EXPERT SYSTEMS IN MANAGEMENT ACCOUNTANCY

by

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A Doctoral Thesis

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Abstract

Expert systems and management accountancy have been linked by a relatively small literature which is largely represented by descriptions of developed systems or speculation on the potential value of developing systems. This literature is unfortunately not particularly convincing and, in particular, fails to provide a theoretical underpinning in either expert system or management accounting terms. The thesis therefore begins afresh by asking whether expert systems can be valuable in the context of management accountancy. Propositions are established which ask whether management accountancy can be represented by the kind of knowledge and skill which can be embodied in expert system form. The propositions are developed by relating management accountancy to Newell and Simon's (1972) theory of human information processing, which is consistent with expert system development. The theory is explored in three different contexts: in the problem solving of six management accountants talking through a small management accounting case study, in the resolution of practical management accounting problems within three organisationally based case studies and in the development of an expert system for use in teaching and learning. The findings suggest that whilst Newell and Simon's theory of information processing is valuable in structuring some of the tasks which comprise management accountancy, the theory is a poor descriptor of human management accounting expertise. A framework is developed which explains the findings and which itself constitutes a theory which requires further investigation. The framework is the first potentially valuable outcome of the research. A second potentially valuable outcome is to show that small expert systems can be valuably used in management accounting teaching and learning because of the rapid prototyping capability of expert systems. Further research into this is also recommended. A final value of the research is in showing some of the ways in which different research methods can add to an understanding of management accountancy through a consideration of human information processing. This is an under-researched area of interest.

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CHAPTER 1

INTRODUCTION

1.1 Background to the thesis

T.S.Eliot wrote:

> "Donne, I suppose, was such another
> Who found no substitute for sense.
> To seize and clutch and penetrate;
> Expert beyond experience."

In referring to Donne, the "metaphysical poet", Eliot provides a reminder that sense (or rationality), expertise and experience are concerns which go beyond the twentieth century. The present thesis takes a contemporary issue, the use of expert systems in management accountancy, but tries not to lose sight of the universal questions which are raised by such an investigation. In particular, the fundamental question which is addressed here is whether the expertise of the management accountant can be simulated in transparent, rational terms by means of an expert system or whether such expertise must remain shrouded by the nature of personal experience.

The account presented here is an attempt to capture the outcome of research conducted up to the end of 1991. It is not a chronological account of what has taken place. Nor is it intended to be the final word on the issues which are raised. The chronology is explained by a research strategy which relied upon intuition and an openness to new lines of research which is characteristic of the Dionysian approach (Szent-Gyorgyi, 1972). Building and using an expert system in classroom settings led to questions about the possible use of expert systems in practical settings which in turn led to questions about the nature of management accounting expertise at the level of the experienced management accountant. The necessity to ground such research in theory, which is particularly important for the Dionysian approach (Smith, 1975, pg.22), creates a logical structure which reverses this chronological order. Because an important theory capable of enlightening expert system development begins at the individual expert level, questions are firstly asked about the expertise of the management accountant. Next, management accounting problems are placed in a practical context and, finally, the building of a practical expert system is explored in a teaching /learning context.

1.2 Initial definition of expert systems

Expert systems represent a group of computer programs which "advise, analyze, categorize, communicate, consult, design, diagnose, explain, explore, forecast, form concepts, identify, interpret, justify, learn, manage, monitor, plan, present, retrieve, schedule, test and tutor" (Michaelson et al, 1985). They deal with problems which are sufficiently difficult to require significant human expertise (Feigenbaum, 1985).

Edwards and Connell (1989) contend that definitions of expert systems, such as that provided in the first paragraph, are confusing, beg a number of questions, are not generally accepted and leave only one thing clear; that "for a computer system to be classed as an expert system, it must somehow embody a representation of expertise". The critical element is therefore the concept of "expertise". Capturing the expertise of human experts working in the field is a normal and necessary part of expert system development (Vasarhelyi, 1989). Expertise itself implies a combination of knowledge and skills (Vasarhelyi, 1989) which emphasises the need to consider not only the knowledge base of a particular domain but also the skills necessary to apply the knowledge base in solving particular problems.

1.3 Value of expert system research

There are a number of reasons why research into the use of expert systems in business and accountancy might be expected to be valuable:

- The potential commercial market for expert systems is significant. Expert systems were expected to be part of a $4 billion market by 1990 (Grigoriou and Willey, 1987) and have been projected to be part of a $113 billion market over the next fifteen year period (McCarthy, 1989).
- Case histories of users who have gained significant financial benefits by introducing expert systems have been presented, although there is a question over the extent to which such case studies are representative of more general experience amongst past or prospective users (Edwards and Connell, 1989).
- Worthy claims have been made for the use of expert systems. There is a potential to develop "ideal" decision aids (Vasarhelyi and Bao, 1984) which may improve the quality of decision making (Abdolmohammadi, 1989). This includes improving consensus or agreement of judgement among experts within the same business and improving efficiency to obtain competitive advantage (Messier and Hansen, 1989). Within an educational context, Kaye (1987) