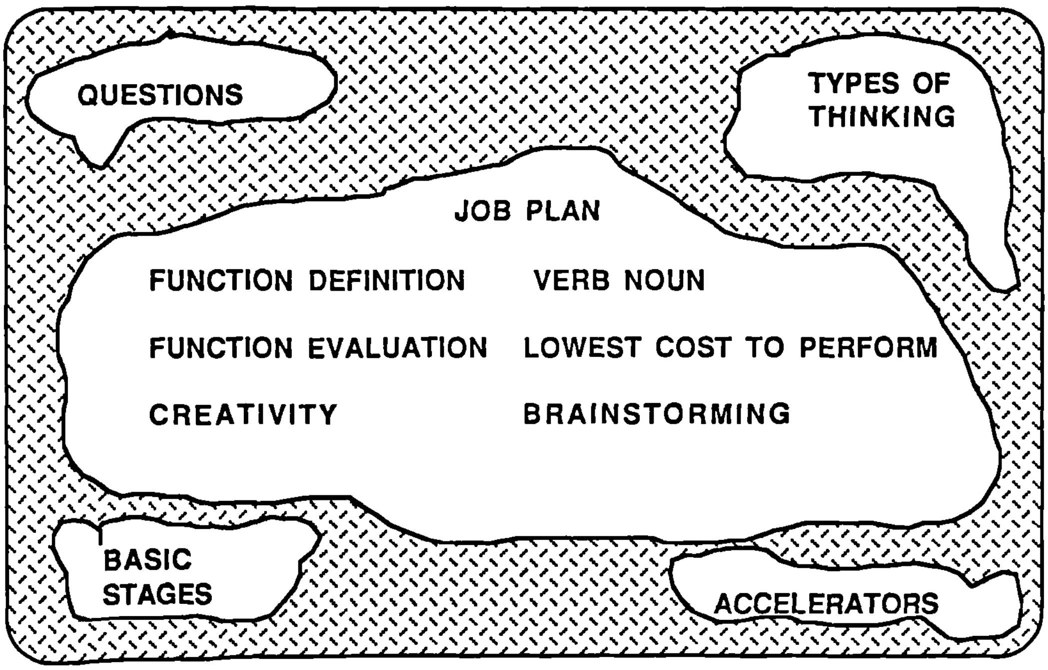
2. 1 Introduction

Over the decade 1961 to 1972 VE was concentrated in the manufacturing and process industries. During this period value engineering developed from a general all-embracing philosophy into a much narrower technique. This development maintained and emphasised the fundamental principles of VE but tended to dispense with its broader issues. The following section traces the development of VE from philosophy to technique.

2.2 The value engineering philosophy of Miles

The original value engineering concept developed by Miles (1961 and 1967) was a broad based philosophy. Its aim was the elimination of unnecessary cost - that is cost incurred that adds nothing to the product or its ability to sell. Miles' philosophy is illustrated in Figure 1.

Figure 1 - The value engineering philosophy of Miles



Miles' philosophy consisted of three basic stages, incorporating four types of thinking, built on a questioning approach to problem solving. This approach was organised into a job plan, the operation of which was boosted by results accelerators. These components of the overall philosophy are outlined in greater detail below.

2.2.1 Basic stages and types of thinking

Miles outlined that value engineering, in its capacity as a problem solving technique, aimed at eliminating unnecessary cost, operates in three basic stages.

1. Mind tuning or preparation of the mind.

2. The employment of four different types of thinking namely:

    i. accumulation of information;
    ii. penetrating analysis;
    iii. creative mental activity;and
    iv. judgment type mental activity.

3. Development and refinement activity which puts the thinking into use.

2.2.2 Questions

The fundamental approach behind these basic stages is the asking of, and obtaining answers to, a series of questions about the subject, namely:

i. what is it?
ii. what does it cost?
iii. what does it do?
iv. what else would do? and
v. what does that cost?

These questions and their subsequent answers supply objective data to decision makers or designers of a product that allows them to select suitable design alternatives at a lower cost.

2.2.3 Job plan

In order to study a product Miles recommended that the basic stages and questions be arranged into a systematic format. This format he termed the job plan, which encompasses a series of stages to be followed for effective value engineering studies. There are five phases,

1. Information phase.
2. Analytical phase.
3. Creative phase.
4. Judgment phase.
5. Development phase.

1. Information phase

This stage involves collecting information on the existing product with regard to costs, quantities, general design etc.

2. Analytical phase

This stage involves the examination of the functions which the product under study is required to perform. The understanding of product function is critical to the VE process. In order to fully appreciate customer requirements, functions need to be identified, clarified and named. Miles outlined a two-stage procedure for doing so; define the function and evaluate the function.

A. Define the function

All requirements of the customer need to be defined in terms of function. This is done by allocating a verb-noun to each item. For example, a customer requires that an electricity supply 'provides light' and 'provides power'.

B. Evaluate the function

Once functions are defined then a value is allocated to each function. Value is defined by Miles as the lowest cost to achieve function with the qualities and specification that the customer requires. This figure of value can be obtained by comparison. The comparison must however be real and historical costs ought not to be relied upon. Miles illustrated an example of a screen for an electric motor that had the following functions,

i. Exclude substance.
ii. Allow ventilation.
iii. Facilitate maintenance.
iv. Please customer.

The values were allocated as follows,

i. The function of 'exclude substance' was evaluated as the cost of sheet metal required to shield the motor.

ii. The function of 'allow ventilation' was based on the additional cost of putting holes in the sheet metal.

iii. 'Facilitate maintenance' was evaluated by adding the cost of a spring clip to the metal to allow its removal.

iv. 'Please customer' was based on the cost of painting the metal.

The cost of providing the functions was calculated as follows,

Exclude substance (sheet metal)	$0. 15
Allow ventilation (extra cost of holes in metal)	$0. 15
Facilitate maintenance (spring clip)	$0. 10
Please customer (paint metal)	$0. 10

	$0. 50

The screen in question, however, was costing $6.

The definition and evaluation of function illustrated above shows how the technique allows the product to be thought of in a different way. The screen did not need to be made of an expensive mesh with complex fasteners, it could fulfil its function in a much simpler way. The cost of the redesigned item was $1. 25, a saving of $4. 75.

3. Creative phase

Once function is defined and evaluated the job plan of Miles moves to the creative phase. This phase encourages the free association of ideas to arrive at alternative methods of achieving function. In order to create the right environment it is important that judgment of ideas is deferred until all alternatives have been generated. The optimum number of people present at the creative phase is between three and ten although good creativity can, according to Miles, be generated by the individual.

4. Judgment phase

This stage of Miles' job plan involves the evaluation of ideas generated at the creative phase. It is carried out by one person in consultation with other attendees of the creative session.

5. Development phase

This stage involves the selection of ideas that will be developed further. This is carried out by an individual in consultation with those responsible for generating the ideas. At this stage those items not considered worthy of further consideration are discarded and the remaining ideas are developed.

2.2.4 Accelerators

Miles' early work recognised that VE is fraught with difficulty and to help overcome this he introduced a series of result accelerators.

The purpose of these accelerators is to inject extra power when the VE techniques are flagging. They encourage the user of VE to avoid generalities such as *"it's not practical"*. They advocate the questioning of products, sources and tolerances and encourage creative thinking by overcoming roadblocks. Examples of roadblocks are *"The customers like it that way"* and *"It doesn't make sense but it is policy"*.

The work of Miles was a general philosophy or method of thinking aimed at the elimination of unnecessary cost. His broad approach is highlighted by his definition of VE:

". . . a philosophy implemented by the use of a specific set of techniques, a body of knowledge and a group of learned skills. It is an organised creative approach that has for its purpose the efficient identification of unnecessary cost, i.e. cost that provides neither quality, nor use, nor life, nor appearance, nor customer features."

In the decade that followed, this definition was narrowed and the philosophy was focussed into a technique. This 'development' is examined further.

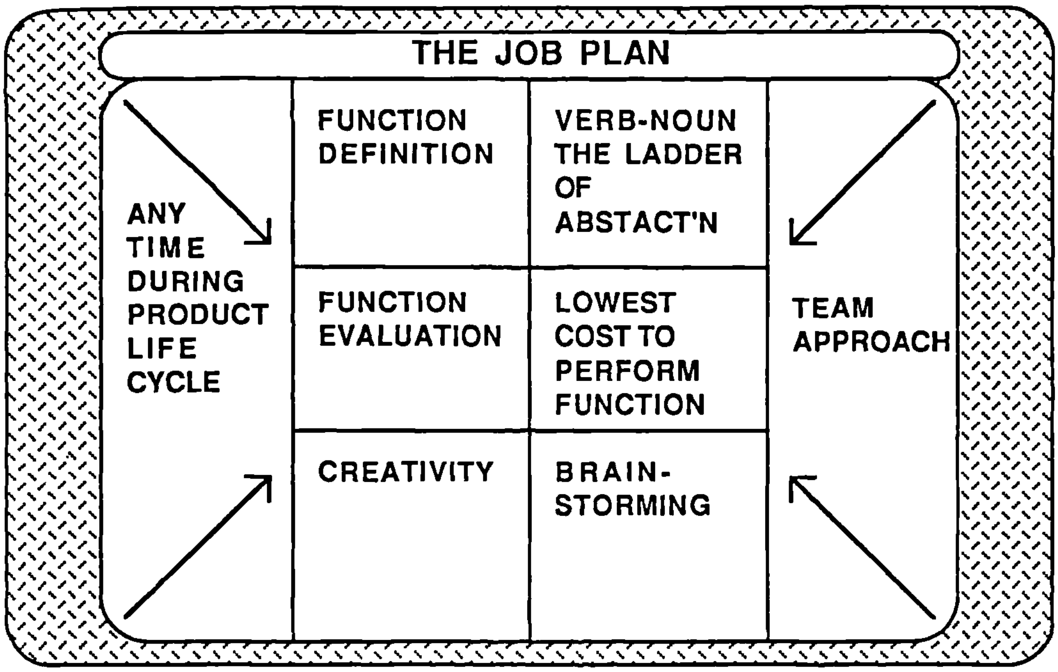
2.3 The development of value engineering in manufacturing; from philosophy to technique

The progression of value engineering over the decade 1961 to 1972 focussed a random all-embracing philosophy into a more systematic framework or technique. Mudge's (1971) definition highlights the more methodical approach:

"... the systematic application of recognised techniques which identify the function of a product or service, establish a monetary value for that function, and provide the necessary function reliably at the lowest overall cost".

This later approach is highlighted in Figure 2.

Figure 2 - Value engineering at the end of the 1960's



The overriding feature of the later approach is the emergence of the job plan as the systematic framework around which VE studies are structured. Within this the technique of function analysis has emerged as the prominent feature of VE. The basic principle of function analysis (the definition and evaluation of function as a means of generating alternatives) has remained unaltered. The ladder of abstraction has been introduced as an aid to function definition and brainstorming has emerged as a means of creativity. In addition the timing of VE studies and the personnel for implementing them have been given greater consideration. Each one of these changes is examined in more detail below.

2.3.1 The ladder of abstraction

Heller (1971) recognised difficulty in implementing the verb-noun and introduced the ladder of abstraction to aid function definition. The technique is based on all words being abstracts in one form or another. The word apple does not fully describe the shape, size and colour of an apple but it is more explicit than fruit, i.e. it is lower in the ladder of abstraction.

Figure 3 - Words as abstracts

FOOD

FRUIT

APPLE

To aid function definition the ladder of abstraction is used along with questions of HOW? and WHY?, moving down and up the ladder respectively. Heller (1971) considers the functions of a pencil.

Figure 4 - Heller's ladder of abstraction

HOW ↓	COMMUNICATE IDEAS TRANSMIT THOUGHT WRITE WORDS MAKE MARKS	↑ WHY

High in the ladder of abstraction is 'communicate ideas' which is the ultimate function of the pencil. This is achieved by 'transmitting thought' in turn achieved by 'writing words' and 'making marks'. Moving up the ladder of abstraction checks the logic by asking the question WHY? Marks are made therefore in order to 'write words', 'transmit thoughts' and ultimately 'communicate ideas'.

The ladder of abstraction shows how function definition moves away from the actual pencil to highlight other, hopefully better ways, of communicating ideas (always providing that this is the true objective).

2.3.2 Brainstorming

Raven (1971) suggests brainstorming as the most effective aid to creativity. It encourages the free flow of as many ideas as possible, however ridiculous they may appear, as a means of arriving at fresh solutions to the problem of fulfilling function.

2.3.3 Timing of VE studies

Miles (1961), although recognising the potential of value engineering on designs, generally assumed the process would be applied to hardware. ASTME (1967) however, based on the premise that 'prevention is better than cure', assumed the opposite. Later authors, Gage (1967), Raven (1971) and Mudge (1971) viewed the process as equally applicable to designs and hardware. Further, these later authors agreed with Miles and ASTME that VE could be applied at any point in a product's life cycle, either as a 'one off' or on-going process.

2.3.4 Responsibility for VE.

Miles (1961) loosely advocated the use of a team in implementing VE. The team approach was more strongly reinforced by Gage (1967), Oughton (1969) and Mudge (1971). Gage went so far as to include the group approach in his definition of value analysis,

"VA. . . involves problem stating by analysis of function and problem solving by formal group creativity."

The team can either be permanent, can operate completely ad hoc, or can maintain a core nucleus, drawing in specialists as required.

2.4 Summary of VE in manufacturing, 1961 to 1972

Miles' (1961) work was fundamentally a broad philosophy which by a questioning approach to processes, systems and components, sought alternatives based on an examination of function. Over the period of 1961 to 1972 the Miles philosophy was rationalised and organised into a much more systematic approach. Although this diminished the broad scope of VE the fundamental principles remained. Value engineering at the end of the sixties was therefore a three pronged attack of function definition based on the verb-noun, function evaluation based on the lowest cost to achieve function, and creativity based on brainstorming. The means of organising these techniques into a systematic framework was the job plan. In addition by the end of this period there was general consensus that a VE study ought to be carried out by a team and that VE is applicable at any stage of a product's life cycle.

3. VE in construction, 1972 to present day

3.1 Introduction

The transition of VE from manufacturing into construction resulted in two major changes. The first was the introduction of the forty hour workshop as a means of carrying out VE studies and the second was the development of two distinct schools of thought on how to apply VE techniques.

Each of these aspects is examined separately.

3.2 The forty hour workshop

The 40 hour workshop is, according to Kelly & Male (1988), the most widely accepted means of carrying out VE studies on construction projects in the US. The workshop is a study implemented away from the 'normal' design environment, over a period of 5 days. The origins of the workshop are murky but it appears that it was the original invention of the US Navy. The Navy constitutes one of the largest VE construction programmes in the US and as such the workshop approach has become acceptable to the rest of the profession. The General Services Administration and the Environmental Protection Agency, both among the largest US VE users, equally recommend use of the workshop.

3.3 Two schools of thought

The thinking on VE in construction can be separated into two distinct schools. These have been termed Ellegant and Dell'Isola to correspond with their leading advocates, although the invention of the systems cannot be entirely attributed to them. Each school is described in greater detail below.

3.3.1 Developments in the Ellegant school

Figure 5. The Ellegant school of thought.

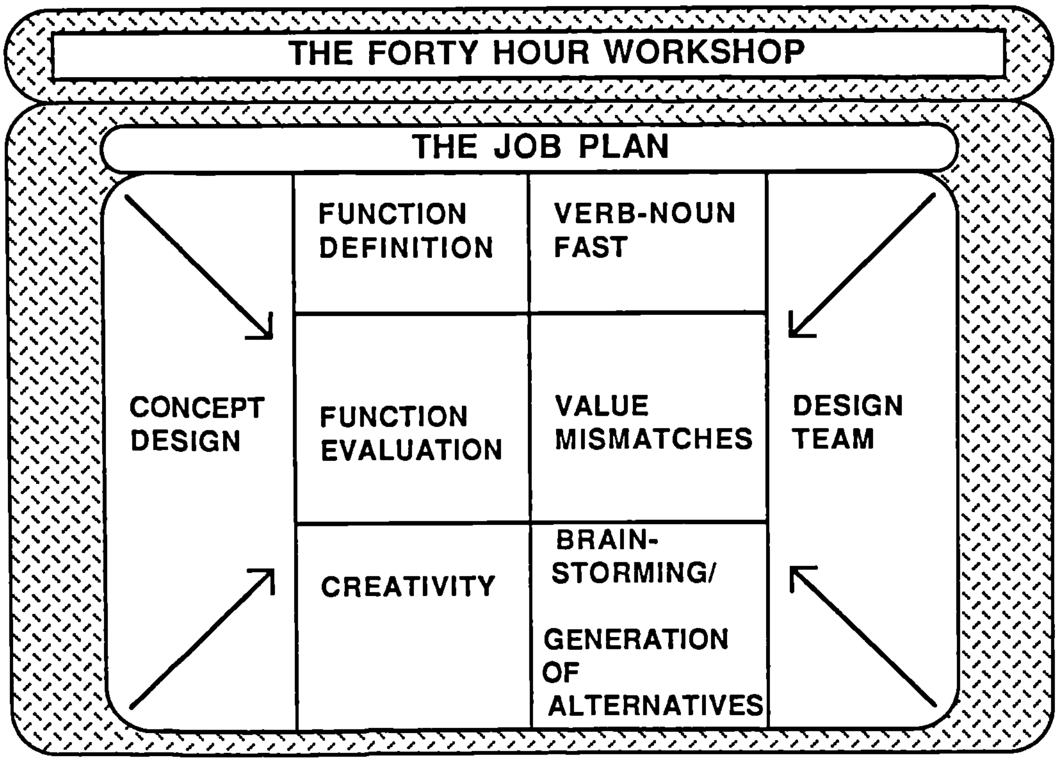


Figure 5 shows that the major developments in the Ellegant School in the application of VE were,

1. The use of FAST diagrams as an aid to function definition.

2. The allocation of actual cost to function, to highlight value mismatches.

3. The use of controlled brainstorming, based on the value mismatches, to generate alternatives.

4. The implementation of the study at the concept design stage.

5. The use of the design team to carry out the study.

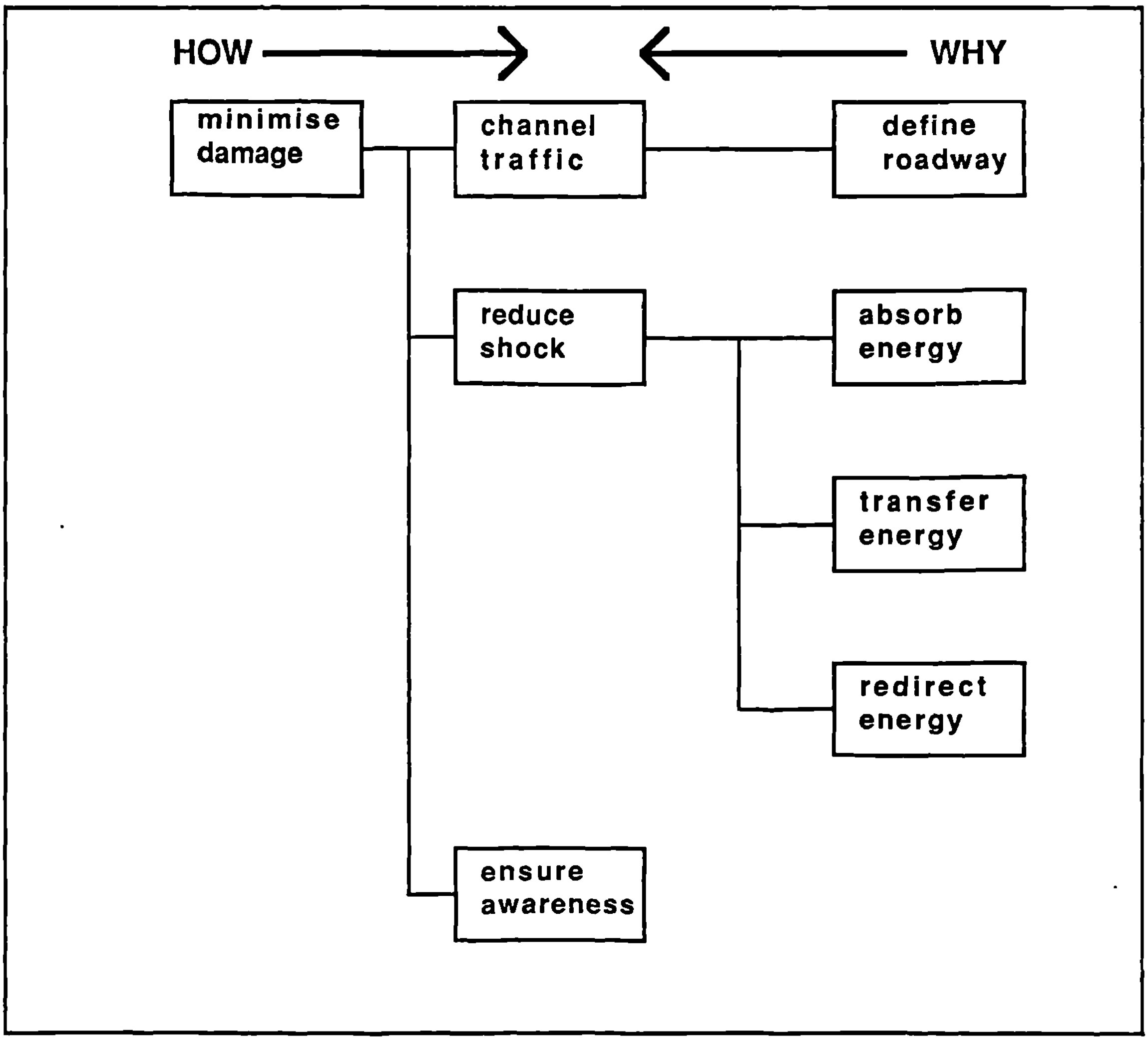
Each item is examined in turn.

1. FAST diagrams as an aid to function definition.

FAST diagrams were developed by Bytheway (1965) and are basically function logic diagrams. They are constructed by asking a series of WHY HOW questions about a particular function. Bill Kelly (1986) illustrates a FAST diagram for a crash barrier which is shown in Figure 6.

The answer to the HOW question lies to the immediate right of the function of which the question is asked. Damage is therefore minimised by three items, channelling of traffic away from the danger, reducing shock in the event of impact and ensuring awareness of the danger. The answer to the WHY question lies to the immediate left, so that the answer to the questions why is traffic channelled, shock reduced and awareness increased, is to minimise damage. Functions are located in time sequence and those occurring concurrently are listed vertically. The advantage of FAST diagrams is twofold, firstly they help to define the problem and secondly they help to break it down into manageable individual problems.

Figure 6 - FAST diagram for a crash barrier



Snodgrass and Kasi (1986) developed their own brand of FAST diagramming called task FAST, designed specifically for use on entire construction projects. This is opposed to the original system of technical FAST which, having been designed for the manufacturing industry could only be used on an assembly or portion of a construction design. Snodgrass and Kasi (1986) outlined the FAST diagram as an integral part of function definition and laid down a three step process for producing one.

A. Identify the function

Snodgrass and Kasi adhere to the verb-noun definition.

B. Categorise the function

All products have one primary user need which Snodgrass and Kasi called the task. This task is performed by interrelated functions. Some of these functions are required to make the product work and are termed basic functions. Any additional function required to make the product sell is termed a supporting function and can be grouped under one of four function headings,

i. Assure convenience.
ii Assure dependability.
iii. Satisfy user.
iv. Attract user.

C. Establish the hierarchy of functions.

Once functions have been defined and categorised they are arranged into a FAST diagram which establishes the hierarchy of functions.

Snodgrass' and Kasi's task FAST still contains the common element of the HOW WHY questions shown in the ladder of abstraction and the technical FAST. The major difference with task FAST is the grouping of supporting functions into four pre-ordained headings.

2. The allocation of actual cost to function to highlight value mismatches.

The basis of allocating actual cost to function is to allow a direct comparison on a function by function basis of actual cost with perceived client worth. The purpose of the exercise is to highlight value mismatches where the cost of a function does not match with the client's perception of what the function is worth. Two examples are shown below.

Snodgrass and Kasi (1986) allocated cost to the functions of a bridge deck designed to carry traffic and pedestrians. The width of the deck was broken down into the following components:

Table 1 Widths of a bridge deck

Component	Width
Pedestrian parapet	300mm
Cycle and pedestrian walkway	1200mm
Parapet	300mm
Kerb	225mm
Shoulder (2 Nr)	900mm
Lanes	7200mm
Middle kerb	225mm
Middle parapet	300mm

Snodgrass and Kasi then allocated functions to each component, for example, shoulder and lanes were given the following functions:

Support Vehicle
Prevent accident
Accommodate disabled vehicles
Prevent skidding

They then allocated the width of the shoulder and lanes amongst the functions using the following steps and highlighted in Table 2,

A. Two lanes of traffic can be supported on 6000mm (2 x 3000mm) therefore the cost of constructing this width is allocated to 'support vehicle'.

B. 1000mm each side of the middle kerb is required to keep vehicles away from the kerb, therefore 2000mm is allocated to 'prevent accident'.

C. 1000mm clear distance is required between lanes in order to maintain a flow of water and therefore 'prevent skidding'. 1000mm of width is therefore allocated to the function of 'prevent skidding'.

D. Snodgrass and Kasi then allocated cost to function by converting the allocated widths into a volume of concrete. The bridge deck was 212mm thick of which 30mm was used to cover the reinforcing bars to prevent corrosion. The widths calculated above were therefore pro-rata to this proportion (212/30) when calculating function cost, so that the 30mm was excluded. The remaining 30mm was allocated to the function of 'extend life'.

Table 2 Component functions

Component	Functions	Width Allocated
Shoulder and lanes 9000mm overall width (7200 + (2 x 900))	Support vehicle Prevent accident Accommodate disabled vehicles Prevent skidding	6,000mm 2,000mm 1,000mm
		9,000mm

This allocation of cost shown above for the shoulder and lanes was completed on all components so that all cost of the bridge deck was allocated to a function and therefore all functions were allocated a cost.

Although none of the recognised VE construction texts implement a function costing for a complete building, this was attempted by Laurie Dennis (1988) under the guidance of Snodgrass. Dennis carried out the study on a California Prison which she separated into nine functional uses.

The construction estimate was compiled by element and each elemental cost was allocated among the functional uses, so that for the foundations, having an elemental cost of $92,750 -

Table 3 California State Prison, foundation costs

Functional use	Foundation cost allocated	Area sq.ft.
Sleep	24, 757	5619
Indoor recreation	34, 267	8, 540
Control room	1, 803	487
Personal hygiene	1, 443	737
Office	1, 443	216
Store supplies	1, 443	386
Store property	0	1
Circulation	19, 208	2151
Mechanical/Electrical	8, 386	654
Total	**92,750**	**18,791**

The allocation of elemental cost was based on an approximate pro-rata of the area occupied by the functional use. This exercise was carried out for each of the major elements so that each elemental cost was allocated amongst the functional uses. Within each functional use, each element was then allocated a function. A completed example is shown in Table 4. These functions and their costs were then transferred to the FAST diagram.

Table 4 California State Prison, allocation of cost to function

Function Use = sleep		
Element	**Function**	**Cost**
Foundation	Allow sleeping	24, 757
Substructure	Allow sleeping	30, 898
	Resist elements	422
Superstructure	Allow sleeping	31, 640
	Resist elements	0
Exterior closure	Confines inmates	211, 372
	Allow sleeping	17, 661
	Resist elements	0
	Allow daylight	0
	Humanise environment	581
Roofing	Resist elements	62, 375
Interior construction	Separate persons	19, 177
	Allow sleeping	24, 230
	Allow privacy	33, 973
	Humanise environment	19, 550
	Allow sleeping	21, 634
Mechanical	Allow sleeping	46, 317
Electrical	Allow sleeping	70, 024
Total		**614, 611**

3. The use of controlled brainstorming based on the value mismatches to generate alternatives.

Once functions and costs are on the FAST diagram the client then allocates his own perception of worth to the functions, thereby highlighting any 'value mismatches'. These indicate areas where the designers have placed emphasis, which the client does not require, or vice versa.

Alternatives are then generated on the mismatched areas. This is known as controlled brainstorming.

Controlled brainstorming was defined by Chamberland (1988) as speculating on only a number of functions highlighted as areas of poor value. This is opposed to open brainstorming which is concerned with the generation of ideas on all aspects of the project.

4. The implementation of the study at the concept design stage.

The manufacturing value engineers viewed VE as a process applicable to any stage of a product's life cycle. Snodgrass and Kasi (1986) and Bill Kelly (1986) however, advocated that VE is most effective when applied in the conceptual stages of a project. It can even, according to Ellegant (1990), be applied before any design is complete, operating on a right first time principle.

5. The use of the design team to carry out the study.

Ellegant (1984) and Barlow (1989) argued that value engineering is most effective if carried out by the design team as opposed to the independent or ad hoc team advocated by earlier texts. Using the design team produces more successful studies and makes implementation easier, as any ideas considered unworkable are eliminated at the evaluation phase.

3.3.2 Developments in the Dell'Isola School

Figure 7. The Dell'Isola school of thought.

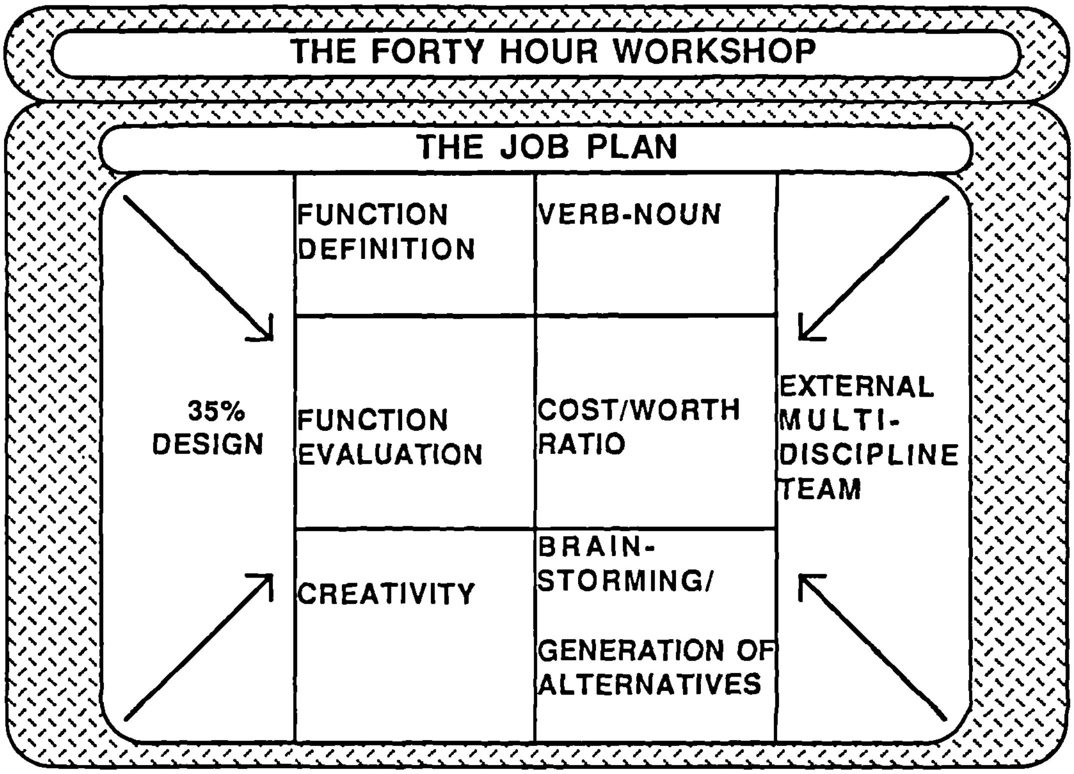


Figure 7 shows that the major developments in the Dell'Isola school were as follows:

1. The use of the cost worth ratio for function evaluation.

2. The use of controlled brainstorming based on the cost worth ratio, to generate alternatives.

3. The implementation of the study at the 35% design stage.

4. The use of a multi-discipline external team to carry out the study.

These are examined below in greater detail.

1. The use of the cost worth ratio

To assist in the evaluation of function and to select areas of poor value Dell'Isola (1988) recommends the use of the cost worth ratio. This is the ratio of the actual cost of a function to its worth. Worth is defined as the lowest cost to perform necessary functions in the most elementary manner feasible. Zimmerman (1982) and O'Brien (1976) also used the cost worth ratio as a means of highlighting areas of poor value.

2. The use of controlled brainstorming based on the cost worth ratio to generate alternatives

Dell'Isola (1988), Zimmerman (1982) and O'Brien (1976) suggested controlled brainstorming be applied to those areas highlighted by the cost worth ratio as poor value and therefore areas of potential cost reduction.

3. The implementation of the study at the 35% design stage

Dell'Isola (1988) recommended an on-going VE programme as opposed to a single VE study. He suggested an initial VE effort that should be no later than the 30% design stage. A second review was proposed at approximately 50% design along with a third review at 90% design. Where only one study was possible Dell'Isola (1988) recommended that it take place at 35% design.

O'Brien (1976) also stressed the importance of the on-going approach to VE. He outlined the major stages in the design process where VE can be applicable,

A. Schematic design (35%)

This stage offers the best opportunity for VE as prior to this a formal design team would not exist. At this stage the VE team could be provided with information on,

i. Layout and site plan
ii. Major elevations
iii. Selection of structural systems

B. Preliminary design (60%)

This stage incorporates information on

i. Architectural design at 1:100
ii. Development of mechanical and electrical schemes
iii. Exterior design development
iv. Outline of materials and specifications
v. Sections

Preliminary design (60%) stage can offer a fairly good opportunity for VE although proposals tend to be of a more technical nature, relating to construction as opposed to concept design.

O'Brien (1976) and Macedo et al (1978) recommended that where there can only be one study it ought to be at the scheme design stage (35%).

4. The use of a multi-discipline external team to carry out the study

Dunstone (1970) recommended that the value engineering team, as well as being multi-disciplinary ought to be an external one, previously unconnected with the project. His opinion is based on the experience of the US Navy who found that designers working on a project were too close to it to make an impartial evaluation of function.

Zimmerman (1982) and Dell'Isola (1988) agree with the Navy's procedures, Zimmerman going so far as to include the presence of an external team as a requisite of successful value engineering,

"In fact one of the requirements of value engineering is that the team members cannot be involved in the original design."

4. Conclusion

The development of value engineering in construction from its inception in manufacturing has been a two-stage process. Firstly the philosophy of Miles (1961) was rationalised into a more methodical structured approach. Secondly VE was adapted for use in construction and two very distinct schools of thought developed. The schools of thought vary on three major issues. First in the implementation of function analysis (definition and evaluation), second on the timing of the study and finally on the make-up of the VE team.

The following chapter makes a critical appraisal of VE literature, tracing its development and examining the two schools of thought that exist in construction.

Chapter 3

A critical review of value engineering literature

1. Introduction

In keeping with the preceding conclusion the first section of this chapter examines the development of VE in manufacturing. This is followed by an examination of value engineering in construction as advocated by the two schools of thought.

2. Value engineering in manufacturing

Miles' (1961) early work on value engineering was a philosophy aimed at the elimination of unnecessary cost, based on an examination of function. What is so striking about Miles' work is its all-embracing nature. He does not confine his activities to the factory floor but encourages a broader view whereby answers to problems are sought from suppliers, from the examination of standards, criteria and tolerances. His philosophy is based on a very questioning approach that constantly searches for better solutions, not only in the manufacturing process but in management organisations, marketing concept, purchasing, procurement and engineering detail.

Within his philosophy Miles outlines various value engineering techniques that aid the search for unnecessary cost. In using these techniques he preaches a certain degree of flexibility that relates to the circumstances surrounding the particular project. However, whichever of the techniques are used all value engineering studies must contain three basic steps,

1. Definition of function.
2. Evaluation of function.

3. Use of the required knowledge coupled with creativity to develop alternatives that accomplish function and cost.

Gage's (1967) thinking accords with Miles. He states that VE is different from other cost cutting exercises in that it defines and evaluates a problem in terms of function and solves that problem by creativity. According to Gage, <u>if these three fundamentals are not embraced then the system employed is not value engineering.</u>

The rationalisation of VE over the decade following Miles maintained this three-pronged attack as the central VE issue. All work of this period agreed that the fundamental principle of VE was function definition based on the verb noun, allocation of value based on the lowest cost to achieve function and creativity. However in the development of VE in manufacturing there was one fundamental deviation from the original thinking.

Miles' work is clear that definition of function is based on what the customer wants. It is not based on the existing functions which the product performs. The later work of Mudge (1971) takes the latter approach by defining functions of existing parts. Although subtle, this is a significant difference. There is clearly a disparity between what the customer wants and what he actually gets; that is why there is a need for value engineering. Miles' starting point for VE is what the customer wants, whereas Mudge begins with what the customer gets. Within these two methods there is a great degree of overlap, but the fundamental approach is different.

Mudge, therefore defined existing function, whereas Miles defined customer requirements. Defining existing product functions however is not as effective as defining client or customer requirements. Firstly it is more difficult. It is harder to establish the function of an existing product than it is to define a function the customer wants, because the designer's original intention may not be available. Secondly, the interaction of components may not be easy to separate. In addition, the function of an existing product is not always easy to establish because design exists at different levels. For example, a bolt has the purpose of securing something in position in order to meet a more general function. Is the function of the bolt therefore to meet the general function or is it merely to 'secure position'? Finally, it is not a logical approach to define existing product function, as this does, to an extent, admit components have a function before it has been proved. It is the VE equivalent of the philosophical statement. . . .

"I think therefore I am"

3. Value engineering in construction

The two schools of thought that exist in construction differ in broad terms on three major issues. Firstly on the use of function analysis (definition, evaluation), secondly on the timing of studies and thirdly on the composition of the VE team. On the one hand the Ellegant school advocates a study at the concept design stage, using the design team, employing FAST diagrams and value mismatches. The Dell'Isola School by contrast recommends a study at the scheme design stage, with an external team, employing the cost worth ratio as a means of highlighting areas of poor value. The three contentious issues are examined below.

3.1 Function analysis: The Dell'Isola school of thought

The Dell'Isola school function analysis consists of function definition based on the verb-noun and function evaluation based on the cost worth ratio. This approach is examined below.

3.1.1 The verb-noun function definition

An example of function definition was given by Zimmerman (1982) and is reproduced in Table 5.

Table 5 Components and functions of a bridge (Zimmerman)

Component	Function
Excavation	Prepare site
Piles	Transfer load
Footing	Distribute load
Shafts	Elevates load
Spanning members	Support deck
Bridge deck	Supports traffic
Parapets	Protect traffic
Embankments	Elevates roadway
Roadway	Supports traffic
Drainage	Directs flow
Expansion joints	Allows movement
Protective coatings	Reduce maintenance
Bridge bearings	Support structure
Misc. road items	-
Lighting	Provides safety
Mobilisation	Prepares construction.

The above example contains a series of serious flaws.

1. The striking factor of this function definition is that it only defines functions of construction elements. This appears to limit the scope of VE in that it only encourages the search for alternative elemental solutions by relating to the actual construction, as opposed to the design of the bridge.

2. Excavation is not a component of a building, it is a means to an end. The function of an excavation is always to prepare the site. The definition of the function of excavation as 'prepare site' leads to the question 'how can the site be prepared other than by excavating?' It could be argued that asking the 'how' question automatically leads to alternative methods of excavating; by hand, by machine etc.

However, these solutions could be arrived at without defining function by simply asking 'what other methods of excavation are available?'. It is difficult to see how creativity is promoted with this type of function definition.

3. The separation of foundations into footings and piles relates to how the bridge is being constructed and not to how it is being used. Piles are the solution to a problem of how to support the bridge. By including them as a component merely stifles creativity in that it locks into the solution of piles. It examines only the solution and not the problem. Had the component been given as foundations, having the function of 'support bridge', then the creativity aspect is introduced, since it leads to alternative methods of how to support the bridge. This might propose a suspended bridge which could provide the best solution. The function of 'transfer load', however, indicated as the function of piles, only locks the VE team into other methods of transferring the load and not of supporting the bridge.

4. The function of drainage is not to direct flow. The true function of drainage on a bridge is to prevent flooding. This could be done in a number of ways, including construction of a roof over the bridge. If the assumption is made that drainage directs flow then the system of piping is immediately locked into and once again creativity is stifled.

5. The function of an expansion joint is not to allow movement - it is to prevent cracking, which it does by allowing movement. The prevention of cracking can be achieved in ways other than allowing movement.

6. The inclusion of mobilisation and miscellaneous road items makes nonsense of the whole system of function definition. It is clear that the components have been taken directly off an estimate of cost.

7. The example does not make clear that it was ever established that a bridge was in fact the best solution to the problem. If function analysis had been used correctly then it may have pointed to a tunnel as a better alternative.

Similar examples of 'elemental' function definition exist in Dell'Isola (1988) and O'Brien (1976). The fundamental problem with this type of definition is one of level. A building design can exist at two levels: concept design and elemental solution. There can clearly be advantages in defining functions of either. Function definition at the concept design stage can focus onto client requirements so that only required functions are included in the project. Once design is more developed function definition can be applied in the narrower field of the building's elements. This can prove equally advantageous. Windows in shops have entirely different functions than windows in prisons and correctly defining their function can assist in effective design.

The example posed by Zimmerman (1982) however cannot be classified into this latter category. The function definition outlined, appears to be an autonomous definition that does not relate the components to the project. Zimmerman defines the function of a drain as direct flow - but this is the function of <u>any</u> drain, it is *not necessarily* the function of a drain on this particular project.

In addition the elemental function definition of the Dell'Isola school has other problems.

1. It deals only in existing functions. There can be no proof that these bear any relationship to required function.

2. A building can consist of many elements. Defining all functions of all elements would be a very lengthy process.

3. The functions of all elements do not change with the project type. Foundations of a building almost always support load. In such circumstances there is little purpose in defining function.

4. Elemental components interact with one another and no account for this is made.

5. An element can serve many different functions. A wall can 'support floor', 'enclose space', or 'provide security'. The Zimmerman approach does not appear to account for this.

3.1.2 The cost worth ratio

O'Brien (1976), Zimmerman (1982) and Dell'Isola (1988) use the cost worth ratio as a means of highlighting poor value in a particular function. This section of their work is a deviation from the thinking of Miles (1961). In the computation of worth, Miles clearly stated that the search must culminate in the cheapest possible solution that fulfils function. All three authors stray from this definition. O'Brien is particularly overt in his disagreement, illustrating an example of a pencil. In a previous evaluation, based on the lowest cost to achieve function, the pencil's worth was equated to a nail that 'makes marks'. O'Brien feels that this is unrealistic and the comparison of worth ought to be the lowest acceptable quality of pencil. This misses the point completely, as the idea is to evaluate the function, not the pencil. The comparison of the nail allows the value engineer to think creatively because if a nail will do the job what else will? Lead, chalk, a finger in powder, a wet finger - this is the basis of creativity - it allows the mind to think about a problem in a different way.

In an example of evaluation of worth Dell'Isola (1988) allocates to the external walls of a superstructure the function of 'support floors'. The cost of the walls is $147,121 and they are allocated a worth of $100,000. This is incorrect. The worth allocated to 'support floors', $100,000, could not amount to 60% of total cost because the floors could be supported on acro props at a fraction of this cost. Dell'Isola has not allocated worth based on the lowest cost to perform function but on the cost of a cheaper alternative. In doing this Dell'Isola is limiting his search for alternatives to cheaper elemental solutions. This is only a traditional method of cost cutting.

In addition the actual definition of function cannot be acting as an aid to creativity. If it were then the definition of function as 'support floors' would have generated an alternative costing less than £100,000.

It appears that the Dell'Isola school pay only lip service to function analysis; in reality the process appears to be largely inert.

The elemental definition of function and the cost worth ratio appear to do little, other than apportion elemental cost to highlight those areas that cost more than average. The purpose of this, it appears, is to generate alternatives to pre-determined elemental solutions in an attempt to reduce cost.

In the light of this it is difficult to envisage that the Dell'Isola school offers anything other than a cost cutting service. Despite paying lip service to it, the three fundamentals of VE: function definition; function evaluation; and creativity: appear to be missing.

3.2 Function analysis: The Ellegant school of thought

The Ellegant school uses the verb-noun as a means of defining function. In addition it uses FAST diagrams to structure functions to show their importance in an overall hierarchy of project requirements. Functions are evaluated by allocating actual cost to function and comparing this with the client's perception of worth. This approach is examined below.

3.2.1 The verb-noun function definition

Ellegant (1989) recognises that the scope of VE as practised by the Dell'Isola school is limited. He argues that few value engineers practise function analysis correctly. Few practitioners in defining function go beyond 'support load' (as illustrated by Zimmerman) and do not encourage the team to distinguish between components and real functions, resulting in cost reduction and not VE. Ellegant (1989) argues that in order to provide value, the study of function and its relationship to cost is paramount. The VE team must understand why the owner builds and not what he builds.

It was recognised in the examination of the Dell'Isola school function analysis, that a project's design can exist at two levels: concept design and elemental solution. The concept design can be further divided into the overall structure and the requirements of space and layout within that overall structure. For example the overall structure of a school, is made up of spaces: classrooms, canteens, sports areas. It is in addition constructed of a series of elements: foundations, walls, roofs. Dell'Isola applies function definition (albeit incorrectly) to the elements whereas Ellegant is in favour of defining requirements within the overall structure. Is this however the most effective level when trying to define the functions of existing designs?

Defining the functions of the structure as a whole is problematic because the functions of buildings relate to much more than client requirements. A University client may wish to educate students, facilitate research and raise funds (not necessarily in that order of priority). He does not need a building to do this. His real need for a building springs from other sources. Permanence, tradition, planning control, building regulation approval, investment, organisation, competition and marketing. In addition the actual number of functions of an overall structure may be infinite. The function of a hospital could be said to be the extension of life on the one extreme, down to the treatment of scratches at the other. In between lies a multitude of other functions which could be political, social, economic or medical. Attempting to establish all functions of an overall structure appears to be an impossibility.

Assuming that a function analysis cannot be based on the overall structure, should function definition be based on space or elements or both?

The definition of space is useful in establishing client requirements and generating alternatives to them. The function of a restaurant in a discotheque is far removed from the function of a restaurant in a hospital. Function definition can highlight this and aid effective design.

Defining functions of elements in relation to a particular structure can also aid design in that the external walls of a bank serve different functions than the external walls of a conservatory.

The original function analysis of Miles concentrated solely on required client function irrespective of existing design. Both the Dell'Isola and Ellegant schools have adapted the definition of existing function used by the later manufacturing value engineers. In addition they have adopted it at different levels. Both levels can, if employed correctly, assist in generating alternatives and an ideal situation on a project would be to carry out a function definition at both levels. Time restraints may, however, restrict an elemental function analysis.

3.2.2 FAST diagrams

The system of FAST diagramming is illustrated by Bill Kelly (1986) using an example of a guard rail (crash barrier) and is shown in Example 1.

The Bill Kelly approach to the FAST diagram has a series of flaws,

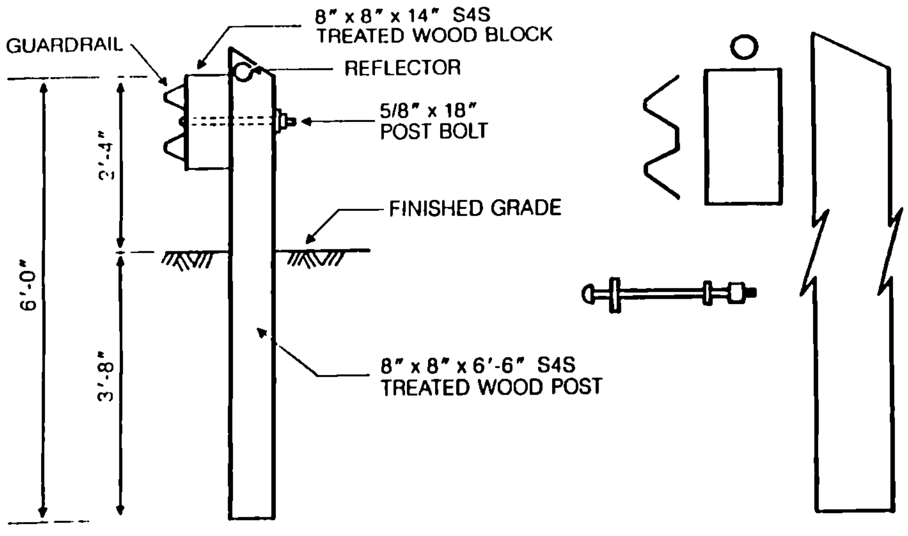
1. It is difficult to see any purpose in taking the 'how' question to the extent of supplying a nut and washer. The diagram is intended to be an analysis of function, yet in practice it is more like a component analysis.

2. The allocation of cost to the FAST diagram does not indicate the cost to perform function but merely the costs of the individual components. It would be expected that totalling the cost of the components would automatically lead to the cost of the function, when calculated from right to left. The layout of the diagram however is such that computation is not possible. The allocation of cost does not therefore appear to achieve anything other than was already known.

3. Based on the original approach to function analysis the diagram does not appear to meet the objectives, in that it does not define the functions of the crash barrier but defines the functions of the components of the crash barrier. In addition it does not evaluate the function but merely costs the components.

4. Having examined the work of Miles it would appear that the correct way to analyse the function is to establish what is required. The barrier is presumably to either prevent traffic from falling over the edge or going into the path of other cars. In addition it is used to highlight the edge of the road. The functions required are therefore to avoid impact (either with other cars or what lies beyond the barrier) and to highlight the road or illuminate danger. Faced with these two functions the next question is what else would fulfil them? Avoid the impact could be achieved by a wall, a concrete upstand, a mound of earth. In order to highlight the edge of the road the wall or upstand could be painted yellow or the mound of earth could be highlighted by beacons. The cheapest of these alternatives forms the basis of the

SKETCH THE ASSEMBLY.



LIST THE PARTS — DETERMINE FUNCTION OF PARTS.

PART	FUNCTION	FUNCTION	FUNCTION
8" x 8" x 6'-6" WOOD POST			
8" x 8" x 14" WOOD BLOCK			
STEEL GUARDRAIL			
BOLT			
WASHERS			
NUT			
REFLECTOR			
TREATMENT			

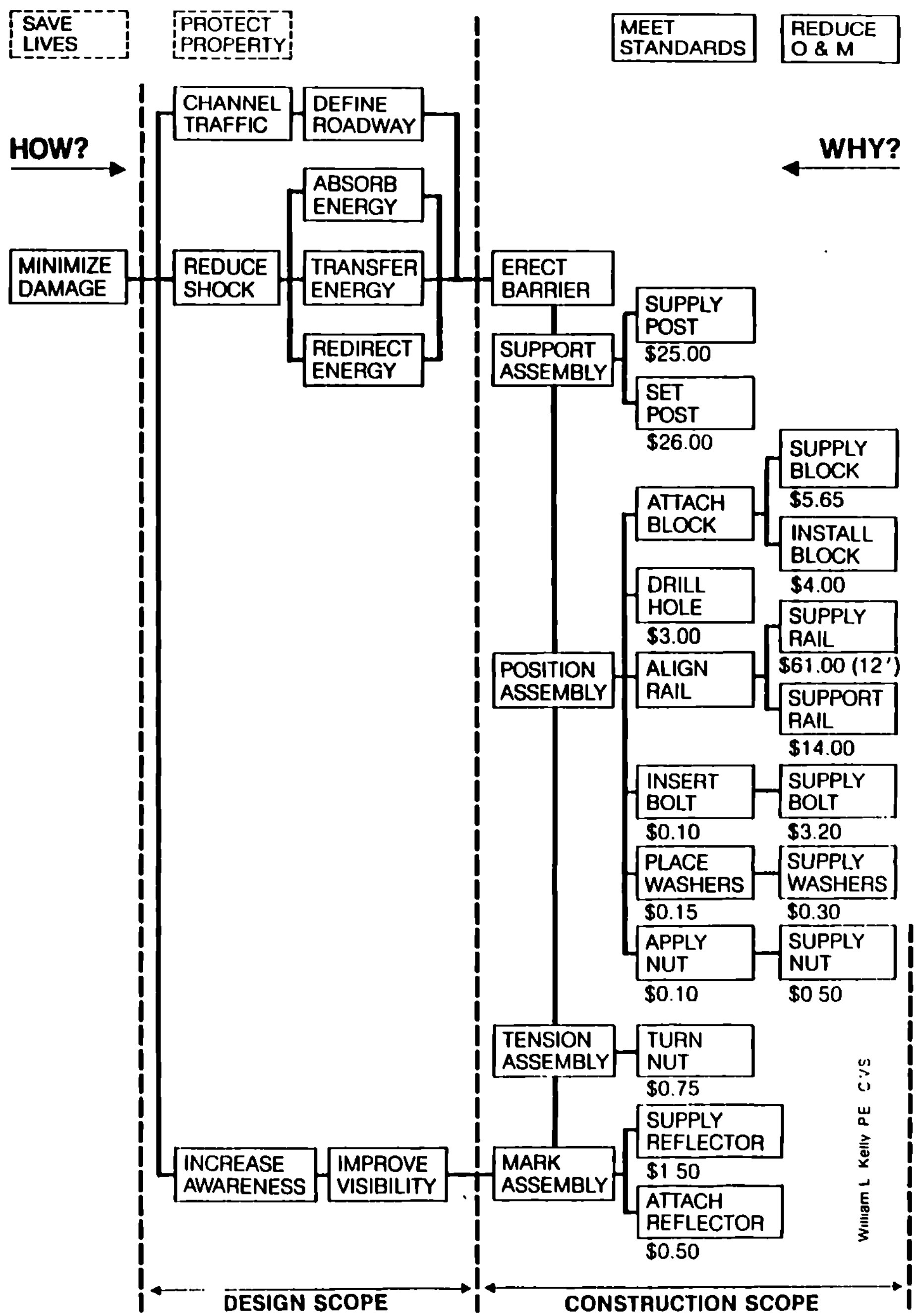
SELECT THE HIGHER ORDER FUNCTION.

ASSIGN COSTS.

1	POST	EA	5	WASHERS	EA.
2	BLOCK	EA	6	NUT	EA.
3	GUARDRAIL	*LS	7	REFLECTOR	EA
4	BOLT	EA	8	TREATMENT	EA

*POSTS 12' c.c. SO COST 12' FOR EACH POST

GUARDRAIL FAST DIAGRAM & COST MODEL



evaluation of function which can then be compared with the cost of the barrier. Once this comparison is achieved other alternatives can be generated and evaluated until the best solution is achieved. It is difficult to see how the FAST diagram aids this process in any way.

5. It appears that Kelly's FAST is attempting to integrate the solutions (components) with the question (function). This fails to achieve anything since the whole concept of value engineering is to state the problem then look for a creative answer; it is not an attempt to fit a preconceived solution into a problem.

Examination of literature highlighted that in addition to the technical FAST outlined by Kelly, there is another type, task FAST. This is examined below.

3.2.3. Task FAST

Snodgrass and Kasi (1986) illustrated a FAST diagram for a ramp that provides access to a factory and that is shown in Example 2.

It was established that the users wanted a ramp for four basic reasons.

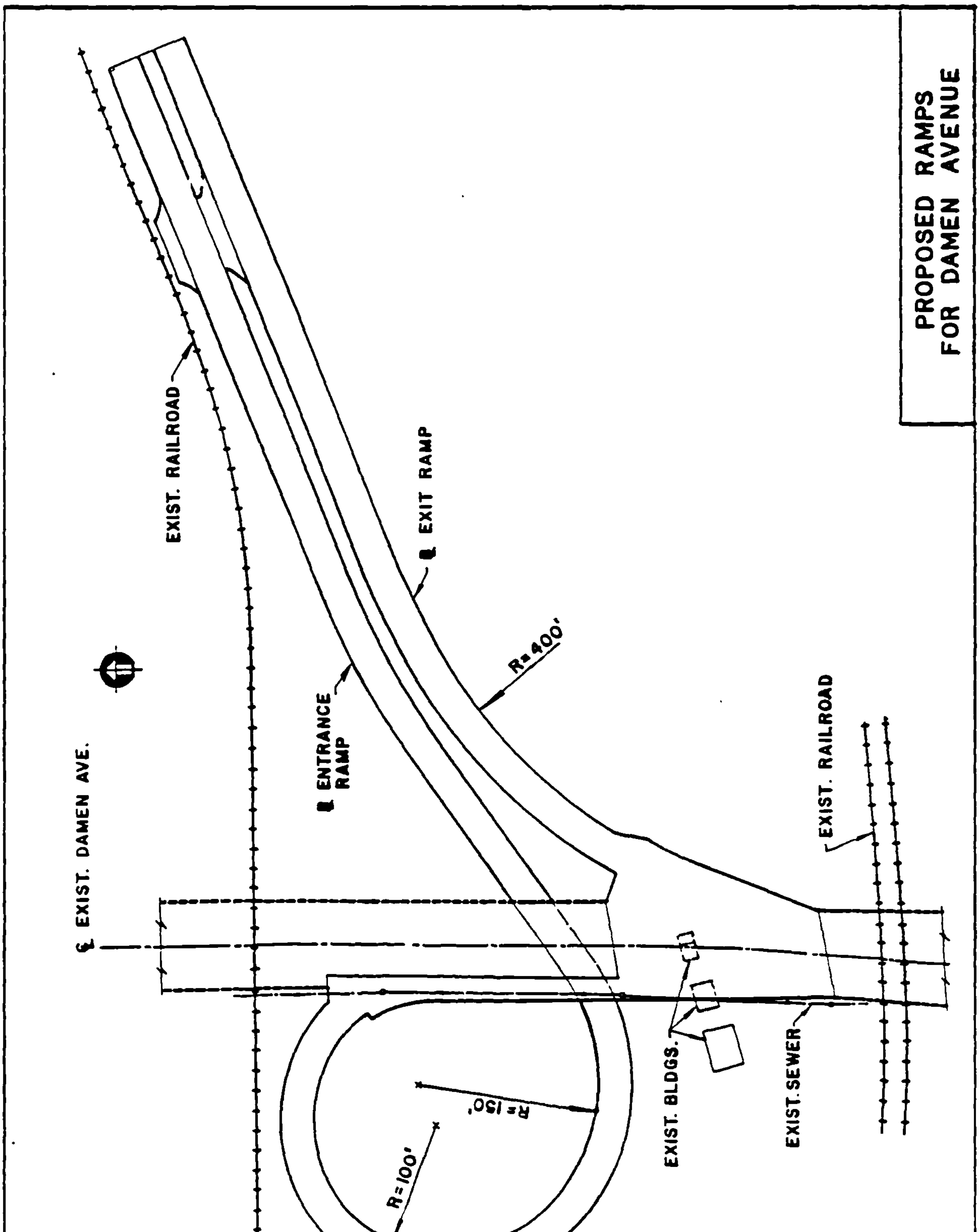
Guarantee access
Attract industry
Provide entrance/exit
Create jobs

These functions were arranged in an appropriate order to answer the how why logic,

HOW ---------> <--------- WHY
Create jobs---Attract industry---Guarantee access---Provide entrance/exit.

Snodgrass and Kasi recognised that the scope of the project was limited to the furnishing of an entrance and exit and as such a scope line was placed directly before this function. Any function falling before this scope line, e.g. attract industry would require further investigation of alternatives. The function lying to the immediate left of the scope line therefore became the

EXAMPLE 2


PROPOSED RAMPS
FOR DAMEN AVENUE
EXIST. RAILROAD
℄ EXIT RAMP
R=400'
℄ ENTRANCE RAMP
℄ EXIST. DAMEN AVE.
EXIST. RAILROAD
EXIST. BLDGS.
EXIST. SEWER
R=150'
R=100'

task which is being achieved, i.e. guarantee access is the main reason for having the ramp.

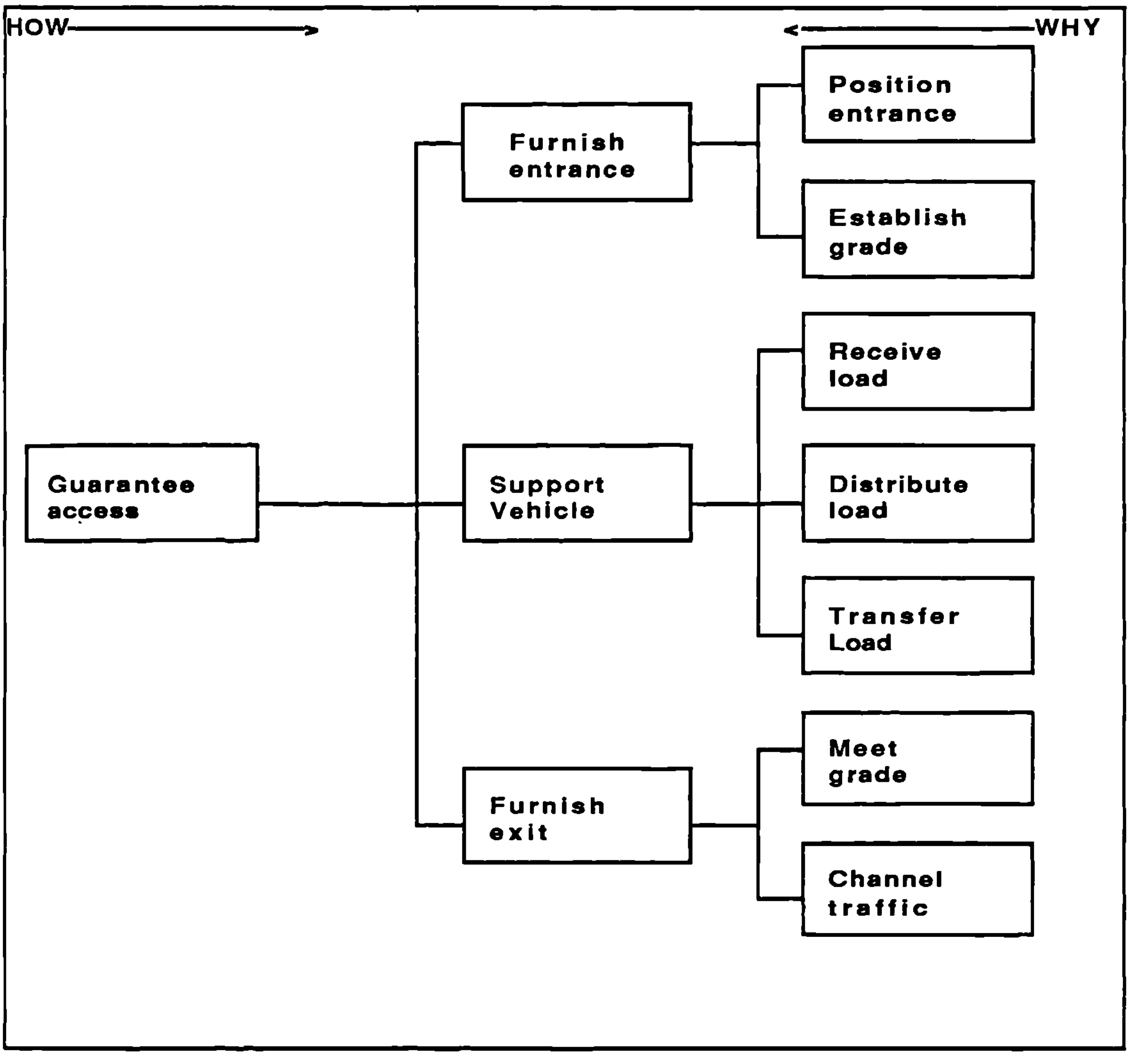
Snodgrass and Kasi then asked the question,

"How does the ramp guarantee access", and answered,

Furnish entrance
Support vehicle
Furnish exit

The diagram was then produced by asking 'how' of these functions, to produce the FAST diagram of basic functions shown in Figure 8.

Figure 8 Task FAST



Snodgrass and Kasi added to the FAST diagram a further list of functions.These were expressed by specialists as the needs and wants of the project. These functions were grouped under four categories of,

Assure dependability
Assure convenience
Satisfy user
Attract user

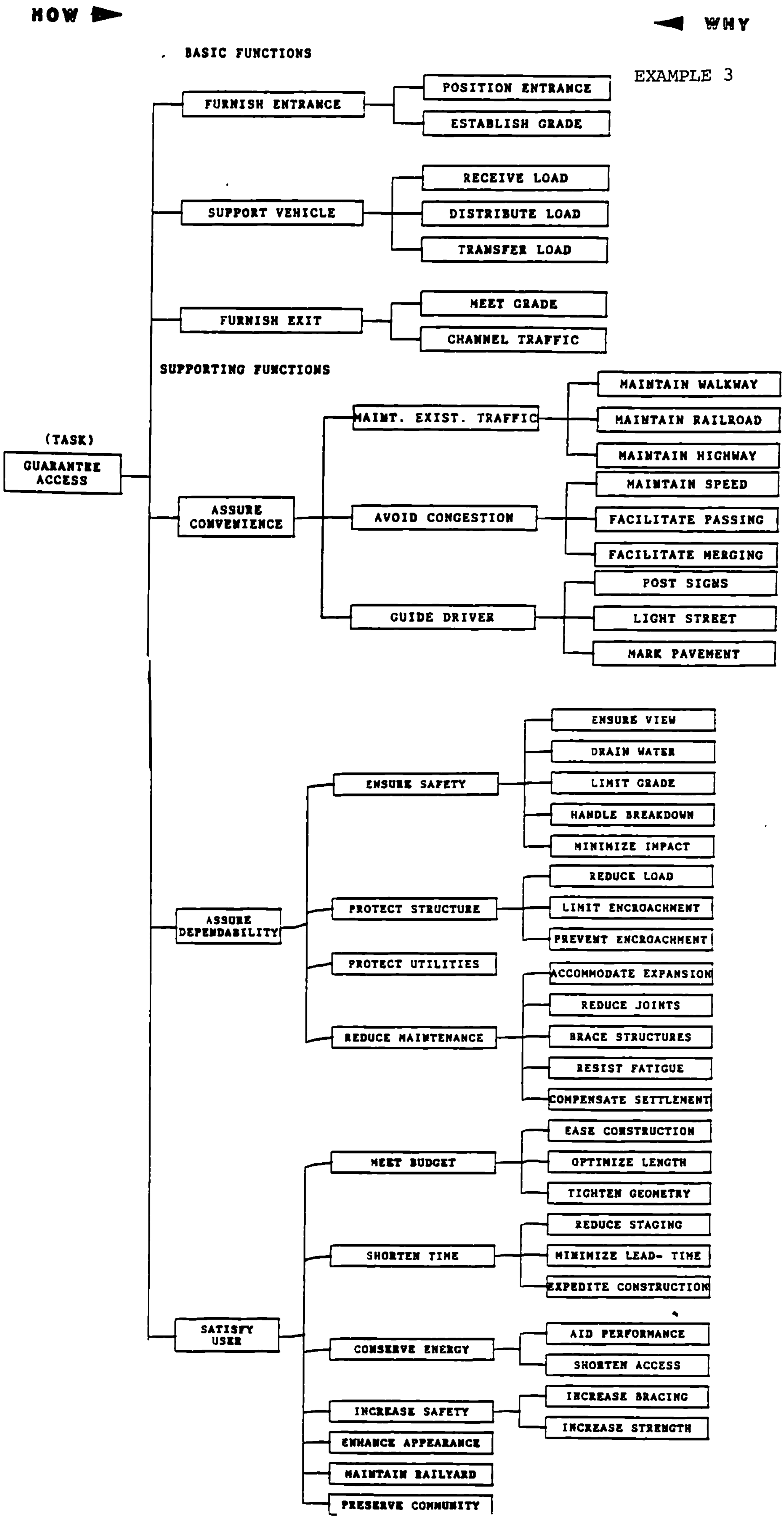
The further list of functions was transferred to the FAST diagram grouped under one of these four categories.

The final diagram is shown in Example 3. Within it there are a series of flaws,

1. It is impossible to tell which functions belong where. The maintenance of existing traffic while the ramp is being built is allocated to the function of 'assure convenience'. In what appears to be a contradiction the function of protecting the existing structure is allocated not to convenience but to 'assure dependability'. Therefore two items, both related to existing structures and not to the new ramp, have entirely different functions. The protection of the existing structure makes the ramp more dependable whereas the maintenance of traffic flow makes it more convenient. This function definition appears very subjective.

2. The actual criteria that govern why a function belongs in a particular category appears suspect. Why for example does the minimisation of maintenance cost assure dependability? The user of the ramp is not concerned how much the client spends on maintenance of the ramp. This leads to the question of whose dependability is it? Is it the user's or the client's?

3. The actual functions of 'assure dependability and convenience' and 'attract and satisfy user' do not appear appropriate to construction. Firstly, outside the speculative property development section of the construction industry, which is involved in renting and selling, a finished building product is not wholly concerned with attracting users. Likewise the terms 'convenient' and 'dependable' are not qualities associated with buildings. Clearly it is more convenient to have automatic doors, hot air hand dryers, hand height electrical sockets, lifts, demountable partitions, but how can these possibly be quantified? Are Snodgrass and Kasi suggesting that every component in the building that is there for the purpose of convenience be allocated under this function? If so then what is a door if not a convenient method of getting into the building?


HOW
WHY
EXAMPLE 3
BASIC FUNCTIONS
FURNISH ENTRANCE
POSITION ENTRANCE
ESTABLISH GRADE
SUPPORT VEHICLE
RECEIVE LOAD
DISTRIBUTE LOAD
TRANSFER LOAD
FURNISH EXIT
MEET GRADE
CHANNEL TRAFFIC
SUPPORTING FUNCTIONS
(TASK)
GUARANTEE ACCESS
ASSURE CONVENIENCE
MAINT. EXIST. TRAFFIC
MAINTAIN WALKWAY
MAINTAIN RAILROAD
MAINTAIN HIGHWAY
AVOID CONGESTION
MAINTAIN SPEED
FACILITATE PASSING
FACILITATE MERGING
GUIDE DRIVER
POST SIGNS
LIGHT STREET
MARK PAVEMENT
ASSURE DEPENDABILITY
ENSURE SAFETY
ENSURE VIEW
DRAIN WATER
LIMIT GRADE
HANDLE BREAKDOWN
MINIMIZE IMPACT
PROTECT STRUCTURE
REDUCE LOAD
LIMIT ENCROACHMENT
PREVENT ENCROACHMENT
PROTECT UTILITIES
REDUCE MAINTENANCE
ACCOMMODATE EXPANSION
REDUCE JOINTS
BRACE STRUCTURES
RESIST FATIGUE
COMPENSATE SETTLEMENT
SATISFY USER
MEET BUDGET
EASE CONSTRUCTION
OPTIMIZE LENGTH
TIGHTEN GEOMETRY
SHORTEN TIME
REDUCE STAGING
MINIMIZE LEAD- TIME
EXPEDITE CONSTRUCTION
CONSERVE ENERGY
AID PERFORMANCE
SHORTEN ACCESS
INCREASE SAFETY
INCREASE BRACING
INCREASE STRENGTH
ENHANCE APPEARANCE
MAINTAIN RAILYARD
PRESERVE COMMUNITY

In a similar nebulous approach dependability is listed as anything that makes the building safer, stronger or more reliable. Safer than what? Stronger than what? More reliable than what? Than it needs to be? Than its competitor?

4. In the FAST diagram the following functions appear under 'satisfy user'

   Meet budget
      Ease construction
      Optimise length
      Tighten geometry
   Shorten time
      Reduce staging
      Minimise lead time
      Expedite contract

   These are not functions of the structure. They are requirements the client has of the contractual arrangements. They have no relationship to the satisfaction of the user.

5. The functions that answer the questions 'how' do not answer 'how do you furnish exit' but 'how does the predetermined solution meet the function'. In addition the logic is incorrect. Access to a site is not guaranteed by supporting a vehicle, not under any circumstances. The solution has been locked into too quickly and the problem has not been correctly analysed.

6. The most serious flaw in Snodgrass' and Kasi's work is that they have not proved that the ramp is the best solution to the entrance/exit problem. However their opening statement in the production of the FAST diagram is,

   "how does the ramp guarantee access ?"

   Once again the VE equivalent of the philosophical statement ,

   "I think therefore I am"

in that they assume the existence of the ramp before it has been proved. What the Snodgrass and Kasi's diagram is really asking is,

How do you construct a ramp?

By having. . .

A high side. . . . . Furnish exit
A low side. . . . . Furnish entrance
A ramp in the middle. . . . . Support vehicle.

They are drawing a component diagram of a ramp that elevates traffic by the use of a road. This is nothing other than what was already known.

Snodgrass and Kasi do, at face value, appear to be considering client function (why the client builds) as opposed to what he builds. In reality they are relating a construction solution (what exists) to client function (what is required). They have constructed the FAST diagram of basic functions then fitted the existing solution to it.

The FAST diagram does not aid function definition. In VE terms, particularly in construction, there seems little purpose in trying to force client function through a rigid system in an attempt to evolve a construction solution, as there is often no relationship between the two. In addition it can be concluded that the diagrams are illogical and subjective.

3.2.4 Allocation of cost to function

Once the FAST diagram is constructed the Ellegant School allocates actual cost to function. The objective is to compare actual cost with the client's perception of function worth. This highlights any value mismatches, to which alternatives can then be generated.

This procedure presents a problem in that most construction estimates are based on trades (brickwork, carpentry) or elements (foundations and walls). When client functions are defined then the problem arises of how to allocate these trade or elemental estimates to client function. This was illustrated by Snodgrass and Kasi, and Dennis in Chapter 2. Once again their work is flawed for the following reasons.

1. Elements of a building and the costs associated with them have no relationship to function. Most functions of a building could be carried out in a tent. The walls, roofs and other elements are not there to allow functions to be carried out but for other reasons (performance or tradition). The type of exercise carried out by Dennis is therefore wholly artificial.

2. There is a further problem with the allocation of cost to function: whilst elements can be costed, functions can only be valued. Allocating cost to function is rather like comparing apples and pears.

The purpose of VE is to evaluate function based on the lowest cost to achieve it. This can be done without the laborious exercise of allocating actual cost to function. Such an exercise is erroneous and pointless in that the comparison is wholly artificial. Furthermore it does not compare like with like.

In addition to their interpretation of function analysis the two schools of thought have two other fundamental disputes: the timing of the studies and the staffing of them. These are examined below.

3.3 Timing of VE studies

The Ellegant school recommends that VE be carried out as early as possible whereas the Dell'Isola school suggests 35% as the most effective time. Boland (1975) in an investigation of the most effective timing for VE recognised that there are two levels to value engineering: macro applied to the overall concept design and micro applied to components, elements or materials. Boland and Styne (1989) felt that for VE to be effective it ought to be applied to both levels, as an on-going process covering the whole project and its entire life cycle cost.

The notion of carrying out more than one value engineering study was examined by Sperling (1989). Sperling's work illustrated that there is some benefit to be derived from doing two VE studies, one at concept and one at 35% design. Kim (1989) takes the opposite view to Sperling. In his research, effectiveness was found to decrease rapidly when VE activities were repeated for the same project.

Kelly and Male (1990) also recognised the macro/micro division in value engineering. However, unlike Boland they did not interpret this split as warranting two or more value engineering studies. They concluded that true VE can really only be carried out up until scheme design and that anything beyond that is cost reduction. (Maguire and Dawson (1989) clearly recognised that some aspects of value engineering were cost cutting, and in reporting savings highlighted those proposals which did, and did not, affect function). Kelly and Male further argued that both value engineering and cost reduction (which do have some overlap) have a place in the design process but the effectiveness of VE is lost once the concept stage is passed. They argued that maximum benefit is obtained if the VE is undertaken early in the design process because,

1. Function analysis can only be applied to a small number of concepts.

2. Function analysis has greater impact when applied to a concept than to a single component.

3. VE is better received earlier than later.

4. Once the project is at an advanced stage the VE team is more likely to suggest alternative components for technical solutions rather than using function analysis to generate alternative concept or design solutions.

The timing of VE studies is a highly contentious issue. The major alternatives are to have a study at concept design, 35% design, or both.

At concept design function analysis is limited to the space functions of the project since design is not sufficiently developed to allow an analysis of elements. At the later 35% design stage function analysis may also encompass elemental definition. However, the development of the design up to this point may prohibit change in the space requirements. Having a two-stage VE process overcomes both of these problems. However it is argued that the latter stage of such a process may really only be cost reduction by another name. This is incorrect. Elemental function definition with due regard to the building's use, is as effective as function analysis at concept design. It may not produce savings of such magnitude but it is equally effective in making for a better design.

There is an additional factor that needs to be considered in the examination of function analysis. The advocates of function analysis, i.e. the Ellegant school recommend a study at concept design. The Dell'Isola School, which only appears to pay lip service to the technique, recommend a study at 35% design. In the absence of function analysis, the late timing of the Dell'Isola study reinforces the view that their VE practice only amounts to cost reduction. If a cost cutting exercise is planned, it is easier at 35% design as the scope is greater and the implementation easier.

3.4 The VE team

In the construction industry disciplines work autonomously. As a result ideas are not debated or thought through. Boland (1975) and Rwelamila (1988) argue that if VE is to overcome this problem the VE team must be multi-disciplinary. All other VE authors agree. The point of contention between the two schools of thought is whether the design team should be used for the study or whether the team ought to be an external one. Dell'Isola (1988) stresses the importance of an independent viewpoint whereas Ellegant (1989) argues for the design team.

Kim's (1989) research falls halfway between the opposing views. He showed that VE is most effective when design personnel constitute two thirds of the team. Without any design members present cost reduction may be as much as halved.

Using the design team is presumably cheaper than using an external team, but, it is claimed, such an approach lacks objectivity. It is possible however that the technique of function analysis, applied more rigidly by the Ellegant school than the Dell'Isola, gives the design team the necessary objectivity that Dell'Isola (1988) claims is lacking by using them.

It may also be the case that the presence of the external team makes VE more marketable. The Ellegant approach basically amounts to the technique of function analysis - a difficult concept to sell. The Dell'Isola approach however consists of a "value engineering team" - experts trained in the elimination of unnecessary cost. This is undoubtedly more marketable than a technique based on the definition of functions by verbs and nouns.

4. Formulating the problem

The examination and critique of value engineering literature has facilitated the formulation of the basic problem for the thesis. The aim of the study is the investigation of United States value engineering to determine if the British system of cost control could benefit from it. The study of theory highlighted that there are two schools of thought. In order to facilitate the investigation it is necessary to establish which school of thought is actually practised.

The critique of VE highlighted that the development of function analysis has been a largely negative one that has distorted the basic principles as outlined by Miles (1961). This questions if function analysis has become so distorted that any cost reduction achieved by VE can be attributed to it. It is possible that function analysis is not responsible for any VE output which may instead be the result of a traditional cost reduction exercise. The thesis therefore needs to establish the output of US VE and to measure it's relationship to the technique of function analysis.

Once VE practice is defined, and its output measured with regard to function analysis then a comparison with UK procedures can be made. This comparison seeks to establish whether VE is different from what is engendered in UK procedures. If it is, then is it necessary to further investigate if it can be adopted by the British.

The examination of US VE in the manner indicated fails to include an appraisal of the effective use of function analysis in construction. As this has never really been established the thesis seeks to examine the original VE technique to test if it can be used effectively in construction.

The basic questions which the thesis seeks to answer are therefore as follows:

1. Which school of thought is practised in the United States?

2. What is the output of VE studies and is function analysis responsible for the output?

3. Is the practice of VE something other than that which already exists in the UK?

4. If so, could this practise be effective in the UK?

5. What is the effectiveness of the original function analysis technique in construction?

5. Formulating the research propositions

1. Which school of thought is practised in the United States?

The main value engineering texts are all written by members of the Dell'Isola school. These authors are, in addition, practitioners. Dell'Isola and Zimmerman are among the largest VE consultants in the US. Of the prominent members of the Ellegant school, Snodgrass and Barlow are academics. The remaining leading advocate, Ellegant, is a practitioner of a 'one-man' company. In the light of this it is reasonable conjecture that the Dell'Isola school is the dominant method of carrying out VE studies.

2. What is the output of VE studies and is function analysis responsible for the output?

Examination of theory suggested that within the Dell'Isola school, function analysis has been reduced to the establishment of high cost elements and the generation of alternatives to them. This in itself is not VE but merely cost reduction. It is therefore proposed that the scope of VE is limited by the use of elemental function analysis to the search for alternative technical solutions and that VE as practised is merely cost reduction.

3. Is the practice of VE something other than that which exists in the UK?

Quantity surveyors in the UK, operating within the cost planning system, carry out cost control exercises on an elemental basis to limit project cost. In addition they will, during the design process, carry out cost reduction exercises when budgets are exceeded. Based on this, it is further deduced that VE, as practised in the US is nothing additional to that which already exists, within the UK cost planning framework.

4. If so, is the practice applicable in the UK?

Cost consultancy in the UK, unlike its US counterpart, commands a separate fee and it is unlikely that clients would be willing to pay additional monies for VE studies. In addition the differences that exist between US and UK procedures do not facilitate direct implementation of the US system in the UK.

5. What is the effectiveness of the original function analysis technique in construction.

The use of function analysis, at face value, appears to offer a method of eliminating unnecessary cost by the consideration of alternatives. It is therefore proposed that the technique of function analysis could aid effective design and reduce cost.

The research propositions can be summarised as follows:

1. The Dell'Isola school is practised in the US.

2. The scope of VE is limited by the use of elemental function analysis to the search for alternative technical solutions and VE as practised is merely cost reduction.

3. VE as practised is nothing additional to that which already exists within the UK cost planning framework.

4. VE as implemented in the US could not be practised in the UK. The differences between US and UK procedures do not facilitate direct implementation of the US system in the UK.

5. The technique of function analysis could aid effective design and reduce cost.

Chapter 4

Research method

1. Approach to the thesis

The overall approach to the thesis is shown in Figure 9. The research was carried out using the hypothetico-deductive method outlined by Sekaran (1984) and therefore followed seven similar steps,

1. Observation
2. Preliminary information gathering
3. Theory formulation
4. Research proposition development
5. Data collection
6. Data analysis
7. Conclusion

1.1 Observation

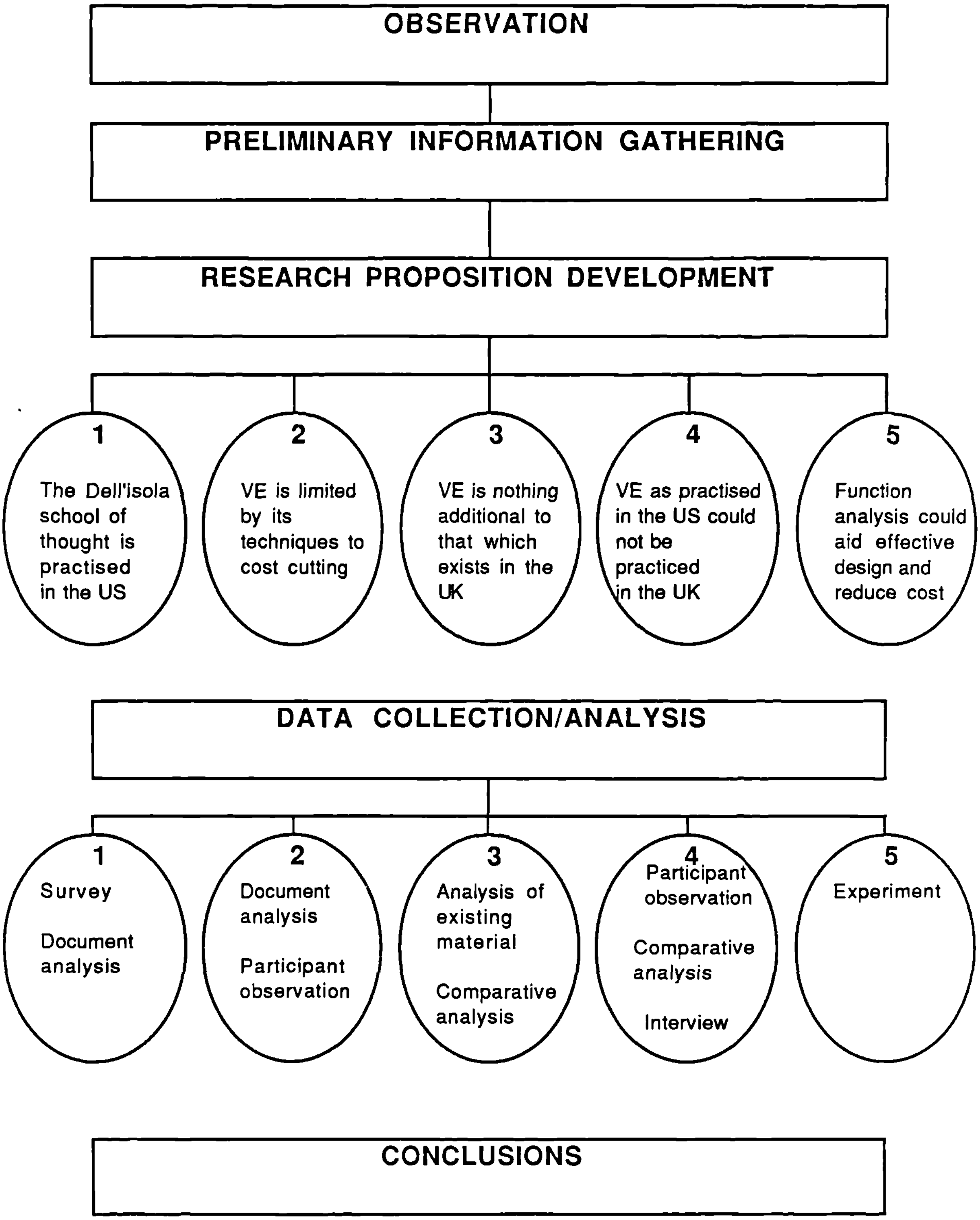
The author observed that an interest is developing in value engineering within the UK construction industry. Further, interest is divided between those who advocate VE as a potentially powerful tool to improve value, as opposed to those who believe it is largely ineffective and inherent in existing procedures.

1.2 Preliminary information gathering

Literature survey was chosen as the method of preliminary information gathering. This was for the following reasons.

1. So that all components of VE could be gathered and the important ones highlighted and contrasted. It is possible that the immediate investigation of VE practice, or the interviewing of value engineers could result in omissions from the overall framework. A literature review would provide greater precision and clarity.

Figure 9 - Approach to the thesis



2. To enhance testability and replicability of findings based on current opinion.

3. To avoid duplication of previous work.

The literature review facilitated precise formulation of the problem.

1.3 Theory formulation/research proposition development

The problem, as recommended by Leedy (1974), was broken into sub-problems. The research propositions therefore consisted of five statements each corresponding with a sub-problem.

The research propositions presented a linear statement. As such the investigation of one research proposition was required to be completed before the investigation of the following one. Each research proposition was therefore investigated in turn. A separate chapter of the thesis is dedicated to each of the five research propositions.

1.4 Data collection/analysis

Investigation of the five research propositions required the collection and analysis of data. The research methods employed for each research proposition are shown in Figure 9. The reason for the choice of research method is outlined below, under each individual research proposition.

1.4.1. Research proposition 1

The Dell'Isola school is practised in the US

The question on which the research proposition was formulated was largely one of description. The purpose of the research at this stage was to document the procedures which exist in VE practice, in an attempt to examine whether VE adheres to the Dell'Isola School. The data collection techniques available to such descriptive research were outlined by Marshal et al (1989). These consist of participant observation, in- depth interviewing, document analysis, unobtrusive methods and survey questionnaire.

For this phase observation was viewed as too lengthy a process. VE studies generally take one week and data collection would therefore be too slow. Of the remaining methods survey questionnaire was selected as the means of data collection. As outlined by Moore (1983), surveys represent an efficient method where the data to be collected is largely superficial.It was viewed that attempting to establish the broad practice of VE fell into this category.

A problem presented by a survey was that it might, due to the diversity of thinking, be answered on the basis of what the respondent perceived as the correct answer, as opposed to his true practice. To overcome this the survey responses were therefore checked against historical VE documents collected in the United States from VE clients and consultants. Document analysis could provide a valid research method because all VE studies produce formal documentation which outline the procedures followed, the people involved, the design stage and project particulars. These could therefore be checked against the responses in the survey.

The investigation of the first research proposition was therefore a two stage process. First the survey would establish the broad body of opinion regarding VE practice and second document analysis would be used as a check against the responses received in the survey.

The survey contained closed questions as defined by Sommer et al (1991). It consisted of 11 questions and is shown in appendix D. The survey was based on the components of the Dell'Isola and Ellegant schools as established by the literature review. In addition respondents were given the opportunity to include an alternative answer if their methods did not correspond with either school.

Prior to sending the survey it was piloted by telephone. Two consultants were chosen at random from the sample selected (see below). They were read the survey and asked if they understood the questions. Both replied that they did.

The survey was then sent to a broader population. The sample was selected from the Society of American Value Engineers Consultant Directory which contains a list of 40 consultants involved in VE in construction. Of the 40, 2 practiced outside the United States and were not therefore considered in the research. Of the remaining 38, 2 were used to pilot the survey, 22 were sent the survey by facsimile and 14 by post. Two methods of communicating the survey were used as it was felt that there was a possibility that few replies would be received by post. If a company listed a facsimile machine number in the SAVE directory then they were sent the survey by this method.

The response received by the survey was 67%, or 24 replies out of a possible 36. The assumptions made on the data received were based on a body of opinion represented by a minimum of 16 responses i.e.: 44% of surveys sent or 67% of responses received. The dissenting responses not agreeing with the general view were diverse and did not represent an alternative body of opinion. Even if all 12 surveys for which there was no response disagreed with the data received it would not be sufficient to alter the assumptions made, since it could only represent 33% of responses received. For this reason no further statistical analysis was carried out on the data.

The next section of the investigation checked that documents from VE studies corresponded with the survey. The purpose of this was to check that the answers given in the survey were a true reflection of VE practice. The survey responses indicated that the majority of practice adhered to the Dell'Isola school. Therefore only documents pertaining to consultants in this school were checked. The studies to be checked were collected from two consultants and one client. The consultants were SH&G and Hanscomb Associates. The client was the US Navy. The Navy contract out VE work to consultants, all of whom responded that they were from the Dell'Isola school. The Navy sample included five consultants. Studies were selected at random. The documents from each study were analysed on the basis of the components established as being those of the Dell'Isola school.

1.4.2. Research proposition 2

The scope of VE is limited by the use of elemental function analysis to the search for alternative technical solutions and VE as practised is merely cost reduction.

The research related to this research proposition was trying to establish the relationship between function analysis (input) and the nature of the savings achieved (output). To answer the research question, three points needed to be established: the function analysis used in practice, the output it produced and the relationship between the two.

The question on which the research proposition was based was one that required explanation in order to be effectively answered. Explanatory research, as outlined by Marshall et al (1989), can be best supported by four types of data collection: participant observation, in-depth interviewing, survey questionnaire and document analysis.

Document analysis was chosen as the method to establish the output of VE studies as this was the fastest and most accurate approach. Participant observation could examine only one study per week and as such was impractical. Collection of data by survey or interview could not be justified since it would be against the respondents interest to admit if VE achieved little in terms of output.

The data produced by the document analysis was often difficult to interpret and occasionally classification of data was subjective. Although the final outcome of the data was certain it was felt that the results were only a guide to the output of VE studies. The data was not scientific and for this reason was not analysed statistically.

In attempting to establish the nature of function analysis in practice and its relationship to VE output the only feasible approach was that of participant observation. Document analysis producing only inert data could not show the practical interaction of events. Interviewing and survey were equally ineffective since the element of subjectivity was too great to produce dependable results.

1.4.3. Research proposition 3

VE as practised is nothing additional to that which already exists within the UK cost planning framework.

The research question posed by the research proposition required description of the cost control procedures that exist in the UK, in order to facilitate comparison with US value engineering. The research question therefore posed two problems; firstly, the description of the UK cost control system and secondly a comparison of US VE and UK cost control. The first element being descriptive by nature was researched by an analysis of existing material pertaining to the subject. This method was chosen on the basis of simplicity and speed. The second element of the research question was based on a comparison of the two systems. The comparison was based on the above analysis of existing material and the information gathered in the examination of research propositions one and two.

1.4.4. Research proposition 4

VE as implemented in the US could not be practised in the UK. The differences between US and UK procedures do not facilitate direct implementation of the US system in the UK.

The previous stage of the research highlighted a degree of overlap between value engineering and United Kingdom cost control. From the point of view of application to the UK it was viewed that only that which was additional to the existing UK system needed to be investigated. It was assumed that the aspects of VE that were similar to existing UK procedures would be readily acceptable to it. The research question therefore sought to examine if any components of VE that were additional to the UK cost control system could be effectively employed in Britain. To answer this question any supplementary components of VE needed to be examined in their existing and intended capacities. In addition the difference between these intended and existing capacities needed to be established. The research proposition therefore posed three issues:

1. What is the status of any supplementary components of VE in the United States?

2. In what way does the British system vary from the American?

3. Can the supplementary components of the American system be employed in the UK?

The first issue was partly descriptive and partly exploratory in that it was trying to investigate and document the components of interest. As such, based on the work of Marshall et al (1989), observation was chosen as the research method.

The next issue was to establish how the UK system differed from the American. This was based on a comparison of the two systems, in turn based on existing material pertaining to the subject. This comparison provided an acceptable research method as the problem was largely descriptive.

The third and final issue related to the acceptability of the US approach in the UK. This, once again being an exploratory problem, could, as outlined by Marshal et al (1989), be researched by two types of data collection: observation and interviewing. Observation was discounted on the grounds of entrance and availability and interviewing was selected as the means of data collection. The interview although only covering a small number of points needed to explain them in some detail. As such, and as recommended by Moore (1983), in-depth semi-structured interview was selected as the method. The sample for interview was based on a general review by the author of which UK companies were involved in VE. Information came from trade journals, other VE researchers and word of mouth. It was felt that the interviews covered the majority of VE activity in the UK.

1.4.5. Research proposition 5

The technique of function analysis could aid effective design and reduce cost.

The research question posed by the research proposition was predictive. It forecast an improvement in design, and reduction in cost based on the use of function analysis. As such the research method was experimental.

It was hoped to carry out an experiment of function analysis on a real project. This however was impossible, largely due the time restraints of the design teams that were approached. In addition clients were wary of imposing a study on their design teams. It was therefore decided to use the MSc Construction Management students at Loughborough University to test out the technique. This posed certain difficulties. First was the problem of generalisation. Students at Loughborough are there for the purposes of obtaining a masters degree and will presumably attempt to please. In addition the relationships that would be present in a real design team would not exist between classmates. Further, the students would have no interest in the project. It could be safely assumed that the real design team, having worked with the project for some time would have reacted differently to the students. Finally, many of the students were foreign and their mode and method of thinking could not be generalised to the UK construction industry at large. With regard to external validity an experiment using students was therefore seriously limited.

External validity problems could, as outlined by Drew (1976), be overcome by the introduction of a control group, whereby two groups of students analysed a project with only one group using function analysis. Any differences between the results produced by the two groups could therefore be attributed to the function analysis, providing all other items remained equal. The results produced by the function analysis group could still not be generalised to the population as a whole, but a more certain inference could be made as to the effect of the technique. The use of control groups however posed other difficulties. The function analysis technique would need some sort of facilitator. The author taking this role would present internal validity problems in that she might guide the group in a direction they would not otherwise have gone. As no other facilitator was available it was necessary to select one member of the class and teach him the technique of function analysis to enable him to take the role. This presented problems. The technique of function analysis is esoteric and there could be no guarantee of success. A function analysis with the author, although suffering problems of internal validity, would at least highlight the benefits of the technique when fully understood by the facilitator. It was therefore decided to attempt two approaches to the experiment. Firstly the masters group of 1990/1991 were used to design a building using a function analysis facilitated by the author. Secondly the masters group of 1991/1992 were used and split into two groups. Group A acted without function analysis and Group B were outlined the technique by a classmate who had been previously briefed. It was viewed that the outputs of groups A and B would also provide an interesting insight if they could be compared to the output of a QS working individually. Where a project is overbudget the QS working independently is the closest to the 'real' scenario of a UK cost reduction exercise. It was therefore decided to introduce this into the study and compare the result with those produced by the group.

1.5 Conclusions

The conclusions drawn were based on the answers to questions posed in the research propositions.

Chapter 5

Results - US value engineering practice

1. Introduction

1.1 Research proposition

The Dell'Isola school is practised in the US.

1.2 Research method

Survey and document analysis. A copy of the survey is given in appendix D.

2. Survey results

2.1 Responses to survey

As outlined in the research method chapter, 36 surveys were sent to VE consultants, 22 by 'fax' machine and 14 by post. In all, 24 responses were received, 12 from the 'fax' survey (54%) and 12 from the postal (85%). (Total response 67%). The following is a summary of the results. Questions 1 to 9 were multiple choice, and questions 10 and 11 were open to any response.

1. What method do you use for carrying out a VE study?

40 hour workshop	16
Charette	1
Other	7

The 7 'other' responses all used the workshop but varied the length according to the needs of the project.

2. At what stage of the design do you usually carry out a value engineering study?

10% Concept	0
35% Schematics	16
60 - 90% Production	1
Other	7

The 7 'other' responses were combinations of two or more timings as follows,

10% and 35%	2
35% and 60%	1
10%, 35% and 60-90%	4

3. Who is generally responsible for carrying out the value engineering study?

The design team	1
An external VE team	18
Other	5

The 5 'other' responses were as follows,

Both the design team and external team	4
Implementation team	1

4. What forms the agenda of value engineering studies?

The job plan	23
Other	0

(One consultant did not respond to this question)

5. What percentage of your studies contain a FAST diagram?

0-25%	9
26-50%	5
51-75%	1
76-100%	9

6. Which of the following most closely represents the function analysis that you use?

Foundations .... Support load	16
Casualty .... Treat emergency	1
Other	7
Function analysis not used	0

The 7 'other' responses were as follows,

Both types of function analyses	2
All aspects of the project	2
FAST diagram	1
Whatever the use	1
Project image activate	1

7. What method do you use for highlighting areas of poor value?

The cost worth ratio	7
Value mismatches	6
Other	11

The 11 'other' responses were as follows,

Both the cost worth ratio and value mismatches	5
Cost function ratio	2
Cost models	1
Cost comparison	1

Value mismatches and cost function relationship	1
Computer programme	1

8. What is the basis of evaluation when highlighting areas of poor value?

The cost of a cheaper alternative	1
The cost of the cheapest alternative	0
The lowest cost to achieve function	13
Client perception of worth	3
Other	7

The 7 'other' responses were as follows,

Lowest cost to achieve function and client perception of worth	3
Cost of a cheaper alternative and the lowest cost to achieve function	1
Cost of a cheaper alternative, cost of cheapest alternative and the client perception of worth	1
Most effective way to achieve function	1
Criteria germane to the study	1

9. On which areas of projects do you generate VE proposals?

All areas	17
Areas highlighted as ones of poor value	4
Other	3

The 3 'other' responses were as follows,

Areas highlighted as one of poor value and areas of high cost	1
High cost areas	1
High cost elements	1

10. Who do you consider to be the United States leading VE consultant?

Almost all respondents answered that their own company was the US's leading VE consultant.

11. Who do you consider to be the United States leading VE client?

Department of Defence	10
Government	6
General Services Administration	1
General motors	1
Kellogs	1
State of Utah	1
MG6	1
Kodak	1
No response	2

2.2 Discussion on survey responses

Table 6 shows the response anticipated in each school of thought along with the % response received that agreed with it.

Table 6 - Survey responses - agreement with the schools of thought

Anticipated response - Dell'Isola School	Response received	Response received	Anticipated response Ellegant School
Q1 40 hour workshop	67%	67%	40 hour workshops
Q2 35% schematics	67%	0%	10% concept
Q3 An external VE team	75%	4%	The design team
Q4 The job plan	96%	96%	The job plan
Q5 0% Use of FAST	13%	25%	100% Use of FAST
Q6 Foundations ... Support load	67%	4%	Casualty ... Treat emergency
Q7 The cost worth ratio	29%	25%	Value mismatches
Q8 The cost of a cheaper alternative	4%	13%	Client perception worth
Q9 Areas highlighted as poor value	17%	17%	Areas highlighted as poor value

The data shows that the responses received adhered more to the Dell'Isola school than the Ellegant. Examination of VE literature highlighted that the main items of contention between the two schools were the application of function analysis, the timing of the studies and the use or otherwise of an external team. The survey responses received on the latter two items positively adhered to Dell'Isola, with 67% and 75% agreement as opposed to 0% and 4% agreement with Ellegant.

Insofar as the method is concerned the general practice of VE definitely lies in the Dell'Isola school. 67% of responses indicated that they used the 40-hour workshop. With the exception of 1 response all other consultants used the workshop but had a more flexible approach to its length. With regard to the timing of the studies there was 67% agreement with Dell'Isola on the 35% design stage. However of the remaining responses only 1 outwardly disagreed with Dell'Isola, the remainder indicated that they implemented studies at 35% as well as another time, depending on the project. With regard the use of the external team the majority of responses agreed with the Dell'Isola school (75%). Once again however where there was disagreement it was not based on an opposing view. With the exception of 1, the responses that disagreed indicated they used a mixture of the external and design teams.

Although the method of carrying out VE studies adhered to the Dell'Isola school, the techniques used did not show such a clear pattern. It was anticipated that the Dell'Isola school responses would indicate a minimum use of FAST, the definition of elemental function, the use of the cost worth ratio, the evaluation of function based on the cost of cheaper solutions and the generation of alternatives on areas highlighted as ones of poor value. This however was not the case. The majority of responses showed a high use of FAST, evaluation based on the lowest cost to achieve function (54%) and proposals generated on all areas (71%). In addition the survey showed that the cost worth ratio was only used 29% of the time. These results were surprising and it was suspected that respondents may have answered based on the perceived correct answer as opposed to their true practice. Survey results were therefore checked against historical VE documents. The documents that were checked came only from consultants who indicated in the survey that they practiced in the Dell'Isola school. This was because having now established that the general body of practice was with Dell'Isola, the next step was to narrow the investigation to accurately establish the techniques employed by that school. The important issue that was highlighted by the survey was that although the Dell'Isola school did not have a 100% positive response, it had captured the broad body of opinion. Although all responses did not agree with the Dell'Isola school the dissenting opinions did not show an alternative body of opinion. For this reason only documents pertaining to the Dell'Isola school were examined in order to pinpoint the nature of VE practice.

3. Document analysis

The purpose of this section was to check that the answers given in the survey corresponded with the documents.

55 studies were examined, all of which came from consultants who indicated in the survey that they were from the Dell'Isola School. The research was

attempting to establish the practice of VE in the US so therefore only the Dell'Isola school was examined as this had been shown by the survey to form the general body of opinion. The documents from each study were analysed on the basis of the components listed in the survey. The following results, summarised in Figures 10 and 11, were obtained.

3.1 The forty hour workshop

All studies collected outlined the method by which the study had been carried out. The use of the workshop, along with its length, was indicated.

55 studies were examined.
100% employed the 40 hour workshop to carry out value engineering studies.

3.2 Timing of the study

The timing of the studies was indicated in the VE reports. Design information was not available to check whether the timing indicated was accurate. This issue was checked with the Consultants. They confirmed that in the vast majority of cases the timing indicated in the report was a true reflection of the project's design stage.

Figure 10 - VE Methods 1

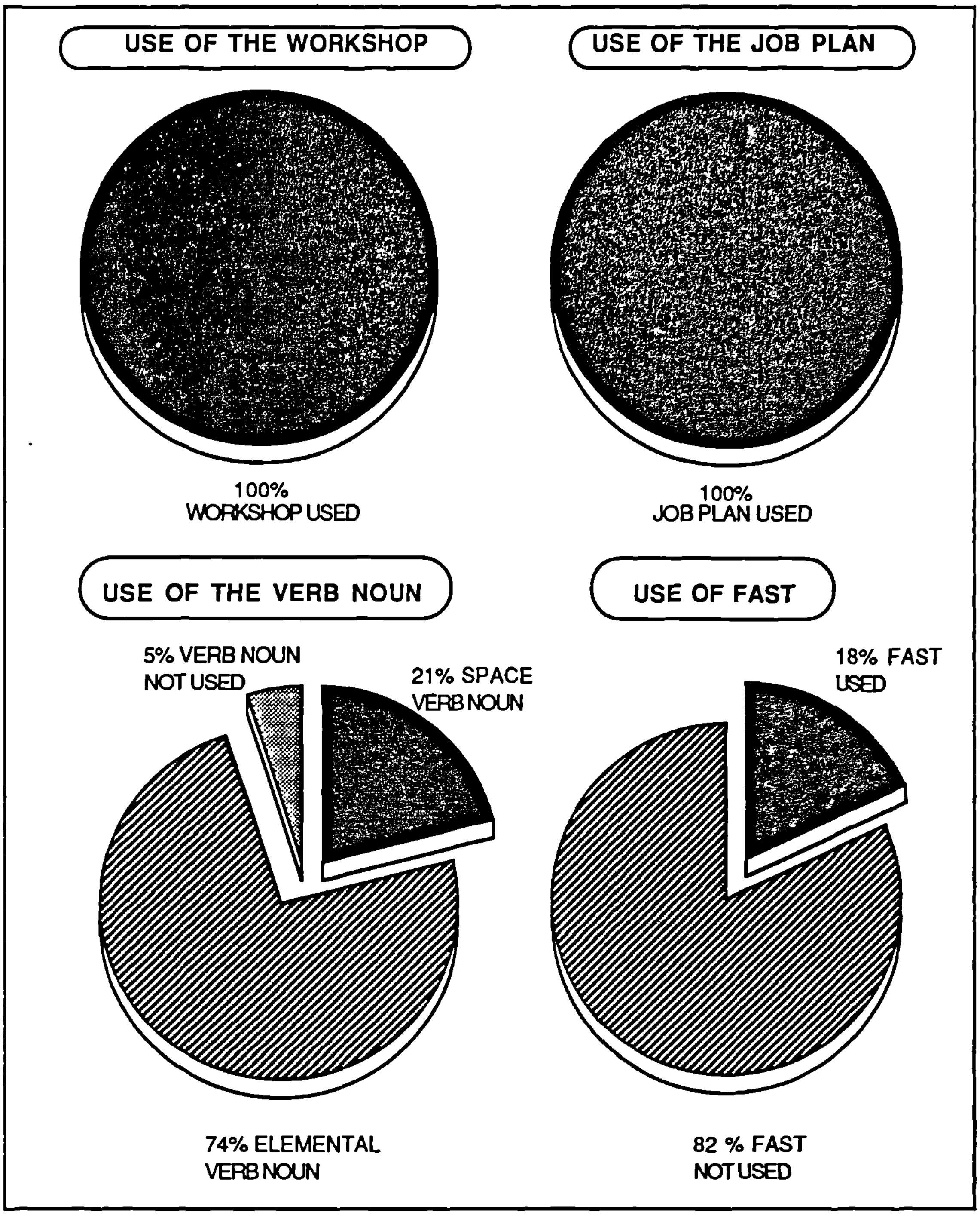
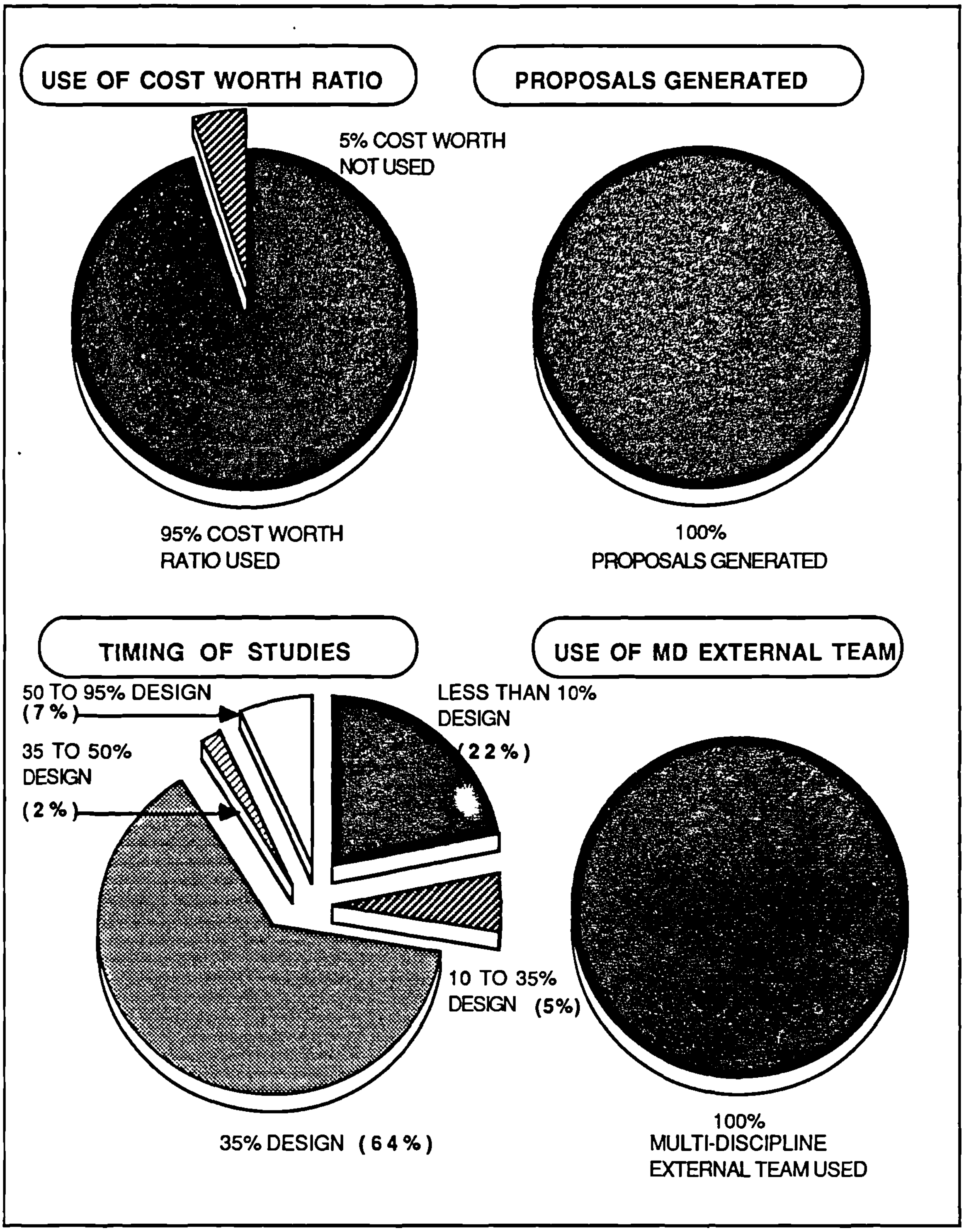


Figure 11 - VE Methods 2



55 studies were examined.

12 (22%) were carried out at 10% design stage or less.
3 (5%) were carried out at between 10% and 35% design.
35 (64%) were carried out at 35% design.
1 (2%) was carried out at between 35% and 50%.
4 (7%) were carried out at between 50% and 95%

3.3 Team approach

All reports gave the names, companies and disciplines of those involved in the studies.

55 studies were examined.
100% used a multi-discipline external team.

3.4 The job plan

55 studies were examined.
100 % were structured around the job plan.

3.5 Function definition

3.3.1 The verb-noun

All completed studies documented a completed function definition.

55 studies were examined.
12 (21%) defined functions of space based on the verb-noun.
41 (74%) defined functions of elements based on the verb-noun.
3 (5%) did not define function.

3.3.2 FAST

Where a FAST diagram was compiled it was always included in the study documentation. This item was checked with the Consultants. They confirmed that if a FAST diagram was not included in a report then it had not been compiled.

55 studies were examined.
10 (18%) employed FAST
45 (82%) did not employ FAST

3.6 Function evaluation

There are two aspects to the function evaluation issue. Firstly is the technique used to highlight poor value and secondly is the actual basis of evaluation. These were examined separately

3.6.1 The technique

Where a function evaluation was made it was shown in the completed VE documentation. The absence of such a calculation was checked with the Consultants who confirmed that absence from the documentation indicated that no evaluation was made.

55 studies were examined.
52 (95%) used the cost worth ratio.
3 (5%) used no cost worth comparison.

3.6.2 The basis of evaluation

Although the use of the cost worth ratio can be established from the studies it is impossible to tell what basis the value engineering team used for evaluating the function. The following examples, selected at random from the VE studies, give a useful insight.

Example 4 gives the function of the structure of the building as 'support load', at a cost of $17,200. The worth is allocated as $15,000 based on an increase in the column spacing. This provides a number of possible scenarios,

1. The cheapest possible means of supporting the load was by increasing the column spacings. This is unlikely as the load could be supported by brick piers or acro props at a vastly lower cost.

2. The VE team only looked for a cheaper solution based on the existing one; that is, they asked the question 'how can the frame be made cheaper?'

3. The team from past experience knew that the columns could be spaced further apart and this alone was the basis of the evaluation.

Example 5 also gives an insight into how the thought process may operate.

The function of the external enclosure is given as 'control environment' at a cost of $2.8m. This function was allocated a worth of $2m based on reducing the glazing and parapets and revising the stairs and elevators. It is clear that the study only allocated worth on the basis of a cheaper alternative to the designed solution and not the cheapest way to fulfil function. If they had allocated the cheapest way to provide function they would have omitted entirely, as opposed to merely revising, the stairs and elevators since these do not 'control environment'.

It appears, based on the document analysis, that function is evaluated on the basis of a cheaper alternative rather than on the lowest cost to achieve function.

3.7 Generating alternatives

From the information contained in the studies it was not possible to extract

EXAMPLE 4

BASIC FUNCTION: ENCLOSE SPACE/EXCLUDE ELEMENTS

COMPONENT DESCRIPTION	FUNCTION VERB	FUNCTION NOUN	KIND	COST (x1000)	WORTH (x1000)	COST/ WORTH	COMMENTS
B = Basic Function	S = Secondary Function		RS = Required Secondary Function				
Sitework	improve	site	RS	281.3	250.	1.13	Reduce paving Reduce landscaping
Foundation, slab	support	load	RS	100.4	80	1.26	Redesign slab to conform to design loads
Structure (column and joists)	support	load	RS	17.2	15	1.15	Change column spacing
Pre-engineered building, masonry	enclose	space	B	399.6	325	1.23	Simplify masonry
Plumbing	convey	fluids	S	16	16	1.00	
HVAC	control	environ-ment	S	125.4	100	1.25	Change to gas fired heaters
Fire protection	supress	fires	RS	67.6	67.6	1.00	
Electrical	illum-inate	space	S	122.9	100	1.23	Change warehouse lighting
	distri-bute	power	S				

FUNCTION ANALYSIS WORKSHEET

PROJECT: NIH BUILDING 49
ITEM: BUILDING 49
BASIC FUNCTION: Conduct Research

COMPONENT DESCRIPTION	FUNCTION VERB	FUNCTION NOUN	KIND	COST (x1000)	WORTH (x1000)	COST/ WORTH	COMMENTS
Foundations	support	load	B	669.5	602.6	1.11	Reduce live load
Substructure	support	load	B	824.0	674.0	1.22	Move building to east Eliminate water-proofing Change backfill material Reduce S.O.G. conc. strength
Superstructure	support	load	B	4,171.6	3,000.0	1.39	Post tension slab Reduce live load Reduce bay size Revise atrium stair Eliminate shear walls
Exterior closure	control	environment	B	2,832.6	2,000.0	1.42	Reduce glazing Revise atrium stair Revise elevators Reduce parapet Use brick base
Roofing	exclude	elements	B	90.1	90.1	1.00	Eliminate metal equipment screen at penthouse (savings in 03)

B = Basic Function   S = Secondary Function   RS = Required Secondary Function whether proposals generated were based on all areas or merely those highlighted as ones of poor value. However,

55 studies were examined.
55 (100%) generated alternatives.

At this stage the nature of proposals generated cannot be established. The only certainty is that all studies produce proposals.

3.8 Discussion on VE documents

The documents illustrated 100% use of the workshop, job plan and external team. In addition they showed a high use (74%) of elemental function definition. This was clearly to be expected since all documents came from the Dell'Isola school. What the documents were checking however was the use of the techniques as it was in this area that the survey differed from what was anticipated. It was suspected that respondents may have answered based on the perceived correct answer as opposed to their true practice. Analysis of the documents showed this to be the most likely case. Firstly the documents highlighted that contrary to the survey the use of FAST diagrams was low at 18%. In addition the actual diagrams that constituted the 18% could not be said to be FAST diagrams as outlined by Snodgrass and Kasi (1986). In reality they were more akin to the ladder of abstraction of Heller (1971). Furthermore, a high use of FAST indicated by a respondent was generally coupled with a function definition based on elements. It must therefore be assumed that true FAST diagrams are not used, since an elemental function definition could only ever form the last tier in the FAST, since it answers the question HOW?

Based on the examination of documents even the estimate of 18% use of FAST could be considered generous. FAST diagrams are a fashionable technique that are strongly advocated by SAVE. This may have formed the basis of the VE consultants response to the survey. Based on the survey, documents and attitude of SAVE it is most likely that FAST diagrams are not used.

With regard to the evaluation of function the documents illustrated that despite claims to the contrary, evaluation was based on the cost of a cheaper alternative and not on the lowest cost to achieve function.

Once again it appears that the question was answered based on the perceived correct answer, since SAVE define function worth as, *"The lowest overall cost that is required to perform a function".* The documents however illustrated that this was not the case.

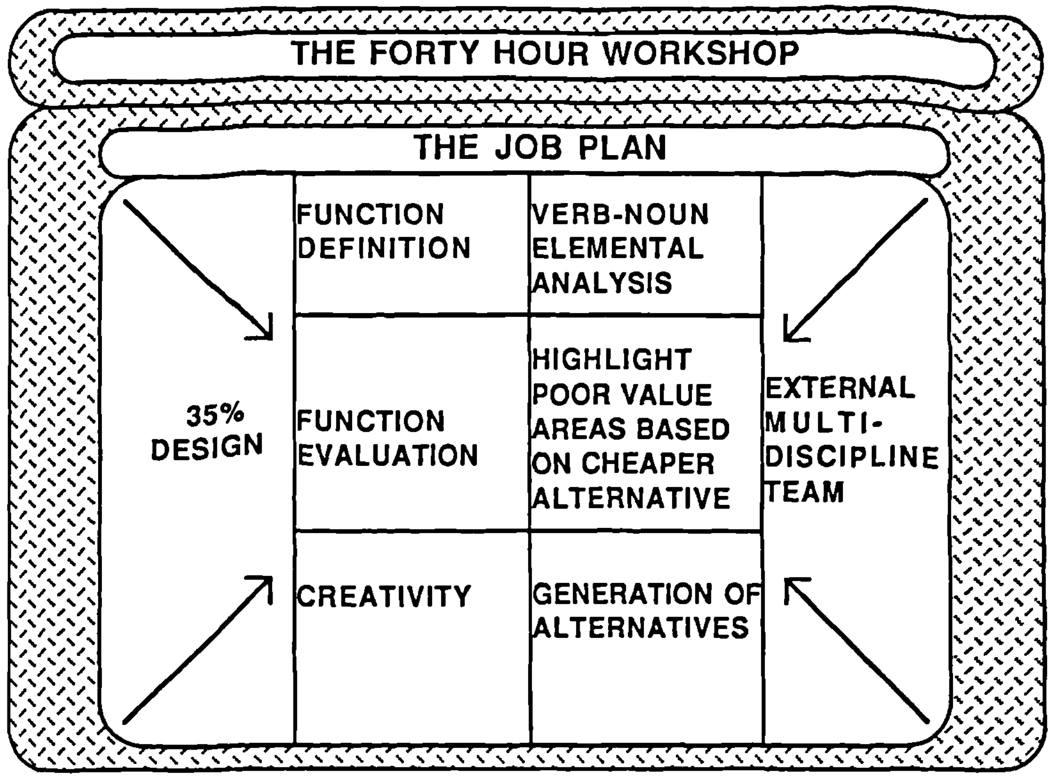
The documents showed the cost worth ratio was used 95% of the time, yet answers to the survey conflicted with this showing no general consensus of opinion. Unlike previous anomalies this cannot be attributed to respondents giving the perceived correct answer, since SAVE do not state a clear opinion either way.

The final anomaly in the expected responses showed that alternatives were generated on all areas and not just those highlighted as poor value. This is surprising. The highlighting of poor value areas seemed an important issue in the literature. In addition, all survey responses indicated that this exercise was carried out. Despite this, most responses (70%) indicated that they generated alternatives on all areas, thereby not utilising the exercise undertaken. It is difficult to explain why the highlighting of poor value areas and the generation of alternatives appear unconnected. This should however be uncovered in the examination of the relationship between VE output and function analysis.

4. General discussion

Overall the investigation of VE practice revealed a fairly clear body of opinion. Value engineering as practised in the US can be defined as a forty hour workshop, carried out at 35% design, by an external team, centred around a job plan. The studies consist of a function definition based on elements, the highlighting of areas of poor value based on the cost of a cheaper alternative, and the generation of alternatives. A summary is represented in figure 12.

Figure 12 - VE in practice



Given the development of VE from the early techniques of Miles (1961), it is surprising that there is such uniformity in VE practice. The reason for this, it appears, is that the development of US value engineering has been primarily from one source, the US Department of Defence. The DOD is one of the largest users of VE in the United States. The other large users are the Federal Government, the EPA and the GSA who use the same system - developed from the DOD method. In the early sixties both Dell'Isola and Zimmerman were employed by the DOD on the VE programme. Since this time they have written texts on the subject and begun practising in their own right. They have become the gurus, they have cornered the market. Others who initially worked for them have since developed their own practices e.g. (Hanscomb Associates) using the techniques and methods perpetrated by Dell'Isola and others. All US VE has originated from one source and as such there is little variation.

It appears that the Government and DOD have become synonymous with VE in the United States. This was reinforced by the survey, with 67% of consultants indicating these two bodies to be the leading VE clients in the

US. As such their method of thinking has been adopted by the vast majority of practising value engineers.

In the literature review the elemental function analysis used by the Dell'Isola school was viewed as limiting the scope of VE to the search for technical alternatives. Now that it has been established that VE in the US adheres to the Dell'Isola method this practice can be investigated to measure if VE studies are in fact only cost cutting exercises. This forms the basis of the next chapter.

5. Conclusion

The practice of United States VE adheres to the Dell'Isola school of thought. It can be summarised as a *forty hour workshop, structured around a job plan*, carried out by an external team at the 35% design stage. The workshop employs elemental function definition, highlights areas of poor value and generates alternatives.

VE in the US is driven by the Department of Defense and Federal Government agencies. As these are the largest employers of VE consultants in the US the practice of VE, which developed largely to suit their needs, has become acceptable as standard practice.

The research proposition was supported.

Chapter 6

Results - Function analysis and VE output

1. Introduction

1.1 Research proposition

The scope of VE is limited by the use of elemental function analysis to the search for technical alternatives and VE as practised is merely cost reduction.

1..2 Research method

Document analysis and participant observation.

2. Value engineering output

Miles (1961) argued, and many others agreed, that VE in the absence of function analysis is merely cost cutting. The examination of VE literature illustrated that the original function analysis technique has been replaced with an elemental function definition. This appeared to narrow the scope of VE to the generation of technical alternatives to elements. In view of this can the practice of VE be anything other than cost cutting?

The most appropriate method for deciding this is to examine the output of VE studies, since these provide the most significant test of what VE achieves.

In keeping with the research method VE output was examined by document analysis. 55 studies were selected from three sources; two consultants and one client, all of whom practiced in the Dell'Isola school. The client was the US Navy and the consultants were Smith Hinchman and Grylls and Hanscomb Associates. The choice of consultant and client was based on the previous research of Chapter 5 which had illustrated that these were standard. As such the results obtained could be generalised to the overall practice of VE in the United States. The Navy studies had been carried out by five different consultants. Studies from the three sources were selected at random to remove any element of bias.

The value engineering studies collected, all contained lists of proposals that were recommended as a result of the workshops. This however could not be a sufficient measure of VE output since there was no indication of which suggestions were actually incorporated into the design. On each of the studies an attempt was therefore made to gather data on implementation of proposals. Once this was complete the data was classified to examine the actual nature of the output. Each of these stages is highlighted in greater detail below.

2.1 Proposed savings

Proposed savings were taken directly from the studies. Often proposals were mutually exclusive. Where this was so, the proposed savings, as listed in the studies, were reduced to account for it and the higher of the two was included.

Table 7 shows that the percentage saving proposed by VE studies was 32.7% of project cost. This represents the maximum possible saving that could be made.

2.2 Implemented savings

In order to obtain data on implementation each of the fifty five studies was followed up to find the actual level of savings achieved. Consultants did not do this themselves so it was necessary to follow up the studies individually by contacting the client or design team. This process encountered some difficulties,

1. Proposals were often implemented partially or in modified form thereby making true savings very difficult to quantify or evaluate. If on any particular study this was sufficient to distort the figures to any substantial extent then the study was omitted from the research.

2. VE proposals were often mismatched with the level of design of the project. For example a proposal on a hospital project was,

   Revise design of parking. $0. 5m saving.

Table 7 - Proposed savings

Study	Name of project	Project Cost $m	Proposed Savings	%
1	College Point Bus Facility New York	36.3	8.76	24
2	Mental health Centre Indianapolis	78.2	5.74	7
3	Child Health Building	64.3	7.45	12
4	New Stadium KKMC	76.1	34.50	45
5	City Hospital Elmhurst	173.3	18.98	11
6	City Hospital Elmhurst	185.0	0.19	0
7	City Hospital Elmhurst	103.0	22.68	22
8	City Hospital Elmhurst	116.0	9.58	8
9	Army Dining Hall Florida	3.2	0.22	7
10	Motor Assembly Cape Canaveral	79.0	7.21	9
11	Chemical Testing Lab	2.4	0.71	30
12	Vehicle Maintenance Complex	5.5	0.76	14
13	Aircraft Parts, Elgin, Florida	1.9	0.52	27
14	Control Tower, Elgin, Florida	4.3	1.30	31
15	Rocket Test Facility, Tennessee	152.4	53.19	35
16	Maspeth Traffic Sign Shop	2.3	1.00	44
17	New York Botanical Garden	5.0	4.00	80
18	Bronx County Court House	3.4	1.92	56
19	Arkansas River, Kansas	9.6	3.77	39
20	Jet Fuel Storage, Oklahoma	4.3	0.59	14
21	Aircraft Equipment Shop, Oklahoma	2.2	0.77	35
22	Vehicle Main. Facility, Oklahoma	2.3	0.77	34
23	Mission Support Complex Oklahoma	3.8	2.04	54
24	Special Training Forces Facility	9.9	2.60	26
26	National Bank of Kuwait	37.6	3.73	10
27	Marine Corp Air Station, Carolina	6.7	3.43	51
28	Aircraft Range Modifications	1.8	1.15	65
29	Waterfront Elect. Dist. Improvement	10.4	5.41	52
30	Elect. Dist. Improvements	5.1	1.80	35
31	Pier Modernisation Yorktown	6.5	1.69	26
32	Hydrant Refueling Modifications	6.7	4.14	62
33	BOQ Modernisation	7.3	2.60	36
34	Seal Team Operating Facility	4.5	3.39	75
35	Aviation Training Addition	4.1	1.24	30
36	Naval Supply Centre	5.4	1.91	35
37	Field Maintenance Complex	3.7	0.53	14
38	Operations Facility	7.1	1.18	17
39	Atlantic Fleet HQ	4.7	0.45	10
40	Drum Storage Facility	3.6	1.83	51
41	Aeriel Targets Improvements	3.1	0.70	23
42	Cass Training Building	2.0	0.88	44
43	Electronics Maintenance Shop	3.7	1.56	42
44	Building 240	2.7	1.54	57
45	Avionics Training Facility	1.3	0.62	48
46	Marine Corp. Air Station	4.9	2.08	42
47	Utilities Upgrade	7.3	3.67	50
48	Mechanics Training	2.5	0.55	22
49	Bachelor Enlisted Quarters	18.3	8.86	48
100	Hill Aircraft Museum, Utah	2.3	0.76	34
101	JFK Federal Building	75.0	-	-
102	Phillip Burton Federal Building	93.0	-	-
103	810 7th St. Washington DC	24.9	1.03	4
104	Dining Facilities Antigua	2.2	0.44	20
105	JFK Terminal Expansion	77.0	4.45	6
106	Carlisle Barracks, Pennsylvania	2.2	1.28	58
	AVERAGE	**28.4**	**4.8**	**32.7**

The project was at the 10% design stage and the car park was not designed sufficiently to be revised to the level of detail that the proposal suggested. The design architect admitted that he had not given the design of the car park any serious thought, but nevertheless had no intention of developing along the lines assumed by the value engineer. Where proposals of this nature affected the overall cost saving to a substantial extent then the study was omitted from the research.

3. A further problem with collecting implementation data was that incorporating the proposal into the design did not necessarily mean it was incorporated into the construction. The view was expressed by some construction managers and clients that VE proposals omitted in the design were put back at a later stage, resulting in additional cost and even delay. No account was made for this as it only occurred a very small number of times.

4. Estimate mark ups were extremely high. The average figure allowed to cover contractors' overheads and profit, inflation and contingency was 35%. These mark ups were also used in the costing of proposals. This threw some doubt on the accuracy of estimates but as it affected all studies was not considered capable of distorting the overall outcome.

5. In VE workshops the VE team usually produced an independent estimate. Examination of these sometimes revealed differences from the original project estimate. On some studies the VE team used their own estimate to price proposals whereas in others they used the project estimate. Although this made individual project savings dubious it was viewed that the overall effect on all the studies would be minimal.

6. The estimating accuracy could also be challenged with regard to individual proposals. For example one proposal was,

   revise structural design of interstitial floors.

Based on an overall budget of $78m this item represented a proposed saving of $1. 6m. The interstitial floor in the hospital was such that almost all other elements of the building were affected by a change in its design. However these changes (some of significant cost increases) were not included in the $1. 6m costing. If a proposal of this nature contributed a large proportion of the overall costing of a study then it was omitted from the research.

7. Often it was necessary to adjust costs, as a proposal did not truly represent a saving. For example two proposals put forward in one study were,

. Deduct boiler breeching from estimate $185, 000

&

Eliminate duplicated equipment items from estimate $511, 000

Both of this items were regarded as implemented by the client contributing a $696, 000 saving. In actuality the savings only represented an adjustment of the estimate. The cost of the first item was merely transferred to another budget and the second item only highlighted an error in the estimate that would have eventually come to light.

These types of item were not included in either the proposed or implemented VE savings.

8. For the purposes of the research only capital cost was considered. Many items in the studies however did indicate a life cycle costing element.

9. Certain items contained in value engineering studies were termed 'design suggestions'. These are items that the VE team feel ought to be reconsidered by the design team but which are not firm proposals, in that they have no costing. They consisted of one of three general categories,

Proposals where the impact was too large for accurate costing.
Proposals that may have resulted in increased costs.
Proposal that were too vague to attach an accurate costing.

For example in one study the following design suggestions were included,

Eliminate cover at bypass lane.
Review shipping/receiving accommodations.
Provide women's locker and toilet room for maintenance workers.
Redesign second floor service building to take advantage of windows.

All the above proposals were indicated as implemented but no costs were attached. There clearly was however some financial implication. No attempt was made to calculate what this implication might be. It was assumed that the overall effect was one of 'swings and roundabouts' and was therefore minimal.

10. Implementation of some proposals affected the costing of others. Generally the studies made an adjustment for this. If not then the research made the adjustment. If therefore there were two separate proposals, one to omit wall plaster and one to reduce wall height then the former proposal would be costed for the reduced wall height, if that proposal were implemented.

After making all necessary adjustments the average implemented saving made by value engineering studies was, as shown in Table 8, 10.7% of project cost. This, due to the problems noted above, was based on 41 studies, as opposed to the original 55.

2.3 Classifying the data

The research question sought to examine whether VE offered something additional to cost cutting. To answer the question it was necessary to define cost cutting and calculate the percentage of proposed and implemented savings that could be attributed to it.

Table 8 - Proposals Implemented

Study	Name of project	Project Cost $m	Implemented Savings	%
1	College Point Bus Facility New York	36.3	8.45	23
2	Mental health Centre Indianapolis	78.2	4.40	6
3	Child Health Building	64.3	-	-
4	New Stadium KKMC	76.1	-	-
5	City Hospital Elmhurst	173.3	14.97	9
6	City Hospital Elmhurst	185.0	0.18	0
7	City Hospital Elmhurst	103.0	15.50	15
8	City Hospital Elmhurst	116.0	-	-
9	Army Dining Hall Florida	3.2	0.03	1
10	Motor Assembly Cape Canaveral	79.0	0.66	1
11	Chemical Testing Lab	2.4	0.17	7
12	Vehicle Maintenance Complex	5.5	0.21	4
13	Aircraft Parts, Elgin, Florida	1.9	0.48	25
14	Control Tower, Elgin, Florida	4.3	0.40	9
15	Rocket Test Facility, Tennessee	152.4	11.47	8
16	Maspeth Traffic Sign Shop	2.3	0.06	3
17	New York Botanical Garden	5.0	3.26	65
18	Bronx County Court House	3.4	0.28	8
19	Arkansas River, Kansas	9.6	-	-
20	Jet Fuel Storage, Oklahoma	4.3	-	-
21	Aircraft Equipment Shop, Oklahoma	2.2	-	-
22	Vehicle Main. Facility, Oklahoma	2.3	-	-
23	Mission Support Complex Oklahoma	3.8	-	-
24	Special Training Forces Facility	9.9	1.79	18
26	National Bank of Kuwait	37.6	2.62	7
27	Marine Corp Air Station, Carolina	6.7	0.55	8
28	Aircraft Range Modifications	1.8	0.10	6
29	Waterfront Elect. Dist. Improvement	10.4	0.94	9
30	Elect. Dist. Improvements	5.1	0.42	8
31	Pier Modernisation Yorktown	6.5	0.52	8
32	Hydrant Refueling Modifications	6.7	0.44	7
33	BOQ Modernisation	7.3	0.53	7
34	Seal Team Operating Facility	4.5	0.57	13
35	Aviation Training Addition	4.1	0.46	11
36	Naval Supply Centre	5.4	0.72	13
37	Field Maintenance Complex	3.7	0.07	2
38	Operations Facility	7.1	0.64	9
39	Atlantic Fleet HQ	4.7	0.25	5
40	Drum Storage Facility	3.6	0.43	12
41	Aeriel Targets Improvements	3.1	0.49	16
42	Cass Training Building	2.0	0.20	10
43	Electronics Maintenance Shop	3.7	0.14	4
44	Building 240	2.7	0.39	14
45	Avionics Training Facility	1.3	0.08	6
46	Marine Corp. Air Station	4.9	0.54	11
47	Utilities Upgrade	7.3	0.69	9
48	Mechanics Training	2.5	0.15	6
49	Bachelor Enlisted Quarters	18.3	0.39	2
100	Hill Aircraft Museum, Utah	2.3	-	-
101	JFK Federal Building	75.0	-	-
102	Phillip Burton Federal Building	93.0	-	-
103	810 7th St. Washington DC	24.9	-	-
104	Dining Facilities Antigua	2.2	-	-
105	JFK Terminal Expansion	77.0	-	-
106	Carlisle Barracks, Pennsylvania	2.2	0.71	32
	AVERAGE	**28.4**	**1.8**	**10.7**

Cost cuts, were, for the purposes of the research classified into two distinct categories,

1. Omissions

Some typical examples of omissions would be the removal of external works, the omission of finishes or the reduction in heights of partitions.

2. Specification changes

These involve the substitution of one type of material for another, examples being the substitution of paint for glazed tile or bitumen felt in lieu of permabit.

In the consideration of cost cuts there is a third aspect which warrants consideration. Architectural work by its very nature can be less 'functional' than engineering systems. As such it is often easier to omit or reduce the architectural features of a building than it is to make savings in an engineering system. In addition the quality aspect of a building tends to lie in its architectural systems. It is important to establish that the savings did not lean heavily towards the omission or reduction of architectural systems.

These three criteria formed the basis for classifying the data which was carried out as follows:

1. All proposals in the studies were firstly allocated into a discipline of either,

   Architectural,
   Engineering (civil and structural) or
   Mechanical and electrical.

   Generally this distinction was easy to make. In some instances however there were difficulties. Where a proposal recommended the reduction of floor space then this was clearly interdisciplinary. It was however impossible, based on the cost information available, (usually cost per square foot) to apportion the saving among the various disciplines. The whole saving was therefore allocated to the architectural category on the assumption that engineering elements are only designed within a space requirement as established by the architect.

2. Each proposal was then allocated a proposal type of either,

   Omission
   Specification change
   Layout

   An omission was the deletion of an entire item such as finishes, garden walls or rooflights. A specification change amounted to the substitution of one type of material for another, such as tiles for slates or trunking for conduit. These two changes form the basis of cost cuts as outlined earlier. A layout change was something that affected the concept of the design such as reducing the floor area or changing the layout of a floor. With regard to engineering they consisted of overall changes in the scope or concept of the engineering design, such as altering the lighting levels or changing the spacing of columns.

   There were naturally overlaps in this process of classification and some proposals were difficult to allocate. In some instances judgment was subjective. However it was viewed that there would be an overall balancing effect.

3. Savings proposed, along with implemented savings for each category, were calculated; in addition the overall implementation rate was computed.

4. The percentage contribution of each category to the total saving and total discipline saving was calculated.

Tables 9 to 12 show a typical completed study with all VE proposals divided into,

1. Discipline - Table 9
2. Proposal type -Table 10
3. Discipline further divided into proposal type Table-11

Table 12 is a typical results summary for an individual study. It shows the overall implementation rate, plus the percentage that each type or discipline contributed to the overall total of that type or discipline. Complete results for all studies are included in Appendix A.

2.4 Final results

Of the 41 studies on which implementation data was reliably collected, 6 could not be broken down into categories. The following tables therefore refer to 35 studies.

2.4.1. Results by discipline

Table 13 shows the percentage contribution of each discipline to the overall total of proposed and implemented savings, along with the actual implementation rate for each discipline.

Table 13 - Results by discipline

Discipline	Proposed Savings % of Total	Implemented Savings % of Total	Implementation Rate %
Architect	33	33	36
Engineer	28	30	31
M&E	39	36	34

2.4.2 Discussion

Within value engineering proposals, there is an equal contribution from all three major disciplines. The inferences that can be made from this are, for various reasons, limited. Firstly the percentages cannot, (due to lack of estimating data) be related to the overall cost breakdowns of projects. A 30% mechanical and electrical contribution to VE savings cannot be viewed as equal to a 30% architectural contribution, if the M & E consists of 20% of project cost whilst the architectural consists of 60%. Further, the figures cannot indicate the level of 'overdesign' that may exist within US projects. It is possible that there is a tendency to overdesign structural systems. Should

NO.	PROPOSED	ACTUAL	DIS	TYPE	PROPOSED	ACTUAL	%IMP	%TOT	%TOT
L4	581000	581000	A	L					
L4	369250	0	A	L					
L9	81030	0	A	L					
L14	299750	299750	A	O					
L20	35390	35390	A	O					
					1366420	916140	67	24	21
S1	10000	10000	E	O					
S2	1619460	1619460	E	L					
S4	56000	56000	E	S					
S2	0	0	E	O					
S3	0	0	E	O					
S4	0	0	E	L					
S5	0	0	E	L					
S6	10000	10000	E	S					
					1695460	1695460	100	30	39
T1	99340	0	ME	L					
T5	75040	0	ME	L					
T6	0	0	ME	L					
M1	117000	117000	ME	L					
M2	245700	245700	ME	L					
M5	0	0	ME	L					
M6	330330	0	ME	O					
M7	63180	0	ME	O					
M8	0	0	ME	O					
M11	15600	0	ME	S					
M15	46800	46800	ME	O					
M17	30110	30110	ME	O					
E1	311000	311000	ME	L					
E2	390000	411180	ME	O					
E3	60840	0	ME	S					
E4	195000	195000	ME	S					
E5	46800	0	ME	S					
E6	228500	228500	ME	S					
E7	115440	0	ME	O					
E8	15600	0	ME	O					
E9	4700	4700	ME	L					
M1	31200	31200	ME	O					
M2	9670	9670	ME	O					
E1	0	0	ME	L					
E2	77700	77700	ME	S					
E4	74000	74000	ME	O					
E5	9500	9500	ME	L					
E7	82800	0	ME	S					
					2675850	1792060	67	47	41
TOT	5737730	4403660			5737730	4403660	77	100	100

TABLE 9 - Results by discipline

NO.	PROPOSED	ACTUAL	DIS	TYPE	PROPOSED	ACTUAL	%IMP	%TOT	%TOT
L4	581000	581000	A	L					
L4	369250	0	A	L					
L9	81030	0	A	L					
S2	1619460	1619460	E	L					
S4	0	0	E	L					
S5	0	0	E	L					
T1	99340	0	ME	L					
T5	75040	0	ME	L					
T6	0	0	ME	L					
M1	117000	117000	ME	L					
M2	245700	245700	ME	L					
M5	0	0	ME	L					
E1	311000	311000	ME	L					
E9	4700	4700	ME	L					
E1	0	0	ME	L					
E5	9500	9500	ME	L					
					3513020	2888360	82	61	66
L14	299750	299750	A	O					
L20	35390	35390	A	O					
S1	10000	10000	E	O					
S2	0	0	E	O					
S3	0	0	E	O					
M6	330330	0	ME	O					
M7	63180	0	ME	O					
M8	0	0	ME	O					
M15	46800	46800	ME	O					
M17	30110	30110	ME	O					
E2	390000	411180	ME	O					
E7	115440	0	ME	O					
E8	15600	0	ME	O					
M1	31200	31200	ME	O					
M2	9670	9670	ME	O					
E4	74000	74000	ME	O					
					1451470	948100	65	25	22
S6	10000	10000	E	S					
S4	56000	56000	E	S					
M11	15600	0	ME	S					
E3	60840	0	ME	S					
E4	195000	195000	ME	S					
E5	46800	0	ME	S					
E6	228500	228500	ME	S					
E2	77700	77700	ME	S					
E7	82800	0	ME	S					
					773240	567200	73	13	13
TOT	5737730	4403660			5737730	4403660	77	100	100

TABLE IO - Results by type

NO.	PROPOSED	ACTUAL	DIS	TYPE	PROPOSED	ACTUAL	%IMP	%TOT	%TOT
L4	581000	581000	A	L					
L4	369250	0	A	L					
L9	81030	0	A	L					
					1031280	581000	56	18	13
L14	299750	299750	A	O					
L20	35390	35390	A	O					
					335140	335140	100	6	8
S2	1619460	1619460	E	L					
S4	0	0	E	L					
S5	0	0	E	L					
					1619460	1619460	100	28	37
S1	10000	10000	E	O					
S2	0	0	E	O					
S3	0	0	E	O					
					10000	10000	100	0	0
S6	10000	10000	E	S					
S4	56000	56000	E	S					
					66000	66000	100	1	1
T1	99340	0	ME	L					
T5	75040	0	ME	L					
T6	0	0	ME	L					
M1	117000	117000	ME	L					
M2	245700	245700	ME	L					
M5	0	0	ME	L					
E1	311000	311000	ME	L					
E9	4700	4700	ME	L					
E1	0	0	ME	L					
E5	9500	9500	ME	L					
					862280	687900	80	15	16
M6	330330	0	ME	O					
M7	63180	0	ME	O					
M8	0	0	ME	O					
M15	46800	46800	ME	O					
M17	30110	30110	ME	O					
E2	390000	411180	ME	O					
E7	115440	0	ME	O					
E8	15600	0	ME	O					
M1	31200	31200	ME	O					
M2	9670	9670	ME	O					
E4	74000	74000	ME	O					
					1106330	602960	55	19	14
M11	15600	0	ME	S					
E3	60840	0	ME	S					
E4	195000	195000	ME	S					
E5	46800	0	ME	S					
E6	228500	228500	ME	S					
E2	77700	77700	ME	S					
E7	82800	0	ME	S					
					707240	501200	71	12	11
TOT	5737730	4403660			5737730	4403660	77	100	100

TABLE II - Results by discipline and type

VALUE ENGINEERING 2

	IMPLEMENTED	%TOTAL PROP	%TOTAL IMP
DISCIPLINE			
ARCHITECTURAL	67	24	21
ENGINEERING	100	30	39
MECH&ELECT	67	47	41
TYPE			
LAYOUT	82	61	66
OMISSION	65	25	22
SPECIFICATION	73	13	13
ARCHITECTURAL			
LAYOUT	56	18	13
OMISSION	100	6	8
SPECIFICATION	-	-	-
ENGINEERING			
LAYOUT	100	28	37
OMISSION	100	0	0
SPECIFICATION	100	1	1
MECH&ELECT			
LAYOUT	80	15	16
OMISSION	55	19	14
SPECIFICATION	71	12	11

TABLE I2 - Results summary

this be so then the savings made will be greater than for the other disciplines.

However, the research was examining whether VE proposals lean towards the architectural side. The results confirmed that they do not. The only circumstance under which this could be wrong is if the architectural content of the projects was less than 30%. If the architectural content was more than 30%, then the actual contribution saving achieved (being one third of the total) is actually less for architectural than the other disciplines, thereby proving the point. Only if architectural content was less than 30% could proposals be said to have an architectural bias. It is unlikely that architectural systems would contribute less than 30% to the overall project total.

2.4.3. Results by type

Table 14 indicates the contributions made to the total by each type of proposal.

Table 14 - Results by Type

Type	Proposed Savings % Of Total	Implemented Savings % Of Total	Implementation Rate %
Layout	32	36	41
Omission	22	23	32
Specification	46	41	31

The highest contribution to the total was by specification changes which contributed 46% of the proposed and 41% of the implemented savings. This, added to the omissions, indicated that cost cuts as previously defined amounted to some 68% of proposals made and 64% of proposals implemented.

2.4.4 Discussion

Value engineering is therefore more than a cost cutting exercise in that one third of proposals (in terms of savings achieved) relate to design concepts as opposed to omissions or specification changes.

2.4.5. Results by discipline and type

Tables 15-17 split the VE proposals into disciplines and type. The first half of the tables in each discipline represents the contribution of the proposal type to the overall total savings. The second half represents the contribution of each type of proposal to the overall total of that discipline.

Table 15 - Architectural discipline

Percentage Contribution to Overall Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	Implementation Rate %
Layout	17	17	30
Omission	5	7	37
Specification	11	9	24
Percentage Contribution to Architectural Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	
Layout	52	52	
Omission	15	21	
Specification	33	27	

Table 16 - Engineering discipline

Percentage Contribution to Overall Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	Implementation Rate %
Layout Omission Specification	7 7 14	6 6 19	20 27 45
Percentage Contribution to Engineering Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	
Layout Omission Specification	25 25 50	20 20 60	

Table 17 - Services discipline

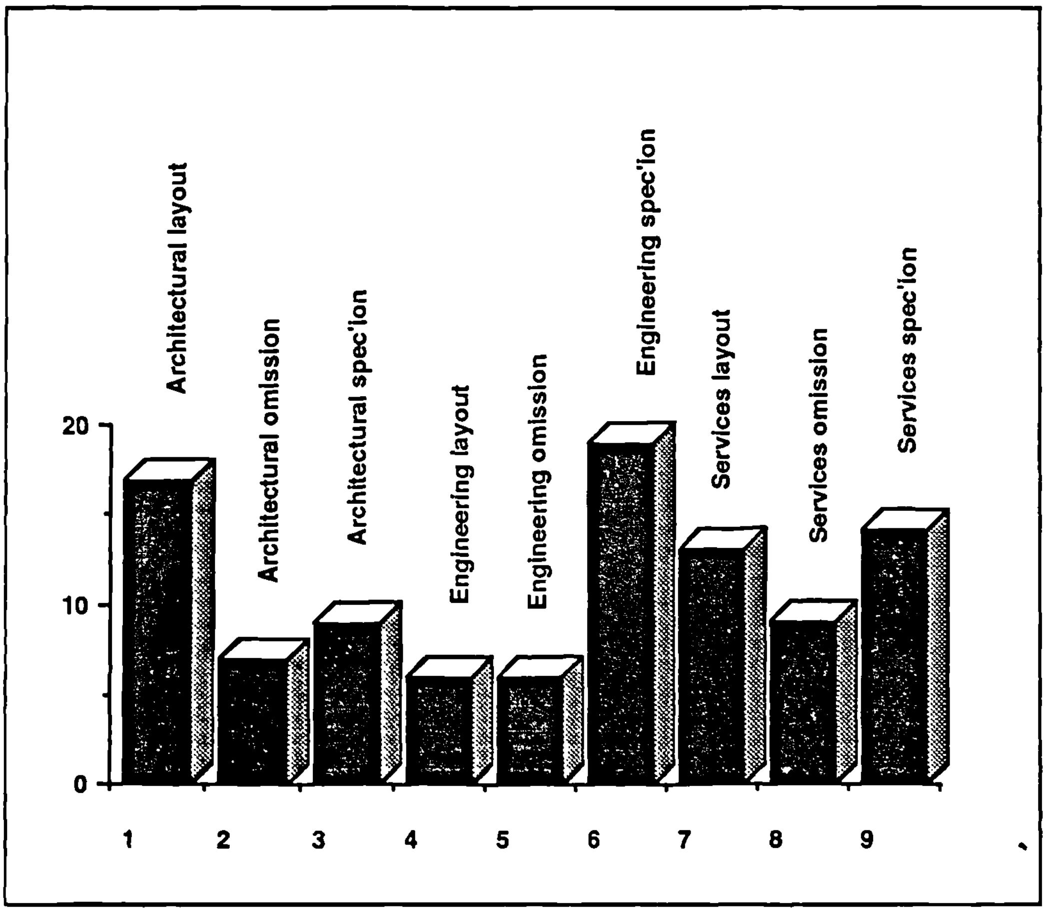
Percentage Contribution to Overall Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	Implementation Rate %
Layout Omission Specification	9 11 20	13 9 14	46 29 25
Percentage Contribution to Services Savings			
Type	Proposed Savings % Of Total	Implemented Savings % Of Total	
Layout Omission Specification	23 28 50	36 25 39	

2.4.6 Discussion

Tables 15-17 indicate two significant points. In the engineering disciplines there is a heavier bias towards cost cuts than there are in the architectural discipline where the bias is towards design changes. This had been envisaged to some degree as the overall design solution of the engineering components is largely dictated by the architectural solution. In addition the number of possible engineering solutions available is limited.

The second important point is that the largest single contribution to the overall total saving was made by changes in engineering specification. This was followed by architectural layout changes and services specification changes and is shown in Figure 13. The results were certainly not what was expected. It appears that VE relates to more than cost cutting and generates proposals on a broader spectrum than is dictated by the techniques.

Figure 13 - Percentage contribution to overall savings



2.5 General discussion on VE output

The nature of the data and the problems that were encountered in its refinement do make the conclusions that can be drawn on VE output fairly limited. However the following inferences can be made with a reasonable degree of confidence.

1. Proposed savings made by VE studies are approximately 30% of project cost.

2. The implementation of these proposals is around 30%, giving an average actual saving of approximately 10%.

3. The proposals, in terms of their contribution to the overall savings come equally from the architectural, engineering and services disciplines.

4. The savings do not confine themselves to cost cuts. Although the majority of proposals do come from this category (64%) a significant number (36%) do actually comment on the design concept.

The research question sought to establish the relationship between function analysis and VE output. As isolated issues the function analysis and output have both been clarified. Function analysis is based on elements and cheaper alternative to them and VE output consists of a mixture of cost cuts and design changes. This is surprising.

The function analysis used by Dell'Isola relates only to the elemental design and based on this it was assumed that proposals would only relate to the same. Where a function analysis defines functions of doors, floors and roofs then it was envisaged that the VE proposals would relate only to those elements or components. It was assumed that the examination of elemental function would not lead to a more general review of design. This assumption has been found to be incorrect and value engineering does implement proposals that comment on the concept design as well as the components or elements of it.

The type of function analysis used by Dell'Isola pointed to a non-creative non-function-orientated process that produced only cost cuts. VE is clearly more than that. This raises the question of whether the function analysis used is responsible for the output. The next section of this chapter examines the relationship between function analysis and VE output.

3. The relationship between function analysis and VE output

As explained earlier, participant observation was selected as the research method for this section of the research question. Once again, for maximum generalization a consultant adhering to the 'standard' Dell'Isola School was selected. Alphonse Dell'Isola is the managing director of SH&G and as such this company was chosen for the research. Four 40-hour workshops were attended. These were selected purely on the basis that their timing corresponded with the observer's visit to the United States. All proceedings of the workshops were recorded and all participants interviewed. Full documentation is appendixed at B. The following is a summary of the issues relevant to the research question.

3.1 Value engineering workshop 1

3.1.1 Function analysis used

The workshop was a training workshop for employees of a construction management company and was run over four days. The employees of the construction management company made up the VE team and carried out VE procedures under the guidance of the workshop leader. The workshop leader presented the function analysis to to be used in the VE study. This in the main consisted of three activities of,

Cost and energy models
Graphical function analysis
Function analysis and cost worth ratios

1. Cost models

The cost model was constructed by using the original estimate and allocating the cost contained therein over a series of elements. Once this cost was apportioned the team then assigned their own estimate of cost to the elements. This is shown in Example 6. As the majority of the team were estimators they had a great deal of experience on which to draw. The allocation of their own costs was very subjective and basically amounted to the team asking if the original estimate was high, low or 'about right'.

The team were not correcting the original estimate, they were allocating costs to the elements based on what they believed the element could be constructed for.

2. Graphical function analysis

Once the cost models were completed the team drew up a graphical function analysis as shown in Example 7. This was a graphical representation of those elements of the building that the team felt were more expensive than average.

3. Function analysis and cost worth ratios

Once a graphical representation of the costs was completed the team moved to the function analysis. This process consisted of various elements of the building being allocated a function. Based on the figures calculated in the cost model, each function was then assigned a cost worth ratio. This was calculated by dividing the cost allocated in the original estimate by the cost estimated by the VE team. As an example, on one section of the building the following functions and ratios were allocated, PROJECT ____________

COST MODEL

SHEET ____ OF ____

Construction	+	Contingency	+	Escalation	=	Construction @ Bid Date

12 Site	Building
8,627,000	
12,043,400	

Legend:
Target ————
Actual/Estimated - - - - -

Bldg. Type ____
Const. Type ____
Use Units ____

Date ____
Phase ____
GSF ____
NSF ____
Floors ____

Comparative Ratios:

Parameter	Target	ACT/EST

Overhead & Profit	Structural	Architectural	08 Mech.	09 Elec.	11 Equip.	10 Gen.Cond. Ovhd.& Profit
PRORATE	18939600	19,951,100			15,301,300	17,219,300
PRO-RATE	22,172,100	22,854,100			15,301,300	17,219,300
Site Preparation	**01 Found.**	**04 Exterior Closure**	**HVAC**	**Service & Distribution**	**Fixed Equip.**	**Mobilization Expenses**
2,938,800	~~5,159,500~~	7,406,500			5,740,500	205,600
3,962,200	5,567,300	8,151,500			5,740,500	205,600
Site Improvement	**Special Foundations**	**05 Roofing**	**Plumbing**	**Lighting & Power**	**Furnishings**	**Job Site Overheads**
1,269,300	~~2,435,600~~	643,100			9,566,800	16,302,900
3,121,300	2,788,000	643,100			9,566,800	16,302,900
Site Utilities	**02 Sub-structure**	**06 Interior Construction**	**Fire Protection**	**Spec. Elec. Systems**	**Spec. Const.**	**Demobilization**
4,418,900	343,900	10,981,500			0	0
4,958,900	343,900	13,139,500			0	0
Off Site Work	**03 Super-structure**	**07 Conveying Systems**	**Spec. Mech. Systems**			**Off Expense & Profit**
0	~~11,000,000~~	920,000			0	710800
0	13,473,700	920,000			0	710800

FINISHES - 5,271,300
PARTITIONS - 1,868,200

EXAMPLE 7

General Work Sheet

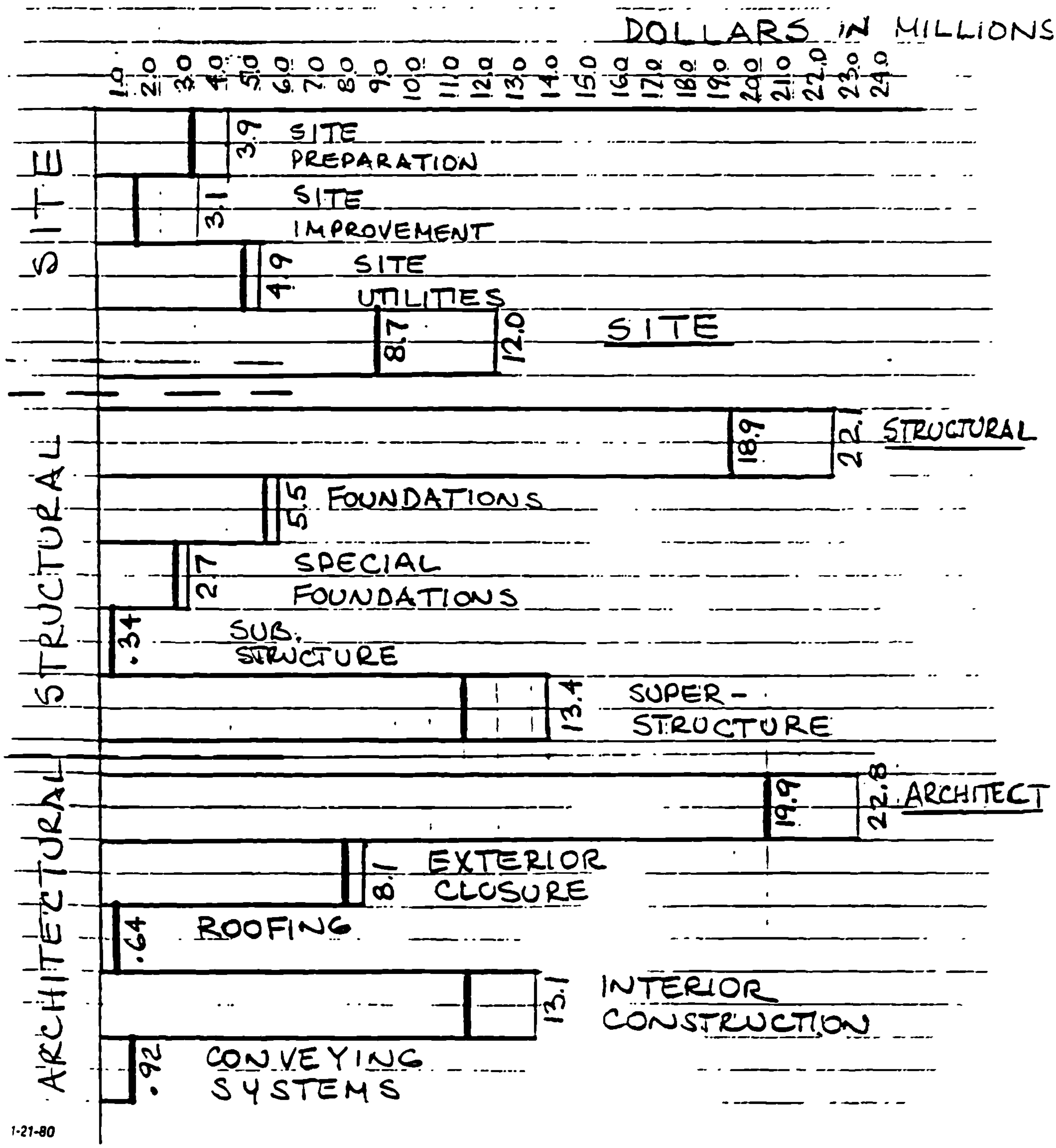
SH&G
Smith, Hinchman & Grylls Associates, Inc.
Architects Engineers Planners
455 West Fort Street
Detroit, Michigan 48226
313/964-3000

Subject: GRAPHICAL FUNCTION ANALYSIS.

Date:

Project No:

Drawn By:



1-21-80

Table 22 - Function analysis and cost worth ratios

Component	Function	Cost/Worth ratio
Site preparation Site improvements Site utilities Exterior closure Roofing	Prepare site Improve site Provide utilities Enclose space Weatherproof building	1. 35 2. 6 1. 13 1. 1 1. 0

3.1.2 Discussion

In the examination of the Dell'Isola school, it was assumed that the process of function analysis was to define function, highlight areas of high cost and generate alternatives to them. In this workshop the process was reversed. Areas of high cost were highlighted graphically, based on an alternative, and then functions of any high cost areas were defined. Finally for those defined functions a cost worth ratio was calculated. The definition of function appeared to be merely an appendage to the process of selection of areas of high cost based on the cost of an alternative.

The documentary evidence that was produced after the study would have, if examined in isolation, pointed to the following thought process,

Component	Function	Cost	Worth	Ratio	Proposal
Granite	Cover floors	379	80	4.74	Change to quarry tiles

In reality the following move accurately represented the process

Granite→ Expensive→ Quarry tiles→ Cheaper→ how much cheaper→ 4.74 times cheaper→ better have quarry tiles

The function analysis was never used in this study as a means of generating alternatives. The highlighting of high cost areas, based on a cheaper alternative, was in itself the machinery of idea generation. Generally there was only one alternative; the process was not used as a catalyst for further generation. For example the cost worth ratio of stainless steel columns was based on the cost of dry wall. The alternative, which ultimately became the proposal, generated the cost worth ratio. The cost worth ratio did not produce the alternatives.

This analysis of the cost worth ratio throws some light on the findings of the survey which, contrary to the documents, showed a low usage of the technique. On paper, as illustrated above, it looked as if the cost worth ratio had been used correctly. In practice there is some confusion, which may have resulted in the lower survey response.

3.2 Value engineering workshop 2

3.2.1 Function analysis used

The workshop was a large hospital project. The VE team were employees of SH&G construction management group. The workshop leader was from SH&G value division. The VE team split into disciplines (amounting to one or two persons). They then examined the design work of their own discipline and listed individually their ideas. There was no interaction between the VE team.

Individual disciplines put forward their VE proposals which were listed on wall charts by the VE leader. Proposals referred only to the discipline of the VE member. As an exception to this the structural engineer did put forward some architectural ideas. The cost estimator made no suggestions but did comment that he felt the job was underestimated. There was no function analysis or brainstorming. There was no highlighting of high cost areas or calculation of a cost worth ratio. The workshop leader was dictated the proposals by the team members and did not involve himself in discussion. He appeared keen to increase the number of VE proposals. Often as each discipline gave their proposals other team members were not listening or took the opportunity to take a coffee break. None of the proposals put forward was developed or built upon by other team members.

3.2.2 Discussion

The proposals put forward by this study consisted of cost cuts and design changes. They cannot be related back to function analysis because none was used. The overriding impression left by this study was that it was a failure. The VE leader did not control the proceedings and the VE team lacked enthusiasm. The design team were present for a short period when the VE team presented their proposals. A lot of ill-feeling developed between the two parties during this stage. It was felt that the VE team did not utilise the design team's knowledge to maximum benefit. The study left the feeling that the VE team never fully understood the project and that the design was too far progressed to really obtain benefit from a VE study. In addition the project was restrained by strict design criteria which made many of the VE proposals unworkable. There was confusion as to what the actual criteria were and whether they could be changed. The budget was never clearly defined and this created further problems. Five days was too long a period for this study and there were intervals of inactivity. The VE team had little understanding of VE principles and were not sure of their expected role. The study lacked a firm structure and suffered from VE team members making personal attacks on the design team.

3.3. Value engineering workshop 3

3.3.1 Function analysis used

The workshop was a refurbishment of a police precinct, a listed building in Central Park. The workshop leader was from SH & G. The VE team were selected by the client from various companies. Prior to the study the VE leader and the team had not met.

After a general introduction, the VE team directed questions to the design team on any queries that they had about the project. Many of the questions raised substantial design issues about the layout of the building and the criteria of design. In addition to the VE and design team the client, police department and parks department were also present. This highlighted very clearly the difficulties the design team had been faced with. The police department's primary concern lay with security and given the opportunity they would have erected a twelve foot wall all around the building. The parks department on the other hand were keen that the structure was visible. The client was also concerned primarily with the preservation of the historic nature of the project. The question and answer session highlighted other problems such as phasing and parking. The architect for example suggested that the work could be phased but the police department ruled that out on the grounds of security. They wanted to make two 'clean' moves, one into temporary accommodation and one back to the main building. The discussions also covered the siting of the temporary accommodation which up until now had not been discussed with the police department, although they had very strong feelings about it. Likewise problems regarding parking were also ironed out. The police department were adamant that the car park must provide adequate space to swing a police car around at speed in an emergency. The architect had not been aware of this criterion prior to the study.

After the question and answer session the workshop leader handed out copies of the original estimate along with the estimate carried out by the independent consultant, present as a VE team member. The architect's estimate was $5. 5m whilst the independent one was $3. 7m. It was agreed that VE proposals would be priced at the lower estimate's rates and prices.

A function analysis had been compiled by the workshop leader prior to the study. The function analysis session consisted of the workshop leader listing components, along with their function, on charts on the walls. The team were not asked for their opinions regarding the function of elements. The charts consisted of six columns as shown below.

Component	Function	Kind	Cost	Worth	Ratio
Internal walls	Divide space	B	258, 000	258, 000	1

The first four columns were compiled solely by the workshop leader who informed the team of the component, function, function type and cost. The team then jointly decided a worth.

The examination of worth was based on whether, in the team's opinion, the original estimate was comparable with average values. Discussion was based solely on experience of costs of previous projects. Where an element was of a relatively low value say $25, 000, it was not allocated a worth as it was viewed that the maximum saving that could be achieved did not warrant spending time on it.

The function analysis did not really appear to serve any useful purpose. It was difficult to believe that the internal walls of a police station only had the function of dividing space. Furthermore the functions did not appear to bear any relationship to the building's use but only to the estimate. For example,

Exterior enclosure	**Waterproof windows** **Restore windows** **Waterproof masonry**

In the original estimate the architect had included a cost element of exterior enclosure, under which he had sub-headings of waterproofing and restoring windows. The workshop leader had merely used these sub-cost areas to describe the functions of the main element.

One member of the team did however question one function. The workshop leader had said that the function of the masonry was to enclose space. One member of the team argued that this was not the case, as the space was already enclosed by the existing walls. The cost of the masonry was therefore only directed at the restoration of the building's original appearance. This clearly put the cost of the masonry in a different light, since many of the team regarded the costs of the masonry to be connected with the structural stability of the wall, which it was not. The workshop leader therefore changed the component and function from,

Masonry	**Enclose space**
to	
Exterior enclosure	**Restore masonry**
The team member had been arguing for	
Masonry	**Restore originality**

He was clearly confused by the workshop leader's new function definition.

Another very confusing issue related to the cost worth ratios and which costs should actually be used. Referring back to the masonry, the VE team felt that the amount included by the architect in the original estimate was too low. The cost of the masonry was allocated on the basis of the original estimate and the worth was assigned based on the team's opinion. Worth was therefore more than cost!

Another problem arose with function analysis in that because the design team were no longer present, the VE team simply did not have enough information. For example, the architect had used Vicuclad on walls instead of plasterboard. This could have been for numerous reasons of fire protection, security, acoustics. This lack of information made a nonsense of the cost worth ratio since the VE team were allocating a worth to something they did not understand. The team allocated a worth to the Vicuclad based on the cost of plasterboard. Plasterboard however would not fulfil the criteria of fire protection or security, if that was the function of the Vicuclad, so it cannot correctly form the basis of the worth.

During this entire exercise most of the VE team looked either confused or disinterested.

Following the function analysis a brainstorming session was carried out. It was a team effort with VE members using the information they had gathered to generate alternatives. Suggestions were interdisciplinary and did appear to relate to much more than simple technical suggestions. For example,

The rehabilitation expert saw danger in the police pulling straight off the car park, often in a hurry, into the road, and that some parking ought to be eliminated to increase the line of vision.

The team considered the length of time that a police scooter would lose by the indirect access provided by the current car parking arrangement. This they estimated at three minutes, which in the case of crime apprehension or prevention could prove vital.

3.3.2 Discussion

The function analysis used in this workshop at face value appeared to have a relationship to the VE output. In practice there was very little connection between the two. The function analysis was an autonomous two hour period in the workshop that was not built upon.

The proposals put forward in this study came from various sources. The question and answer session between the client, design team and VE team, the analysis of the estimate, the input of the VE leader, the presence of the client at the study and the interaction of the team all contributed to the proposals. These factors, which were not present at the previous study, appeared to contribute to a more successful outcome.

Once again however there were problems. The estimate was a source of conflict in the study with constant disagreements as to what the architect had included and why. The presence of the client although useful in many respects, created difficulties, largely due to the personality of the individual. He dominated the proceedings, interrupting the VE leader and the study for irrelevant reasons. It was a difficult situation for the VE leader as the project client was also his client. Another problem was that although the VE team interacted with the design team well, they still lacked background to the project. Often, despite knowing what was included in a project,they could not understand why.

The timing of the study appeared to have a direct relationship with the proposals put forward. This project was at 35% design and the VE team avoided proposals that would require a substantial element of redesign.

The importance of quality in the VE team was also highlighted in this study. One VE member did not believe VE was effective and this was reflected in the proposals he put forward. Once again five days was too long for the study and there were long periods of inactivity.

Overall the study appeared successful. However the proposals put forward and the overall successful output could not be related to the VE techniques; it was due primarily to the people involved and their interaction with one another.

3.4 Value engineering workshop 4

3.4.1 Function analysis used

This VE workshop used the design team, with the addition of several outside consultants to VE their own design. The design team were from SH & G and the study leader was from SH & G value division. The group split into teams of architectural, mechanical, electrical and structural and then generated proposals for alternative solutions within that discipline. While they were doing this the workshop leader, along with the estimator, drew up a function analysis and a cost worth ratio. This development of cost worth did appear to have more of a relationship to function than in the previous studies. For example the VE leader thought that the function of the archives section of the building could be fulfilled by building it single storey on grade instead of over three levels of underground parking. The worth of the elevator to serve the archives building was therefore put at nil. With regard to other elements worth was typically calculated as follows,

Existing cost external walls = $15. 35 for walls 47ft high. (2 x 14ft 6"+18ft)
Height could be 3 x 12ft 6"= 37ft
47 - 37= 10 or approximately 25%
Therefore new cost = $15. 35 - 25% = £11. 50.
Cost woth = $15.35/$11.50 = 1.33

3.4.2 Discussion

This study, last of the four to be attended, summarised the relationship between function analysis and VE output. The VE leader produced the function definition and cost worth ratio and included them in the VE report. While he was doing this the VE team produced the proposals. There was no connection between the two although the VE leader did direct the study towards areas where he felt there was potential for cost reduction.

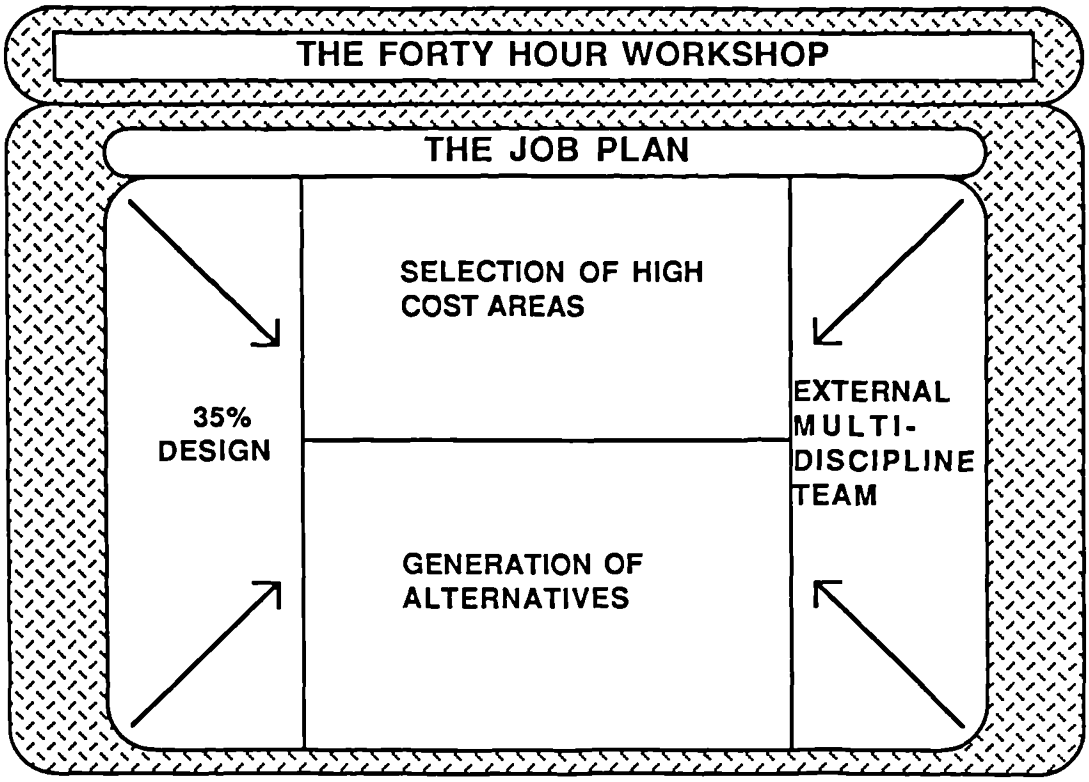
This study was generally successful in that it questioned many design issues and put forward proposals of substantial cost savings. None of these could be contributed to VE techniques. The overriding features of this study were the charismatic personality of the VE leader and the very early timing of the study at less than 10% design. In addition the relationships between the VE team and leader were unusual. The design team were junior to the VE leader who was a director of the same company and they were clearly keen to impress. The proceedings were aided by this. The study was carried out as a public relations exercise in the hope of selling a VE programme to the client (a large public body). The overall atmosphere of the study was very congenial and again this appeared beneficial. There was one other salient point. The client - a local authority funded by the central government - had no incentive to reduce cost. It was felt that despite a good study the actual level of implementation would be very low.

4. General discussion on function analysis and VE output

Value engineering in the US is effective in reducing construction cost by a combination of cost cuts and design changes. The successful output of value engineering in the United States however, cannot be attributed to function analysis. The actual workshop itself as an autonomous unit set aside for cost reduction is a critical factor. Within the workshop, the degree of success or level of output relates largely to the personalities involved, particularly that of the leader, the timing of the study, the interaction of the VE team, the input of the design team and the role of the client. The techniques of function analysis bears little or no relationship to the output.

The governing body of VE in the United States, the Society of American Value Engineers, will not endorse a forty hour workshop unless it has a function analysis. It is assumed that this is the reason for its inclusion in the studies. The technique as practised however is inert. Value engineering in the US is basically a design audit. It consists of a forty hour workshop structured loosely around a job plan. It is carried out at 35% design by an external team. It involves the selection of high cost areas and the generation of alternatives. The selection of high cost areas is a fairly loose procedure. It is based on the comparison of elemental costs with the cost of cheaper alternatives, along with a more general analysis of cost centres of the project. The concentration of VE effort is as dependent on the input of the VE leader as it is on the selection of high cost areas. Often a VE leader, based on his own experience, will guide the team towards examination of a particular section, which he believes has the potential for cost reduction. In addition other factors, such as the input of the client and design team affect the generation of proposals. This nebulous approach results in a fairly broad VE output encompassing design changes and cost cuts from all disciplines. This corresponds closely with the investigation of VE practice that indicated proposals were generated on all areas and not just those of high cost. It also corresponds closely with the examination of VE output which consisted of a mixture of cost cuts and design changes. A summary of VE in practice is shown in Figure 14.

Figure 14 Value engineering in practice



The actual saving achieved by US VE is in the region of 10%. This is a significant saving and even given the distortion of VE techniques is worthy of examination for its application to the UK construction industry. However, the UK construction industry, largely due to the presence of the quantity surveying system, may already encompass some of the elements of VE that produce the 10% saving. The next section of the research examines the relationship between value engineering practice and UK procedures.

5. Conclusion

Value engineering as practised in the US produces overall savings of 10% on project cost. Of this 10%, 67% can be attributed to cost cutting, whilst the remainder consists of more design orientated proposals. The output of value engineering has little relationship to the function analysis used. The technique exists autonomously to satisfy the requirements of the Society of American Value Engineers.

The success or otherwise of a VE study relates primarily to the personality of the leader, the interaction of the VE team and the role of the design team and client within the study. These, coupled with the autonomy of the workshop, are responsible for producing savings. Function analysis as practiced is largely inert and irrelevant to the process. It has no effect on the output.

The research proposition was not supported.

Chapter 7

Results - A comparison of value engineering in the United States with cost planning in the United Kingdom

1. Introduction

1.1 Research proposition

VE as practised in the US is nothing additional to that which exists within the UK cost planning framework.

1.2 Research method

Analysis of existing material and comparative analysis.

2. The UK system of cost control

The RIBA plan of work (1973) outlines the tasks to be undertaken by members of the design team during various stages of a construction project. The plan places the responsibility for cost control with the quantity surveyor, who, through a system of cost planning, controls the cost of design as it develops. Cost planning is the nucleus of UK cost control procedures and as such will be the basis of comparison with value engineering.

The RIBA plan of work highlights that cost planning during the design stage falls into four sections,

1. Advising on a cost range.

2. Preparing an outline cost plan.

3. Preparing a cost plan.

4. Cost checking the design.

2.1 Advising on a cost range

Bathurst's (1980) view is that the purpose of this stage is to establish a target cost. This is based on a cost limit or approximate estimate compiled from areas or schedules of accommodation.

The RICS (1976) in their 'Introduction to Cost Planning' see that the main intention of this stage is to discuss the finance of the project, determining its general viability and to produce a cost limit. The cost limit would generally be prepared using one of two methods, depending on the availability of drawn data. If drawn information were available the preliminary estimate would be based on cost per m^2 or cost per m^3. Where no drawn information were available then the estimate would be prepared on the basis of units of accommodation. Ferry and Brandon (1984) envisaged that no drawings would be available at this stage and no information regarding shape, size or number of stories would be necessary. The estimate would therefore be based on a schedule of accommodation.

2.2 Preparing an outline cost plan

The outline cost plan is not included in Bathurst's (1980) cost planning process and his suggested approach moves from target cost to full cost plan. The RICS (1976) however do include an outline cost plan in their system. They assume an earlier cost input in the design process than Bathurst does. In addition they suggest that cost planning encompasses advice on building design and shapes. The nature of this advice is not clear. It may be interpreted as merely costing the various solutions that the design team puts forward. On the other hand it could be understood to recommend a pro-active cost input in the early design stages.

Ferry and Brandon (1984) in their approach to the outline cost plan confirm what was not clear in the RICS report, that there ought to be an active cost input on decisions of plan shape, height and number of storeys. Under the cost planning system put forward by Ferry and Brandon the cost has control over design.

Tracing the development of the cost planning process, Morrison (1980) claimed that it was the introduction of the outline cost plan, through the RIBA plan of work, that allowed design procedures to be cost led as opposed to design led. The outline cost plan for the first time allocated elemental cost prior to drawn information being produced, thereby enabling the cost to influence design as opposed to the other way round.

Both Morrison (1980) and Ferry and Brandon (1984) concluded that although the early cost involvement, through the outline cost plan, did allow cost to influence design, very often this was not the case, as the appointment of the cost consultant (QS) came too late, often only when sketch plans had been produced.

Morrison established that it was very rare for a QS to be appointed before an architect. In the majority of cases the QS was appointed at a time when the architect had begun to prepare some form of drawn information. Morrison further recognised that cost influence also related to how flexibly the architect viewed his own design. If shape or size was fixed the QS had very little scope in which to work and was limited to the choice of materials and construction details.

Morrison concluded that in the private sector the input of the QS was too late, after major cost items of site, shape, height form etc. had been decided. As a result cost was not allowed to influence the really important decisions. He concluded that although the profession had the appropriate techniques for effective cost planning,

"the practice of such techniques has been observed to be very limited even among those practitioners thought to be among the leaders in the field of cost planning. "

2.3 Preparing the cost plan

Bathurst (1980) outlined that the cost plan stage involves the client in preparing his brief and the architect in preparing sketch plans. The quantity surveyor in close liaison with the architect prepares a cost plan by distributing the cost target, formulated in the first stage, among the elements of the building. This distribution is based on historical data contained in a cost analysis.

The methodology of elemental cost planning outlined by Bathurst suggests that cost can influence design by allocating a specific amount of money that can be spent on each individual element, thereby governing the nature and quality of the design of that element.

Bathurst's method of cost control therefore appears to present an active cost involvement that considers options and is concerned with cost control as opposed to cost monitoring. However the cost input as he suggests does not reach into the realms of plan shape, height, layout or number of storeys. As Bathurst is limiting his design involvement to post sketch design, and as 80% of cost is expended at this stage, then the pro-active cost involvement may be limited to only a small proportion of the cost. In addition there is a further anomaly in Bathurst's work relating to the presence of drawn information. In an example cost plan Bathurst (1980) calculates the cost of the external walls and other elements based on the quantity that the architect has shown on the drawing - the costs are not taken directly from the cost analysis to give a balanced expenditure. Despite Bathurst's assurance that he is designing to cost he appears, with the exception of the level of specification, to be costing a design.

The RICS (1976) suggest that the cost plan lists the constituent parts of the drawing in terms of definable parts of the building and that the cost plan runs parallel with design development. This is very clearly a conflict with Bathurst as it suggests that the cost plan develops in parallel with the design process as opposed to following on from it.

Ferry and Brandon (1984) recommend that the cost plan be produced following final sketch drawings, based on the allocation of the target cost among the elements. Since cost planning involves cost control, the architect must design within the cost plan, which must be available before working drawings proceed. Where there is insufficient data available to complete the cost plan the QS will either fill in the gaps himself with an appropriate specification or alternatively give a guide price to the architect within which he ought to work.

This approach to the full cost plan, recommended by Ferry and Brandon appears to agree with Bathurst, in that it recommends the production of the cost plan based on the final sketch design. However as this final sketch design was initially based on the outline cost plan, the same conclusion cannot be drawn regarding the lack of cost input into the design.

There is a general consensus among the cost planning texts that at the sketch design stage the target cost is distributed among the various elements of the building to give a balanced design. The anomaly in Bathurst's work lies in the presence of drawn information. It is very difficult to prove that a cost plan is influencing design to any significant extent when it is based on sketch plans that show shape, height and number of floors, as all the elements are influenced by these factors. Where this is the case, the cost influence is limited not to the elemental design itself but merely to the specification level of it. The parallel development of the cost plan with design, recommended by the RICS, appears a more logical way of allowing cost to influence design. This idea of parallel development was strongly reinforced by Morrison (1980) and Morton (1987), who both concluded that the design process was not linear as suggested by the plan of work but more flexible and reiterative.

2.4 Cost checking

The final stage of the cost planning process is cost checking. This involves checking that the design and the working drawings correspond with the contents of the cost plan.

2.5 Comparative cost planning

Bathurst (1980), unlike the RICS (1976) and Ferry and Brandon (1984), holds the view that there are two distinct types of cost planning: elemental as described above and comparative. This latter method can be termed costing a design, as opposed to elemental cost planning which is designing to cost. As with Bathurst's elemental cost planning, comparative cost planning consists of three distinct phases,

2.5.1 Advising on a cost range

The target cost is established. Target cost in this instance is an upper limit unlike with elemental planning where it is the actual limit. It is however calculated on a similar basis.

2.5.2 Preparing a cost plan

The cost plan is formulated by the quantity surveyor selecting and pricing a range of alternatives, produced by the architect for various elements of the building. The architect then chooses the optimum solution from the available choices. The total of these must not exceed the upper cost limit.

2.5.3 Cost checking

Phase three is once again the cost checking process. The need for cost checking however will not be so great, as the elemental design is already decided upon. It will merely need to check that the design does not exceed the specification.

Seeley (1984) also recognised a lucid division between elemental and comparative cost planning,

"The comparative method of cost planning differs from the elemental in that .. . a theoretical cost allocation . . . is not accepted as a valid factor for controlling the design of the element. Instead the cost implication of feasible alternative solutions for the elements are considered. "

Morrison (1980) traced the history of cost planning from its inception to modern day. He suggested that elemental and comparative cost planning do not exist side by side. Comparative cost planning grew out of elemental planning to alleviate the pressure that the latter system put on architects. Ashworth (1988) agreed and claimed that practical cost planning consists of a mixture of the two methods.

2.6 Discussion

Cost planning is theoretically a four stage process, integrated into design procedures that is implemented by the QS in consultation with the rest of the design team. The nature of the cost input is not entirely clear. At the outline cost plan stage for example, there is dispute as to whether the cost planning process should encompass advice on building design and shapes, or whether it should merely cost designs put forward by the architect. There is also dispute surrounding production of the full cost plan and the extent to which the architect should design with a limit set by the QS.

The investigation of cost planning practice (largely by Morrison 1980) indicated that although the system provides for it, the degree to which cost actually influences design varies with the availability of drawn information, the timing of the QS input, the flexibility of the design (as viewed by the architect), the nature of the QS role (as he himself viewed it) and the extent to which the architect attempts to curtail QS activity. In addition, rather than being a linear process the cost planning system is largely iterative, moving backwards and forwards as proposals are considered and accepted or rejected.

Cost planning theory suggests two distinct forms of cost planning, operating on a linear basis. In reality, as outlined by Morrison (1980) and Ashworth (1988), the system appears to be more a mixture of the two systems, operating on an iterative basis. Rather than imposing costs on designers within which they must design, the system jointly considers alternative designs then allocates historical costs based on them.

There can be no real certainty as to the extent that the cost planning process influences design, and it is argued, particularly at the concept stage that the procedure is design led. Where there is certainty however is that the system provides, through the allocation of historical cost, opportunity for a direct cost input that considers alternatives within an iterative and on-going system. In addition although the level of integration of the QS within the design team varies, overall the system of cost planning is a multi-disciplinary one.

The operation of the cost planning system within the RIBA plan of work is highlighted in Figure 15.

Figure 15 - The UK cost planning system

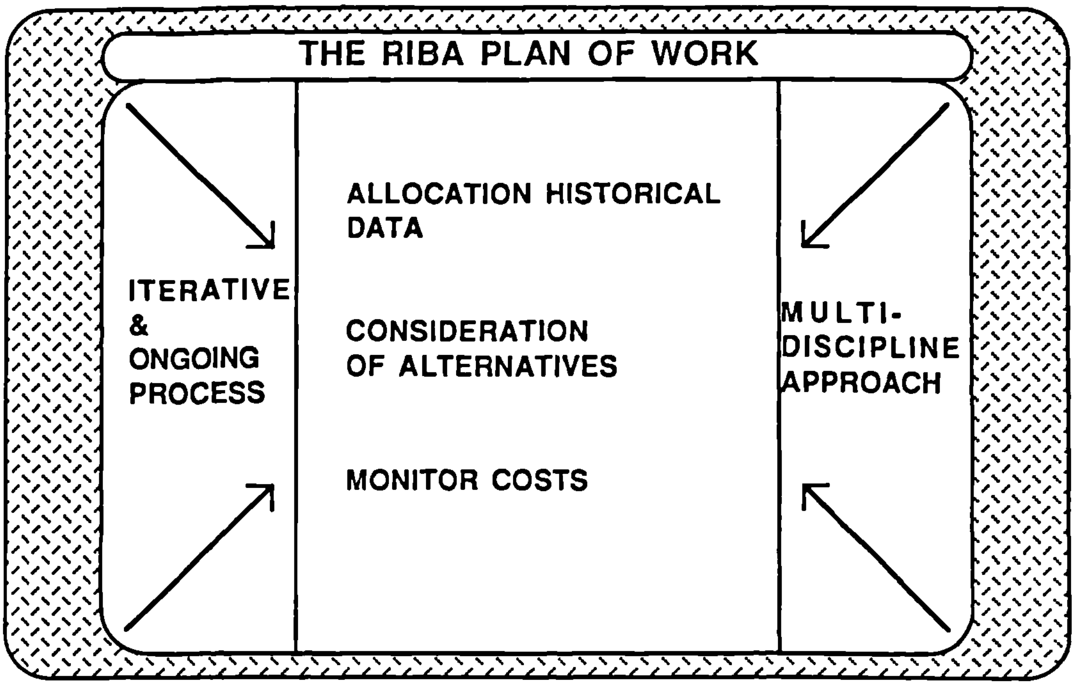
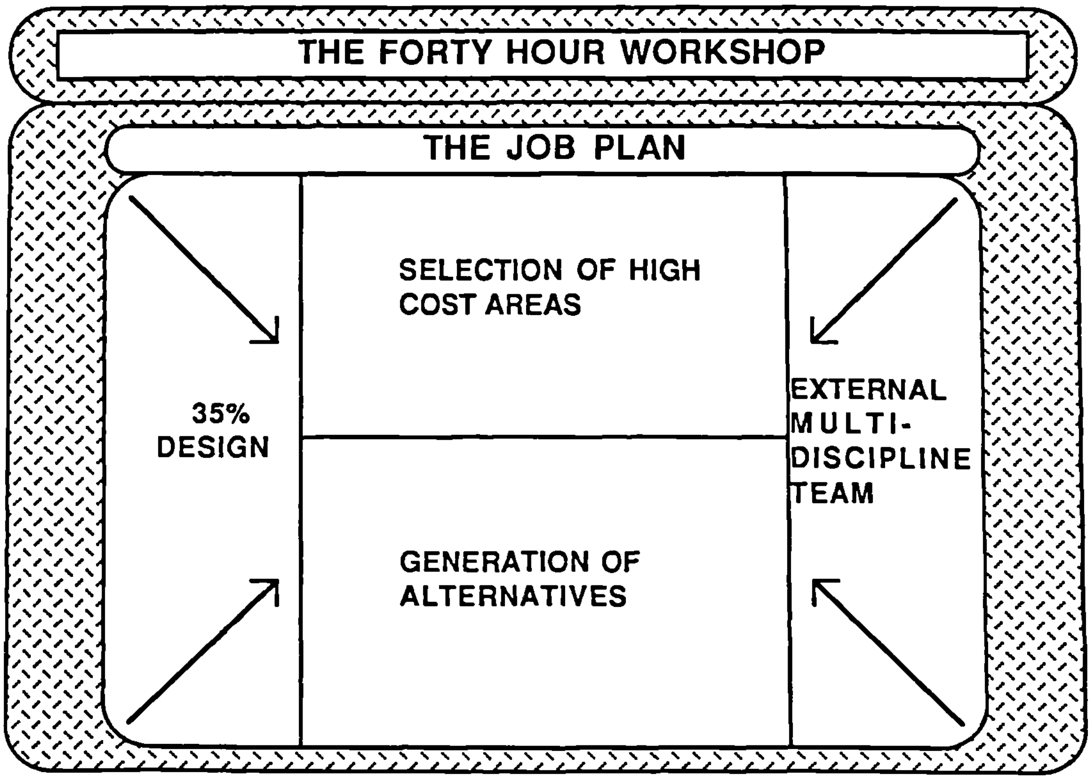


Figure 16 Value engineering practice



3. Drawing a comparison

3.1 Introduction

Figures 15 and 16 show the systems of cost planning and value engineering that are to be compared. Table 19 shows comparable components in tabular form.

Table 19 - Components of VE and cost planning

Value engineering	Cost planning
Workshop	--
The job plan	RIBA plan of work
Selection of high cost areas	Allocation of historical cost data
Generation of alternatives	Consideration of alternatives
35% design stage	Iterative and on-going process
External multi-discipline team	Multi-discipline approach
--	Cost monitoring

Each component is examined in turn.

3.2 The workshop

The RIBA plan of work (1973) envisages a substantial degree of collaboration between the design team. At each of the design stages team meetings are held which architects, engineers and quantity surveyors are recommended to attend. These meetings are design team meetings and are not for the specific purpose of cost reduction, however, the team are recommended to consider costs. The basic meetings and agenda items are shown in Table 20.

The cost planning system does not therefore have a component comparable to the workshop in that there is no independent and autonomous meeting set aside for cost reduction or value improvement.

Table 20 - Meetings recommended by the RIBA plan of work

Stage	Attendants	Agenda items
Feasibility	Architect Quantity surveyor Civil & structural engineer Services engineers	State objectives Determine priorities Define responsibilities Define methods of work Agree sources of cost information, check list of action, timetable and programming.
Outline proposals	Architect Quantity surveyor Civil & structural engineer Services engineers	State objectives Determine priorities Define responsibilities Define methods of work Agree drawing techniques, systems of cost and engineering checks on design, BQ type, check list of action and programming
Outline proposals	Architect Quantity surveyor Civil & structural engineer Services engineers	State objectives Determine priorities Define responsibilities Define method of work Agree timetable, drawing techniques, systems of cost and engineering checks on design, BQ type, check list of action , specification and programming.

3.3 The job plan v the RIBA plan of work

Morton (1984) drew a comparison between the job plan and the RIBA plan of work,

". . the important fact is that the job plan could be satisfactorily used in place of the existing design process as although the techniques within each phase may differ, as will the criteria and objectives, the sequence of activities is comparable.":

Morton drew this conclusion by highlighting that within each individual stage of the plan of work there is a design process which consists of,

analysis---------synthesis---------appraisal---------decision

Morton compared this to the job plan. Analysis was equated to the information phase where there is a gathering of data and an analysis of known facts. Synthesis was compared to the creative phase in that it dealt with experiments and new creations. Appraisal was related to the judgment phase and decision to the development and recommendation phases. Each stage of the plan of work and the individual activities within are therefore, structured in a similar fashion to the job plan.

3.4 The selection of high cost areas v the allocation of historical cost data

The pricing of the UK cost plan is based heavily on the element unit rate and the element cost per unit of floor area. The principle behind the use of data in this format is that it acts as a comparison against other projects.

In the UK system it can be assumed that the allocation of elemental cost falls between two possible extremes. On the one hand the QS selects a suitable cost from either experience, a previous job or a data bank of historical information and the architect or engineer designs within it. The other extreme is that the architect produces a design and the QS estimates the cost of it. Within these two extremes lie a multitude of other possibilities. The architect may make a tentative design which is costed and compared with historical costs and, if required, alternatives may be suggested to reduce cost. Alternatively the QS may suggest a tentative elemental cost which may be adjusted based on discussions of other alternatives with the architect. Whichever approach is employed the basis of the system is the element unit rate and the element unit quantity which are used for the purposes of comparison with other schemes to check that costs do not exceed the norm.

In the US system, areas of above average cost are highlighted by the cost worth ratio or other means, based on the experience of the estimator. This process has the same objective as the allocation of historical cost in the cost planning systems; namely to highlight areas that cost more than the norm. The only difference between the two systems is that with cost planning the cost can be allocated prior to, or parallel with the design, whereas in VE cost is allocated during the study.

The selection of high cost areas in VE is therefore nothing additional to the cost planning process. In fact the UK method is most likely superior. Whereas VE selects high cost areas based on the subjective opinion of the estimator or the VE team, the UK has available a much wider and comprehensive data base.

3.5 Generation of alternatives v consideration of alternatives

As highlighted by the investigation of output, VE workshops generate alternatives on both the design and construction of the project. The cost planning system considers alternatives in two sets of circumstances. Firstly, alternatives are considered during the development of the cost plan and secondly they are generated when the project runs over budget. In the former instance, based on the recommendations of the RIBA plan of work (1973), alternatives ought to be considered on both concept design and forms of construction. In this instance cost planning output is similar to that of VE studies. However, because of the integrative and on-going nature of the cost planning process it is impossible to state the quantity and nature of the alternatives considered. The consideration of alternatives and the compilation of the cost plan is a thought process as opposed to a structured study and as such many alternatives are never documented.

The second instance of alternatives being considered in the cost planning process occurs when the project is over budget. In these circumstances, the quantity surveyor, working with the design team, will present ideas to reduce cost. There are no rules as to the type of proposal that can be made, which would be largely dictated by the degree of design development.

Value engineering offers proposals based on design and construction. Cost planning offers the opportunity to do the same. Because of the integrated nature of cost planning, however, the output of it cannot be measured or compared to VE. However the significant factor is that VE and cost planning both offer the opportunity for the consideration of alternatives on the concept design and the elemental construction of a building. In this respect there is little difference between the two systems.

In comparing the opportunity for consideration of alternatives within VE and cost planning the impact of US design procedures cannot be overlooked. Cost planning, by its nature integrated into design procedures may to an extent, be accounting for the alternatives of the designers and attributing them to the cost planning process. VE, being autonomous, cannot be related back to design procedures in the same way. There will however have been many alternatives considered during the design stage. Again, this aspect of the study cannot be measured. There is no concrete evidence that more alternatives are considered as a result of the cost planning process than would be considered without it. It can only be assumed that there are.

3.6 The 35% design stage v the iterative and on-going nature of cost planning.

The significance of timing lies primarily in its relationship to the alternatives generated that, given the level of design, can be feasibly implemented. As outlined above, there are two types of proposal that can be made, those which comment on the concept design and those which make proposals on the construction or elemental solutions. A value engineering study at 35% can feasibly produce alternatives on the concept design as well as the elemental construction.

The production of the cost plan at 35% design would generally only consider alternatives relating to the elemental design. However, the earlier stages of target cost formulation and outline cost plan would have considered alternatives on the concept design. The important issue is that both systems allow examination of both sets of alternatives. The UK considers them as an on-going process whereas VE considers them autonomously.

3.7 The external multi-discipline team v the multi-discipline approach to cost planning

The cost planning process does not use any consultants other than the design team. However, the RIBA plan of work (1973) is clear that cost planning is a multi-disciplinary activity. Architects, engineers and quantity surveyors are given a collaborative role throughout the various stages of the process.

VE however, uses an independent team to carry out the study and in this aspect it is different from cost planning.

3.8 Cost monitoring

The cost monitoring process that checks design development from the cost plan until tender does not exist in US procedures. The process of VE is autonomous and there is no follow up after the studies.

3.9 Highlighting differences in the two systems

Table 21 shows the major differences between the components of VE and cost planning.

Table 21 - Major differences: VE and cost planning

Value engineering	Cost planning
Workshop	--
~~The job plan~~	~~RIBA plan of work~~
~~Selection of high cost areas~~	~~Allocation of historical cost data~~
~~Generation of alternatives~~	~~Consideration of alternatives~~
~~35% design stage~~	~~Iterative and on-going process~~
External multi-discipline team	Multi-discipline approach
--	Cost monitoring

The table highlights that VE is additional to cost planning on two counts. It is an autonomous approach employing a 40 hour workshop specifically for its purpose and it is implemented by an external and independent team.

4. Discussion

The systems of VE and cost planning are similar to a large extent. Both seek to influence design by the input of cost data to highlight where costs exceed the norm and to present alternatives to them. The application of this cost data is flexible and the consideration of alternatives in both systems tends to cover a wider spectrum than that dictated by the input of cost data. In both systems the extent that alternatives are presented is governed by other factors. In VE the dominant factors were shown among others, to be the personality of the VE leader, timing of the study and the input of the client and design team. In the cost planning system factors included the integration of the QS, timing of the QS appointment and the flexibility of design as viewed by the architect.

The fundamental difference between the two systems, is not in the objectives, but in the means by which they attempt to achieve them. The US approach is autonomous, implemented by an external team, whereas the British approach is integrated, implemented by a QS with varying degrees of design collaboration.

The reason for the different approaches may be the separate quantity surveying system that exists in the UK. Where there is a separate cost consultant, working alongside a design team, it is a logical progression that any cost input should come from him. Where there is no such consultant within the team and where no such profession exists, then the only solution is an autonomous approach. Given that the two systems are aiming towards the same objectives and that only the approach varies, is there really a need for the system of VE (as practiced in the US), in the UK? Possibly there is, since the American system might be better and more effective at achieving objectives than its UK counterpart. However, given that the two procedures of VE and cost planning have developed based on the needs of two different systems, could the US system ever be applied in the UK.

In order to examine if VE can be applied successfully in the UK, only those aspects that are different need to be investigated. It can be assumed that where the components of VE are similar to existing UK procedures they would be readily acceptable to it. The following chapter therefore examines the autonomous aspect of VE along with the use of the external team. The components are investigated in their US context and for their applicability to the UK. In addition the difference between US and UK design procedures is examined.

5. Conclusion

This chapter sought to prove that VE was nothing additional to cost planning.

Although the objectives of the systems are similar, the approach to achieving them is different on two counts. VE is an autonomous approach employing a 40 hour workshop specifically for its purpose and it is implemented by an external and independent team.

The research proposition was not supported.

Chapter 8

Results - Value engineering in the UK

1. Introduction

1.1 Research proposition

VE as implemented in the US could not be practised in the UK. The differences between US and UK procedures do not facilitate direct implementation of the US system in the UK.

1.2 Research method

Participant observation, comparative analysis and interview.

2. Autonomy and external teams in the United States

Examination of live VE workshops in the US highlighted certain problems with the autonomous approach using an external team. These are outlined below. Documentation of complete workshops is contained in Appendix B.

2.1 Personality problems

Four workshops were observed. The first was a training workshop and the remaining three were 'live' studies. Of these latter three, one of the most overriding features was the personality difficulties that arose. These problems came from three sources; the workshop leader, the relationship of the VE team to the design team and finally to the input of the client. In the second study the workshop leader was unable to control the proceedings adequately and the study failed to establish momentum or direction. In addition (largely due to the workshop leader's lack of control) the VE team addressed the project as a personal issue between them and the design team. An 'us and them' situation developed resulting in stand up arguments, sarcasm and general ill-feeling. In the third study the personality difficulties came from the client who interrupted the proceedings, criticised the design team and generally tried to control the study, often spending excessive amounts of time discussing small dollar items. This presented difficulty for the workshop leader as the project client was also his own client. In the last study the most prominent feature was the dynamic and charismatic personality of the leader, coupled with his vast experience. He had an inherent ability to motivate the people working with him. However this final study did present one overriding feature in the lack of client enthusiasm for the study. The project, being a local authority scheme funded by central government, was not a good scheme for VE. The client had waited for the project funding for some years and having now obtained it was determined to spend it. As a result they tended not to consider proposals that they might have done under other circumstances.

2.2 Length of workshops

Of all four studies observed, 40 hours was too long a time period and there were often long periods of inactivity. In addition 50% of workshop time was spent in writing up VE proposals, costing them and incorporating them into formal documentation. This is done primarily because of workshop autonomy. As the VE team will not be involved in the study further, they need to record in detail their proposals, so the design team can decide on a course of action. The other reason for the formal documentation appears to spring from a need by the VE team to justify their existence and that of the study.

2.3 Design criteria

When a client has strict design criteria, over and above that of statutory regulation, it makes workshops difficult. Understanding the design criteria of long-term construction clients (such as hospital authorities) can amount to "relearning" all construction codes and regulations. Unless the VE team have worked with the client themselves for a reasonable period it is almost impossible for them to work effectively in a week long stand-alone study. This was clearly highlighted in one of the studies observed. The VE team attempted to put forward proposals changing client design criteria, believing the project to be 'over-specified'. The proposals were rejected by the design team and client, and created the feeling that the VE team did not know what they were doing.

2.4 Budget

It is very difficult to understand what has been included in an estimate produced by another consultant when there is no standard format and no standard method of measurement. Further, even if procedures are standardised they can only reveal what is included in an estimate and not why. An estimate in the US produced either by, or under the direction of, an architect will have been based on a great number of undocumented assumptions. A VE team estimator with no previous connection with the project may make an entirely different and incorrect set of assumptions in producing his own estimate. In one study observed, the difference between the design team and VE estimates was almost $2 million dollars on a design team estimate of $3.7 millions! Prior to any value engineering this anomaly should have been investigated, as any proposed cost reduction by the VE team was fundamentally flawed from the outset when estimates disagreed to this extent. There were additional problems. All estimates contain an element of self-cancelling 'error', so that agreement of final totals does not constitute agreement on elemental or breakdown cost. Large discrepancies between elemental totals can equally invalidate VE savings. Finally all estimates contain a degree of visible and invisible contingency. An invisible contingency may have been included for good reason, yet to the VE estimator, in an isolated examination of costs, it only indicates an element that is more expensive than average. In reality this may not be the case.

2.5 Timing

The timing of studies does to an extent dictate the type of proposals produced. From the studies observed it did appear that there was a shift from conceptual design proposals toward technical alternatives as the timing of the study moved from 10% to 35% design. In one study the design team deliberately held back presenting certain proposals as they felt the amount of redesign required restricted the range of suggestions.

2.6 The external team

The view generated by all the studies observed was that the VE team did not understand the project as well as the design team. Excluding the design teams from the studies was a waste of expertise and knowledge. The VE teams most definitely lacked background to the projects. This was particularly noticeable when the VE team rated proposals to decide which ones to develop further. Design input was vital at this stage to avoid working up ideas which were wholly impossible to implement. Often, however, this input was not available.

3. A comparison of UK and US design and cost control procedures

The differences in design and cost control procedures were outlined by the 'Reading Reports' of 1979 and 1985 and pose several relevant issues:

1. UK design procedures are more evolving than their US counterparts where the process tends to be more linear. UK clients expect to be able to change the brief during the design and construction periods. US clients on the other hand place more emphasis on the development of the brief and are less likely to change it as the design and construction proceeds.

2. US architects fully design (with the exception of shop drawings) prior to tender. UK architects complete details during construction work. The missing details are deduced by the QS at tender stage.

3. There is a larger amount of M & E design work carried out in the US than there is in the UK, where prime cost sums are used in lieu of design.

4. The US client is more involved in the decision making process. The UK allows greater scope for the interpretation of the client's brief, whereas in the US precise details of the brief are given to the team.

5. The US client is not prepared to pay separately for cost advice. UK clients however are increasingly appointing QS's independently of the architect, to obtain more effective financial management.

4. Investigation of VE in the UK

The data collection was by means of semi-structured in-depth interview.

Full interviews are contained in Appendix C.

4.1 UK value engineering activity

VE activity in the UK falls into four broad categories.

1. VE services offered by consultants.
2. VE systems operated by clients or developers.
3. VE services offered by construction management consultants.
4. VE systems offered by contracting organisations.

The following numbers of each group were interviewed:

1.	Consultants	8
2.	Clients	7
3.	Construction managers	4
4.	Contractors	1

4.2 The alternative approaches to value engineering

The companies were asked to outline the overall approach that they were taking towards value engineering.

Answers to this question, which are summarised in Table 22, illustrate that most companies (75%) involved in VE, used the forty hour workshop. However in addition the majority of companies (70%) also used an alternative system. The companies were asked to outline the alternative systems they employed.

The consultants' VE systems can be summarised into three main groups.

Table 22 - The UK approach to value engineering

Company	Workshop used	Alternative Approach
Consultant 1	YES	YES
Consultant 2	YES	YES
Consultant 3	YES	NO
Consultant 4	YES	YES
Consultant 5	NO	YES
Consultant 6	YES	YES
Consultant 7	YES	YES
Consultant 8	YES	YES
Client 1	YES	NO
Client 2	YES	Investigating
Client 3	YES	NO
Client 4	NO	YES
Client 5	NO	YES
Client 6	YES	NO
Client 7	YES	YES
Construction Management 1	YES	YES
Construction Management 2	NO	YES
Construction Management 3	YES	NO
Construction Management 4	NO	YES
Contractor 1	YES	YES

4.2.1 Cost planning

One consultant's value engineering system was a replica of the cost planning system. What in his view made it value engineering as opposed to cost planning was that it was cost led, thereby forcing the design team to design within elemental costs.

4.2.2 Cost planning plus shorter workshops with the design team

Two consultants had devised value engineering systems that built on the existing cost planning process by introducing a series of short workshops. Consultant 5 suggested that the workshops should be at outline planning and pre-appointment of the contractor. These meetings would overcome the dual problems of late QS involvement and the adversarial role of the contractor. These workshops would not employ function analysis.

Consultant 6 suggested one workshop at the inception of the project from which the cost plan would be produced. This system was based on overcoming late cost involvement, which was seen as the fundamental problem of cost planning. The process would substitute the 35% workshop with cost planning (thereby utilising the existing system) and move the workshop forward to operate only on the concept design. This approach did not envisage the use of function analysis.

4.2.3. Series of workshops with the design team

Four of the consultants interviewed had devised a VE system that consisted of a series of workshops. Of these four, two felt that this series of workshops could only be operated within a project management service and one offered it within a QS service. Only one of the consultants felt that it could be sold separately. The workshop formats that were recommended were,

1. Two workshops, one at concept and one at scheme design using the design team and a form of function analysis, carried out under a project management commission. The cost planning process would still operate but would not drive the system as in the earlier examples.

2. Three workshops, two shorter ones at brief and concept and one forty hour workshop at scheme, all with the design team, with a modified form of function analysis and sold as a separate service.

3. Two full workshops with the design team, one at concept and one at scheme, operating within the standard QS service using an American style elemental function analysis.

4. A flexible series of one day meetings of the design team without function analysis, operating within a project management service.

4.2.4 Client systems

With regard to the clients, out of a possible seven only three used the workshop approach as the sole means of VE. Of the remaining four only two used an alternative approach, whilst two used the workshop and an alternative approach. Of these four alternative approaches one was still examining possibilities and three claimed to be operating their own systems. These can be summarised as follows,

1. A traditional system of costing the design.
2. A system of costing the design by disciplines other than QS's that encourages design team interaction.
3. An unstructured approach to estimating the cost of various technical solutions.

4.2.5 Construction management systems

Of the construction management companies interviewed, two out of four used the workshop with one of these using it as the sole approach to VE. Three out of four therefore offered alternative approaches which can be summarised as follows,

1. Two forty hour workshops, one at concept one at scheme, with an external VE team, without function analysis.

2. A series of meetings of the design team examining the effect on the overall programme and buildability of various technical alternatives to major elements.

3. A system of cost planning operated by a project manager once again based on the inability to distinguish between estimating and comparative cost planning.

4.2.6 Contractor systems

The sole contractor, who also used the workshop, suggested as an alternative, a three day Charette which brainstormed the brief and was followed by a series of design team meetings that checked back on the original intentions. The use of function analysis was considered essential to the process. This function analysis however was related to the analysis of the brief and not the functions of the project.

5. Discussion

Some of the problems that arise in 40 hour workshops cannot be entirely attributed to the autonomous approach by an external team. Personality difficulties for example could equally occur using an integrated or other approach. The important issue surrounding the problems of VE workshops is the actual that the problems exist.

Trying to apply the US system of VE to the UK is only adapting a system that is fraught with difficulty. This is not a good idea, since the likelihood is that the problems would be duplicated. It would be advisable to examine, and hopefully solve, the existing problems of US VE before attempting to apply it to the UK.

In addition to this, the examination of US and UK design procedures highlighted that the latter was not entirely conducive to the application of US VE practice. This was for three main reasons.

Firstly, US procedures are more linear than their UK counterpart. It is much easier to apply a VE workshop to a linear process than it is an evolving one. A VE workshop in the UK applied at any time scale could produce proposals that would always be subject to change. The expectation of the client ultimately has an effect on the use of value engineering. In the UK a client expects to be able to change his mind. It is difficult to imagine therefore why he would ask an external team to review a design when their recommendations could be subject to change. An architect also expects to be able to change his mind. In addition he is quite prepared to leave detail design until the construction stage. In this respect information for an accurate VE study may not be available.

The next reason why the UK may not be conducive to the application of VE is the lack of services design. Incomplete mechanical and electrical design at the 35% design stage may mean that information for a VE study is not available. When it is considered that 30% of implemented savings in the US come from the services sector, the impact of VE in the UK could be substantially reduced, as there is often no M & E design prior to tender.

The final problem in applying VE in the UK is the presence of the independent cost adviser or quantity surveyor. The fact that the UK client already pays a separate fee for a cost consultant may mean he is not prepared to pay another fee for a VE study.

Given that there are problems with the implementation of VE in the US and given that the UK is less conducive to its application, it would be envisaged that VE development in the UK would be along different lines than its US counterpart.

Analysis of VE development in the UK showed this to be true to some extent. It illustrated that VE in the UK is developing along two lines; the 40 hour workshop and a series of alternative approaches taking various different formats.

Examination of the alternative approaches in the UK highlighted two very significant points. Firstly the overriding view given by the interviews was that VE in the UK was not viewed as a cost orientated process. Its application was viewed as solving more global issues than the reduction of cost. The orientation of the design team, clearer stating of objectives and increased client awareness were all viewed as problems that VE could solve. Viewed against VE in the US, which has largely developed as a means of Department of Defence accountability, the objectives for which VE is required in the UK, are entirely different. It is perhaps for this reason that the alternative approaches to VE have developed. This highlights a second critical issue in the development of VE in Britain. None of the companies that had developed alternative systems of value engineering used function analysis correctly. The principles of value engineering as outlined by Miles (1961) were largely ignored. However, of the fourteen companies employing an alternative system ten also used the US style workshop. Of the remaining four companies, their systems appeared only to give the name value engineering to existing systems. It appears then that the development of VE in the UK, has been based on an adaptation of American practice. Earlier chapters illustrated that US VE is a massive distortion from what was originally intended by Miles. The situation has a close resemblance to a game of Chinese whispers, in that a distorted version has been passed on only to be distorted further. Companies in the UK are trying to cultivate VE systems having planted the wrong seed. Given this it is hardly surprising that so many hybrid forms of 'value engineering' have developed in the UK since unlike its US counterpart the UK has no dominating client to follow.

The crux of the original VE system was the application of function analysis. The research so far has not been able to examine the original technique since only distorted versions are practiced in the US. The testing of the application of function analysis in construction is the basis of the next chapter.

6. Conclusion

The autonomous approach by an independent team used in the US is fraught with difficulties.

UK cost control and design procedures are not conducive to the application of US style value engineering.

UK companies involved in VE are developing their own systems of value engineering. These systems appear to be based on an adaptation of American practice.

The research proposition was supported.

Chapter 9

Results - Function analysis

1. Introduction

1.1 Research proposition

The technique of function analysis could aid effective design and reduce cost.

1.2 Research method

Experiment.

2. The form of function analysis

The examination of VE literature illustrated that VE was originally developed in the manufacturing field and that the transition of the technique into construction was not successful. Prior to testing the technique therefore, it needed to be decided how the original technique could be best applied to construction. This is examined below under the component parts of the function analysis technique.

2.1 Function definition

The original function definition of Miles (1961) defined customer requirements as opposed to the existing functions that the product performed. The former method is viewed as the most effective in that, as concluded in earlier chapters, it is the simplest and most logical approach. As such function definition will be based on client requirements.The method adopted will be the verb-noun.

2.2 Function evaluation

The evaluation of function used by Miles (1961) was a comparison of the lowest cost to achieve function with actual overall cost. For example a tie clip, allocated the function of 'hold tie', was evaluated based on the cost of a paper clip which could also 'hold tie'. The cost of the paper clip was then compared to the actual cost of the tie clip. However, the important issue is not the cost of the paper clip; that is a secondary item. The purpose of the exercise is to facilitate comparison that truly highlights the nature of the function. The objective is to force the problem to be considered in a different way. This raises the question of whether function evaluation based on cost is really necessary. Miles (1961) claimed that the basis of function evaluation is comparison. Although Miles did cost his cheapest comparison this is not really necessary, since the comparison in itself provides the evaluation. For example, consider a fountain in a hotel reception which has the function of 'provide prestige'. Many alternatives are available that do this. A statue, a Constable, a tree, a belly dancer. Can these items really be evaluated on the basis of cost? Is not the choice purely subjective and is not the choice ultimately with the client?

Function analysis is in essence only a search for alternatives. That is all it is. That is all Miles ever intended it to be. In a construction design dealing largely with subjective intangibles the comparison is sufficient evaluation of function.

2.3 Creativity

Creativity is intrinsically linked to function definition and evaluation. Correct function definition and evaluation should lead to creative solutions.

2.4 Timing

A function analysis ought to be the same regardless of what stage in the design process it is carried out. As time develops however the amount of redesign increases, as will the resistance to change. In addition as function analysis will only be based on definition of client function, it can be employed after the development of the brief. It is a logical follow on that a 'right first time' approach be adopted. This would avoid the need for redesign and reduce abortive time. In addition it would remove any implication that the designers 'got it wrong'.

The above is not suggesting that function analysis in order to be effective has to be a right first time approach. An existing solution can be available. This may however result in redesign and problems relating to implied criticism of the designers.

3. Experiment 1

3.1 Introduction

The objective of the study was to test if a group of postgraduate construction management students of multi-discipline background could produce a design from a function analysis based on defined client function. The study sought to provide a general overview on the use of function analysis and to highlight any problems associated with it.

An existing drawn solution was available and is shown in appendix E. The study was limited to the ward areas. The existing solution contained the areas shown in Table 23. The first column shows the space allocations. The second column shows the space with circulation space distributed over the areas.

Table 23 Existing solution areas

Area	M2	M2
Wards		
1. Bed bays	1094	1468
2. Sitting room	307	412
3. Dining room	165	222
4. Cleaner	30	40
5. Clothing store	33	44
6. WC	158	213
7. Store	44	59
8. Linen store	38	51
9. Assisted bath	89	119
10. Rehabilitation	148	199
11. Female changing	69	92
12. Consulting/diet room	64	86
13. Kitchen	58	78
14. Ward office	39	52
15. Dirty utility	61	82
16. Clean utility	71	95
17. Disposal	21	28
18. Circulation	851	

For ease of working the students were divided into two groups. The groups were selected at random. The disciplines, ages and years experience of the students are shown in Table 24.

Table 24 - Students for experiment 1

Group 1				
Name	**Nationality**	**Age**	**Discipline**	**Years Experience**
Wratten, D.E.	British	33	Builder	16 (Army)
Ryalls, P.A.	British	52	Builder	20
Maltby, R.H.	British	51	Builder	20
Dennett, D.J.	British	50	Builder	20
Wong, K.K.	British	29	Hydraulics Engineer	4
Nwandu, N.I.	Nigerian	30	Architect	7
Madanat, S.	Jordanian	31	Civil Eng.	10
Assegide, H.	Ethiopian	35	Civil Eng.	11
Khan, N.Q.	Pakistani	25	Civil Eng.	2
Gharib, K.M.	Bahraini	31	Civil Eng.	8
Ingari, W.S.O.	Kenyan	34	Civil Eng.	10
Group 2				
Khalid, S.M.	Pakistani	31	Civil Eng.	8
Inoue, K.	Japanese	33	Civil Eng.	11
Agapiou, A.	British	26	Civil Eng.	3
Confait, C.A.	Seychellois	35	Planner	7
Madlopha, M.E.	Swazi	31	Civil Eng.	6
Walubayi, V.B.	Kenyan	40	Quantity Surveyor	16
Lai, T.K.L.	British	32	Civil Eng.	9
Farooq, U.	Pakistani	25	Civil Eng.	3
Sahat, B.	Malaysian	39	Quantity Surveyor	16
Silva, J.A.S.	Mozambican	32	Civil Eng.	11

On the afternoon preceding the study the students were given a two hour lecture on value engineering, with a heavy emphasis on function analysis. The following two days were then spent on the actual study.

3.2 The project

Student groups were shown the existing design and they discussed it with the architect of the scheme for two hours. It was necessary to have an existing drawn solution to enable evaluation of the student designs. However the students were constantly reminded that although they could use the existing drawing as a basis of questionning the architect. Their designs must not be based on the existing solution.

The existing project had a lot of courtyards, which effected the floor to wall ratio and made the building more expensive than average. The architect was asked the function of the courtyards which he insisted were for the purpose of providing a pleasant environment for the hospital patients. One student was not happy with the architect's answer. He argued that if the courtyards were to provide a pleasant environment why were so few of the patients' rooms overlooking them and why were they included in staff areas. After lengthy discussion the architect admitted that the function of the courtyards was in fact to admit light. This illustrated that function analysis can assist in understanding an existing design. On the other hand it illustrates that the presence of an existing solution can present problems. Out of twenty-one students only one recognised that the function of the courtyard was to admit light, which was only necessary to the extent that the architect had designed a deep building. The others were prepared to accept the architect's explanation.

3.3. Student solutions

After the question and answer session the students moved to the function analysis.

The students were asked, based on the discussion with the architect, what were the functions of the wards. They decided functions were to,

Treat patients
Rehabilitate patients
Allow observation
Control environment
Facilitate recovery
Provide confinement
Facilitate examination

They agreed that within these functions there was a degree of overlap and that the three basic functions of the wards were to,

Treat patients
Rehabilitate patients
Control environment

The definition of function was produced by the students based on their discussions with the architect. However, they were promoted by the author, acting as facilitator. In addition when student discussions went off at a tangent they were brought back into line by the author.

The students were asked to continue the analysis further to try and establish what functions they needed to fulfil in order to meet the above three functions. They produced the following,

Treat patients

Allow stay
Facilitate nursing
Provide food

Rehabilitate patients

Provide environment
Provide recreation
Encourage interaction

Provide counselling
Provide therapy

Control environment

Provide comfort
Provide hygiene
Allow mobility
Segregate sexes
Segregate patients

The following alternatives were produced based on the functions,

<u>Allow stay</u>

Wards
Private rooms
Dormitory
Individual bungalows
Tents
Hotel
Caravans
Bunkers

<u>Provide food</u>

Self catering
Meals on wheels
Canteen
Restaurant
Shop and microwave
Import from catering company
Cook on the premises

Provide recreation

TV room
Swimming pool
Library
TV games
Cinema
Table tennis

Encourage interaction

Meeting place
Garden
Bar
Bedside telephones
Disco
Group games
Lots of tea-breaks
Ballroom dancing
Bridge

Give counselling

Individually
Group
By telephone
By radio
By video

Segregate

Separate rooms
Separate wards
Screens

Some of the alternatives produced were clearly very good, but lack of client input was felt seriously at this point. It was difficult to evaluate the feasibility of the ideas suggested.

The students produced the function analysis by asking the question 'what do we need to do in order to facilitate the recovery of these patients?' However they were not in any way encouraged to ask 'how why' questions as with a FAST diagram. For example, they decided that in order to treat patients effectively they needed to give them somewhere to stay, give them something to eat and nurse them. The asking of the how question was automatic but the students were not encouraged to ask the question until they had obtained a construction solution; they were only instructed to establish what they needed to do. What became apparent in the study was that function analysis is a lengthy process. The production of the above function analysis took a day. For this reason the study had to be restricted to the wards only.

On day two the students were asked to produce space requirements and layout of a new scheme based on the function analysis. They were instructed not to work from the existing solution. In addition they were encouraged to think only about the function and it's relationship of the design and not of previous projects.

The students produced the following space requirements and layouts.

<u>Group 1</u>

Treat patients

Allow stay
$10m^2$ per bed was allowed at 96 patients = $960m^2$

Facilitate nursing
This was seen as covered in the allocation of bed space. In addition an allowance was made for keeping medical facilities of $9m^2$ and for storing linen at $16m^2$.

Provide food.
Of the 96 patients it was viewed that they would not all use the dining room at once therefore 1. $5m^2$ was allowed for 75 patients.

Rehabilitate patients

Provide recreation.
The students decided that recreation was best served by providing two TV rooms each, for 30 patients, at $60m^2$ each.

Encourage interaction.
Interaction was seen to be encouraged by the provision of dining rooms, instead of taking meals in bed.

Provide counselling
Two rooms at $10m^2$ each were provided.

Provide therapy
Two rooms at $100m^2$ each were provided.

Control environment

Provide comfort
Comfort was viewed as heating and lighting and as such the only additional space required was by a boiler room.

Provide hygiene.
In order to provide hygiene the students decided they needed toilets, a cleaners cupboard, a dirty utility and a disposal room. They allocated

Toilets $50m^2$

Cleaners cupboard $18m^2$

Dirty utility $9m^2$

Disposal $8m^2$

In addition the students recognised the need to provide a pleasant outlook as part of the 'provide environment' and decided to provide landscaped gardens outside the building.

Group 2 followed similar procedures to group 1 and also produced space requirements based on the functions and possible alternatives. The space allocations produced by the students are shown in Table 25. All figures include circulation space.

Table 25 - Student solutions

Area	M2	M2	M2
	Existing Solution	Group 1	Group 2
Wards			
1. Bed bays	1468	960	848
2. Sitting room	412	120	
3. Dining room	222	113	120
4. Cleaner	40	18	
5. Clothing store	44		
6. WC	213	50	72
7. Store	59		
8. Linen store	51	16	
9. Assisted bath	119		72
10. Rehabilitation	199	200	80
11. Female changing	92		96
12. Consulting/diet room	86	20	64
13. Kitchen	78	16	48
14. Ward office	52		36
15. Dirty utility	82	9	48
16. Clean utility	95	9	64
17. Disposal	28	8	
Total	**3340**	**1539**	**1548**

Each of the two groups, based on the space requirements, then produced a design.

The following criteria were given,

1. Separate entrance to the wards.
2. Single storey.
3. Food was to be brought in from outside.
4. The optimum size of ward based on the national health service staff hierarchy is twenty to thirty.

Team A produced the design shown in appendix F. Team B failed to produce a design for various reasons. The overriding factor appeared to be the lack of leadership within the team. With team A a natural leader emerged whereas in team B there appeared to be a power struggle with two people competing for the post. Tempers were frayed and voices raised. At the end of the study the teams were asked to analyse why they had failed. Their first reaction was to blame a member of the team who had gone home, but after some time realised that the failure was a team effort. They recognised that constant arguing and changing of direction had achieved nothing. In addition, they also admitted, that despite repeated reminders to the contrary they had not designed from the function analysis but from the existing solution. They realised that the first day, which produced the function analysis, had been wasted, in they did not use it as the basis of the design and that they constantly referred back to hospital projects they had worked on before. Those team members not involved in the power struggle said that they knew that the study was heading down the wrong path but felt they were smothered by the two involved. Of these two one constantly referred to previous projects whereas the other one kept attempting to compile a drawn solution before the schedule of accommodation was complete. It was felt with this team that they definitely required a facilitator of some sort throughout the whole process and not just at the function analysis stage. The other team however, despite the fact that a leader did emerge, were much more democratic and used a card system to vote when discussion did not reach a solution in a reasonable time. They were very conscious of the time and kept to a self-imposed schedule.

3.4 Discussion on experiment 1

The actual design produced by the students is a secondary issue to the process by which they achieved it.

The study did not prove that it is possible to produce a drawn solution based on a function analysis of client requirement. Despite instructions to the contrary, the students did refer to the existing design. However the strength of function analysis does not lie in the production of the drawing but in the consideration of alternatives that precede it. In addition function analysis can focus on project objectives, increase project awareness and increase team-work. Although the results of the study cannot be generalised to the population at large, it is a reasonable inference that providing a design team are open minded, it is possible that it could have the same beneficial effect on a real project.

In its own right the presence or otherwise of an existing drawing is largely irrelevant, except insofar as there is possibly implied criticism of the architect along with an element of redesign. In this experiment the students would have produced a design even if there had been no existing drawing. The presence of a drawing however invariably meant that they used it.

The evaluation of function based on cost is not, as anticipated, really necessary. The generation of alternatives is sufficient evaluation. This type of approach is not far removed from what was originally intended by Miles. Costing can be used as a method of evaluating alternatives if this is reasonable. It is not, however, necessary.

The process of function analysis is closely related to design but has little relationship to cost. In this experiment the students barely mentioned the cost of the project.

A key issue in the success of function analysis lies in the personalities of the team and the leader. In these experiments, which were largely of a pilot nature, two opposite situations developed. In Group A a leader emerged who made decisions and encouraged democracy as well as keeping to a time scale. In the other group there were no such developments and the team failed to co-operate.

The process of function analysis operated by the students was concerned with understanding client need. For this to be effective the presence of the client is essential.

The space requirements produced by both groups of students were approximately half those allocated by the architect.

4. Experiment 2

4.1 Introduction

The purpose of the second experiment was to measure the effect of function analysis. A control group were instructed to reduce cost of a project and their output was compared with a group who used function analysis, also to reduce cost. The groups were selected from the masters degree course in Construction Management at Loughborough University. They were matched on three criteria: age, race and discipline. The match achieved was reasonably good and a group balance was achieved. This is shown in Table 26.

Table 26 - Students for experiment 2

Group A	Nationality	Age	Discipline
Sibuku, M.A.B.	Malaysian	38	Quantity Surveyor
Chan, Y.K.	British (Hong Kong)	31	Builder
Abd Majid, M.Z.	Malaysian	34	Civil Engineer
Bowman, N.	British	24	Builder
Hassan, T.M.	Egyptian	30	Civil Engineer
Group B			
Richu, S.M.	Kenyan	42	Quantity Surveyor
Leung, C.H.	British (Hong Kong)	27	Builder
Jibrin, A.S.	Nigerian	32	Highway Engineer
Copping, A.G.	British	25	Builder
Khanus, K.J.	Tanzanian	35	Civil Engineer
Doran, S.O.	British	28	Project Manager

The order in each group dictates which student was matched with which. Group B used function analysis which was facilitated by Mr Doran.

In addition to the two groups, a QS was selected from the class and asked to reduce the cost of the project. In addition a theoretical client and design team were selected. These are shown in Table 27.

Table 27 - Students for experiment 2

Quantity Surveyor	Hough, S.R.	British	25
Client	Shawa, H.H.	British	49
Design Team	Miller, D.G. (Architect)	British	44
	O'Reilly, M.G. (Builder)	British	30
	Cheregn, Y.B. (Civil Eng.)	Ethiopian	43

4.2 The study

The exercise was very much one of role playing. The client, design team, QS and groups assumed the roles outlined in the briefs given to them. These were as follows.

4.2.1 Clients brief

You are a property developer on the scheme shown on the attached drawings and cost plan. You have run into serious financial difficulty and are in danger of being liquidated. A successful project is your only way out. As such you need to maximise nett lettable and minimise cost. So desperate are you, that you are trying three separate approaches in an attempt to come up with the most profitable solution. You have appointed an independent design group, a value engineering group and a quantity surveyor. You have instructed the existing design team to assist all three groups as much as possible. You intend to be present at any meeting between the design team and the newly appointed groups.

4.2.2 Design group brief

You are the design team for the project shown on the attached drawings and cost plan. The client, a speculative developer, has run into serious financial difficulty. As such he has sought advice from three other sources. Firstly he has employed a separate design team to review your design. Secondly he has employed a value engineering consultant and thirdly a quantity surveyor. His only brief to them is to minimise cost and maximise nett lettable. He has instructed you to work closely with all groups and offer them maximum assistance.

4.2.3 Group A's brief

The client, a speculative developer, has run into serious financial difficulty on the project shown on the attached drawings and cost plan. He has decided that the best option is to employ your group to suggest ways of reducing cost. His only brief is that you minimise cost and maximise nett lettable floor space.

4.2.4 Group B's brief

The client, a speculative developer, has run into serious financial difficulty on the project shown on the attached drawings and cost plan. He has decided that the best option is to employ your group, under the guidance of a value engineer, to suggest ways of reducing cost. His only brief is that you minimise cost and maximise nett lettable floor space.

4.2.5 Quantity Surveyor's brief

The client, a speculative developer, has run into serious financial difficulty on the project shown on the attached drawings and cost plan. He has decided that the best option is to employ you, a quantity surveyor, to suggest ways of reducing cost. His only brief is that you minimise cost and maximise nett lettable floor space.

4.3 The project

The project, a high-tec office development costed at £3.2 millions is shown in appendix G. A cost plan was also available.

4.4 The study agenda

The study was run over one day. It was intended that after a design team presentation, the two groups, plus the QS, would each have the opportunity to discuss the project with the client and design team and direct any necessary questions to them. Over the period of the day this amounted to approximately 75 minutes each. In between discussions the groups prepared their proposals. At the end of the day they made a presentation of them.

4.5 Design team presentation

The design team presented the study as though they had designed it. They outlined that the building was required to be of a high standard, that was 'user friendly' with a relaxed atmosphere. The building needed to be split into areas that were the optimum size for letting and needed a prestigious entrance. Escape was required from the upper floors and the staircases that provided this had the dual effect of facilitating a separate unit for letting purposes.

4.6 Group A proposals

From the outset of the study, members of group A, who were the control group, found it difficult to work together. Almost immediately the team fragmented and examined the drawings separately. They found it difficult to develop ideas. They suffered a lack of motivation and the study never developed any real momentum. They made the following proposals:

1. Divide the project into phases and finance in sections

2. Increase the contract period to improve client cashflow

3. Delete 50% of towpath work

4. Omit the spiral staircases, omit cladding to staircases and replace with 70% brick, add back rectangular staircases

5. Reduce glazed area by 30%, add back brickwork

6. Replace carpet with vinyl tiles

7. Omit skirtings

8. Consider rental of courtyard areas

9. Reduce suspended ceiling void thereby reducing building height.

The team estimated that their overall saving, excluding items one and two, was £350,000.

4.7 Group B proposals

It was intended that group B would use function analysis in an attempt to reduce cost. Although this was attempted, it was felt that the group never really fully understood the technique as an integral part of the exercise. For example, they decided that they needed to satisfy the following functions,

Increase rental
Provide appearance
Improve light
Provide access
Increase interaction

Based on this they produced the following alternatives,

Atrium courtyard with some office space
Crazy golf
Car park

Swimming pool
Park
Sculpture park
Market stalls

These were undoubtedly reasonable ideas, but once generated, the team did not develop them. They tended to oscillate between function analysis and incidental cost saving ideas that did not relate to the function definition. Once they developed alternatives they did not propose them to the design team and client. The group never really established the objectives of the building. Although they realised that the basic function of the project was to 'raise revenue', they never developed this to its proper conclusion. The function analysis facilitator was very weak and despite his assurances to the contrary, it was obvious that he did not fully understand the technique. The proposals that this group produced could not be entirely related to function analysis. They produced the following ideas,

1. Introduce nursery units in the courtyards

2. Omit all finishes from the offices

3. Add another storey at the single storey section thereby increasing nett lettable area

4. Omit frame and change to ring beam and bison units

5. Remove arches over windows

6. Omit lift but leave glass tower as an aesthetic feature

7. Group toilets to allow more economical services layouts.

The overall saving proposed by the group was approximately £420,000. However, when adjusted for items 1 and 3 which incurred additional costs the nett saving was £135,000.

4.8 Quantity surveying proposals

The interesting points in the quantity surveyor's proposals were not so much in the ideas that he produced but the manner in which he worked. He operated, almost entirely, off the cost plan, highlighting items that he felt were unusually expensive. He barely looked at the drawings. He was very aggressive towards the design team. He asked the architect to justify the large cost of the balconies which he argued were only "an architectural feature". He became very frustrated when the architect would not agree to the omission of such features. As the day developed the QS interaction with the design team steadily decreased. He eventually decided that he would put forward cost savings regardless of the attitude of the design team. He produced the following proposals

1. Remove scenic lift
2. Omit external balconies
3. Reduce specification of ridge and hip tiles
4. Remove gable features
5. Omit two spiral staircases
6. Change balustrade powder coating to paint
7. Omit access floor, replace with 75 screed and conduit thereby reducing floor to ceiling height
8. Reduce cost of facing brickwork
9. Omit double glazing
10. Reduce patent glazing specification
11. Omit plaster on internal walls
12. Reduce specification of internal doors
13. Omit borrowed lights
14. Omit skirting
15. Omit matwells
16. Reduce suspended ceiling specification
17. Omit mirrors, toilet roll holders, hat and coat hooks
18. Omit W.C. backpanels
19. Omit signs
20. Lower specification of sanitary fittings
21. Omit all the external works to the courtyard and add back car-park
22. Move toilet blocks to external walls to avoid the need for mechanical ventilation

With the exception of the final proposal all QS ideas related to the omission of items or the reduction of specification. After his presentation he was asked if he had considered the effect his proposals had on the rental value. He said he had not. The savings proposed by the QS amounted to £700,000. This was considerably more than the other two groups produced.

4.9 Discussion on experiment 2

The experiment failed because the function analysis group under the direction of one of their classmates could not produce a function analysis. The student facilitator badly explained the technique and the team never fully understood it. In addition both groups lacked enthusiasm and motivation. They both viewed the exercise as a competition between themselves and the QS as to who could save the *most money. The most* interesting result from the experiment came from the QS's approach to the problem. After a short period of questioning the design team he gave up as "they didn't want to save money". He then proceeded to cost cut the project omitting items and reducing specifications, although he did make one fairly substantial design suggestion. He barely looked at the drawings and operated almost entirely off the cost plan, highlighting high cost areas and concentrating on those. The design teams however did take a different approach in that they looked at the drawings first, with the cost plan taking a secondary role. The savings produced by each group bore little resemblance to one another.

The savings produced on a group basis were more design orientated than those produced by the QS.

The outcome of this study cannot be generalised to the population at large, however some reasonable inferences can be made.

The technique of function analysis is a difficult one to grasp and requires a fully experienced facilitator in order to be effective. The personality issue is a dominant force in function analysis. Poorly motivated teams with disinterested or inexperienced parties will not produce results regardless of the techniques used.

5. General Discussion

The technique of function analysis is largely a design orientated process. The operation of it is strictly concerned with design requirement and solutions to it. Although it's output may be measured in terms of cost the process itself is a creative one. The technique is catalytic and its use appears to give a greater understanding of the project and its objectives, as well as enhanced communications and teamwork.

The technique however cannot be viewed in isolation. Its success or otherwise appears to be largely dependent on the skill, motivation, personalities and relationships of the team and the leader.

Although some inferences can be made about function analysis. The only real concrete conclusion that the experiments produced, was that the technique has potential and is worthy of further research. The experiments highlighted that the technique is dependent for its success on other factors. The understanding and analysis of these factors is the next step in the value engineering issue.

There is one further point that needs to be considered. Function analysis, although undoubtedly a fundamental of value engineering, was originally part of a much wider philosophy. This thesis has examined only the technique and implementing VE as a philosophy is perhaps also worthy of consideration.

6. Conclusion

Function analysis is not an independent technique. It cannot be separated from the project, the facilitator or the team. Its strength lies in its catalytic value which is largely dependent on the method and skill of presentation, the personalities, motivation, experience and inter-relationships of the team and leader.

Function analysis is a design orientated process. Although its measurable output relates to cost the technique is in itself, a creative one.

The experiments did not prove that function analysis could aid effective design and reduce cost. The experiments pointed to an increase in project awareness, better communications and clearer stating of objectives if function analysis is employed by an experienced facilitator, with an open minded well motivated team, who have minimal relationship problems.

On the basis of the pilot work the research proposition could not be either supported or not supported.

The research proposition was not proven.

Chapter 10

General conclusions

1. Introduction

The practice of value engineering in the United States bears little relationship to the original principle, which had as its cornerstone the technique of function analysis. Value engineering in the United States is a combination of a design audit and cost cutting exercise. It is implemented in a 40 hour workshop by an external and independent team, at the 35% design stage. It reduces cost by approximately 10%. It is different from UK cost control procedures in that it is autonomous and it employs an external team. These two factors, which separate VE from UK cost control procedures, are subject to implementation problems in the US, which in all likelihood would be transported to the UK if the same system were employed here. Further, the design procedures of the UK and the US are different and Britain's system is not conducive to the application of American style VE. Finally the development of VE in the UK, although in its infancy, is showing definite signs of being different from the American. When it is considered that the US system developed largely to meet the objectives of the Department of Defence accounting procedures, this is hardly surprising. VE is developing in the UK to satisfy entirely different sets of objectives than exist in the US. The problem with UK development however is that its starting point has been the practice of US VE. This has been largely distorted from the original principle and as such the potential, if any, of function analysis has been overlooked. Preliminary investigation of this technique illustrates that, at least, it is worthy of further research.

The initial problem of this research was to establish if value engineering could be of benefit to existing British cost control procedures. In answering this question there are two fundamental issues that need to be considered. First is the distortion of VE techniques in the transition from manufacturing to construction in the US. Second is the development of value engineering in Britain.

The major reason for the distortion of VE theory appears to be, that the development of VE in construction in the US came primarily from one source, the Department of Defence (DoD). It developed because the DoD needed to be more accountable. In requiring accountability the DoD revealed a gap in the market which, in the persuit of profit, VE consultants were happy to fill. The DoD system however, although serving a purpose, cannot be correctly described as value engineering because it does not use function analysis.

Adding fuel to the standardisation of VE in accordance with DoD procedures was the lack of academic rigour in the field of study as a whole. The literature review did highlight a certain amount of academic input. However this has come largely from those with an interest in VE as either consultants or through providing training (Snodgrass, Ellegant and Barlow). Had there ever been independent academic rigour on VE practice in the United States, it would have revealed the process for what it is. As it is, the only criticisms of the DoD method have come from consultants/academics keen to sell their own systems. The literature critique however showed that these systems in their use of function analysis were often as flawed as the DoD method.

Ultimately whatever criticism is directed at American VE the system is effective in reducing construction cost by 10%. It was these claims (although often exaggerated) of value engineering success that first attracted British interest. In Britain however the objectives for which value engineering is required are not the same as in the United States. It has been shown that the US system allows for a process that satisfies a gap in the government market. This system is aimed at reducing cost and increasing accountability. In the UK the system of cost planning already satisfies these same needs. Quite naturally therefore the British are attempting to adapt the US value engineering system to suit their objectives. In doing so they have used the practice of US VE as the starting point of development. This practice however only exists to satisfy the DoD and cannot be adapted to suit the different objectives of the British market. Attempting such an adaptation is rather like trying to fit a square peg into a round hole.

This study in persuing its objectives has traced the development of value engineering from its inception to its present day position within British cost control procedures. In doing so the understanding of value engineering theory and practice has been significantly advanced. This advancement is summarised below.

2. Advancement in value engineering thinking

1. The development of VE theory from its inception in manufacturing into construction has not been previously documented. This study traced the development of VE and highlighted the distortion of the function analysis principle. In addition it documented how the implementation of VE studies has been rationalised from the original philosophical approach of Miles.

2. The presence of two distinct schools of thought in VE thinking has not been previously recognised. In addition the lack of academic rigour in both schools, particularly with regard to function analysis, was not understood prior to this study.

3.This study, in collecting data from the majority of VE consultants in the US, provided a comprehensive view of VE practice. Prior to this study no such investigation had been carried out.

4. Prior to this study the output of VE studies in terms of cost savings achieved along with the nature of the savings made had not been previously analysed. In addition the study was first to recognise the absence of any relationship between VE output and VE techniques.

5. Prior to the study no comparison had been made between cost planning and value engineering. As a result the similarity between the objectives of the two systems had not been recognised.

6. The study included a comprehensive survey of the use and understanding of VE in the UK. This had not been previously attempted.

7. Problems associated with the implementation of VE studies in the United States were recognised in this study through the observation of workshops. Such detailed analysis had not been previously attempted.

8. The study broke new ground in implementing a preliminary investigation of function analysis in construction. In doing so it established the relationship

of function analysis to behavioural science and group dynamics. This relationship had not been previously recognised.

The study, due partly to a previous lack of academic input, made significant advancement in VE thinking. This advancement, in order to conclude the study, needs to be examined in relation to the original objectives of the research.

3. A re-examination of the research objectives

3.1 Objective 1 - To define value engineering

Value engineering can be defined in three contexts. In theory it is the definition and evaluation of project function as a means of generating alternative solutions in order to provide a more effective design. In practice it is a re-examination of a projects design and cost, implemented by a team divorced from the design process, that seeks to increase client accountability and reduce cost.

The original work of Miles, the transfer of the technique from manufacturing to construction, the difference between theory and practice and the eventual transfer of the technique to the UK call for a contemporary definition of VE. Value engineering is therefore defined as a group orientated design process that through the definition and evaluation of function clarifies project objectives, offers alternatives that meet those objectives and thereby increases the effectiveness of design.

3.2 Objective 2 - To test the effectiveness of the US system of VE as a means of reducing cost and to investigate if any reduction achieved is other than by traditional cost reduction techniques.

Value engineering in the United States saves approximately 10% of project cost and is therefore an effective cost reduction technique. The savings achieved cannot be said to be traditional cost cutting in that some 30% of savings made are design orientated.

3.3 Objective 3 - To investigate whether US VE is additional to, or inherent in, current British cost control procedures.

Value engineering as practised in the United States is additional to British cost control procedures in that it is autonomous and is carried out by an external team. However although the methods are different the objectives of the British and American systems are the same. Both systems aim, through the examination of historical cost and the suggestion of alternatives, to increase accountability and reduce cost.

The theoretical aspect of value engineering, namely function analysis has no parallel in British cost control procedures and can be regarded as additional to them.

3.4 Objective 4 - To determine how VE can be best employed in the UK.

It is unlikely that VE as practised in the United States can be effectively employed in the UK for three reasons. The approach taken to VE in the US, namely the external approach by an independent team, is not effective. In addition this approach is not acceptable in a UK environment. Finally the British design procedures within which VE is to exist are not conducive to the application of the American approach.

With regard to function analysis the technique could possibly be employed in the UK to aid effective design. It must however be recognised that the technique is not independent and is closely linked to group dynamics and the behavioural aspects of group working. In addition the technique is a design orientated one, acting only as a catalyst for cost reduction through the improvement of design.

To facilitate investigation the research objectives outlined above were operationalised into five research propositions. Examination of these drew the following conclusions.

4.Research propositions

Research proposition 1.

The Dell'Isola school is practised in the US.

The research proposition was supported.

Research proposition 2.

That the scope of VE is limited by the use of elemental function analysis to the search for alternative technical solutions and that VE as practised is merely cost reduction.

The research proposition was not supported.

Research proposition 3.

That VE as practised is nothing additional to that which already exists, within the UK cost planning framework.

The research proposition was not supported.

Research proposition 4.

That VE as implemented in the US could not be practised in the UK. The vast differences between US and UK procedures do not facilitate direct implementation of the US system in the UK.

The research proposition was supported.

Research proposition 5.

The technique of function analysis could aid effective design and reduce cost.

The research proposition was not proven.

In addition to the research propositions the study also made the following conclusions.

5. Other conclusions

1. Value engineering originally developed as a broad philosophy based on the technique of function analysis. Adapting value engineering for the construction industry distorted the technique of function analysis from its original principles.

2. The development of VE in the United States has been from a single source, as such a standard system has developed.

3. The US system of VE has developed without the benefit of academic scrutiny. As such many techniques used are not academically sound.

4. Value engineering in the United States is effective in reducing construction cost by approximately 10%. However, this saving cannot be attributed to function analysis and is the result of other broader factors.

5. The savings produced by value engineering cannot be termed cost cuts. They include a more general overview of design as well as more traditional cost cuts.

6. Function analysis is only a theoretical technique in the US. In reality it is not used. It is given lip service only to satisfy the requirements of SAVE.

7. The practice of value engineering in the US, within its cost control framework, offers only two components which do not exist in the UK cost planning system. First, VE is an autonomous approach and second it is carried out by an external team.

8. The opportunity offered by the cost planning process to reduce cost is the same as that offered by value engineering. In addition the objectives of the two systems are similar.

9. The autonomous approach by an external team used in the US is fraught with difficulties. It is likely that these difficulties would also occur in the UK. In addition, British design procedures are not conducive to the application of US value engineering practice. Possibly as a result of this the majority of UK companies involved in VE have developed alternative systems. These systems appear to be based on an adaptation of American practice.

10. Value engineering is required in the UK to satisfy more global objectives than exist in the US.

11. Function analysis could be of possible benefit in the UK. The technique of function analysis however is largely a design orientated process that has no direct relationship to cost. The technique is not independent and it's successful implementation is influenced by other factors.

6. Limitations of the research

The research has four limitations.

1.The successful application of the technique of function analysis was found to be dependant largely on behavioural science issues. This behavioural science aspect was considered to be outside the scope of the study and was not therefore investigated. Even in view of the project scope this lack of investigation must be acknowledged as a limitation of the research.

2.Value engineering in manufacturing was not examined beyond its early theoretical base.

3.Due to its integration within design procedures the output of the British cost planning system could not be measured. Comparison with value engineering therefore had to rely on a theoretical comparison of the two systems.

4. The data used in the research was not conducive to statistical analysis.

7. Recommendations for future research

The study highlighted that value engineering based on the principles of function analysis has a greater relationship to design than to cost control procedures. In addition the use of function analysis in group studies is not an independent technique, its success is reliant on many other factors. It is within this area that the scope for further research lies. The following recommendations are made

1. Criteria that govern the success of function analysis as a tool for effective design.
2. Behavioural studies of design teams working as groups.
3. Group working as an aid to effective design.
4. The improvement of cost planning based on a group approach to design.
5. The integration of function analysis into existing design procedures.
6. The application of function analysis under different procurement methods.
7. A philosophical approach to value engineering in construction.
8. British cost control procedures in the US market.

8. The future of value engineering in the UK?

The development of VE in the UK has been based an an adaptation of US practice and this, due to the difference in objectives, is not suitable for the UK market. If the British development of VE does not shift course it is quite likely that value engineering will have a very limited life span in the UK. There will naturally be a limited market for any technique and no doubt VE as used by, or adapted from, the Americans could sustain a degree of success for a limited period. However if value engineering is to ever succeed in the long term it must go back and examine the original philosophy of Miles.

The technique of function analysis as designed by Miles was design orientated as opposed to cost orientated. When Miles invented it, cost savings were achieved as a secondary result of looking for alternative components. However the true value of value engineering lies not only in the use of function analysis but in the broader philosophy of understanding client need and providing only what satisfies those needs. Function analysis is an exceptionally powerful tool in assisting this but it can never be a panacea of all ills. Much of the worth of value engineering is in the interaction of the team and the clear stating of objectives.

A quotation by one consultant interviewed for this research is perhaps fitting to end this study,

"There are no new problems in the construction industry, only many variations on old ones"

The problems of lack of team integration, poor brief formulation, late cost input and limited client involvement are as prominent today as they always have been. The inherent problem lies in the archaic attitudes that professionals display towards one another. However despite this, and in the narrower field, the British system of cost control is vastly superior to anything the Americans have to offer, including VE.

Any British construction professional who attempts to take on board the US style workshop is making a serious error. His efforts would be better directed at selling himself to the Americans. They have more to learn than we do.

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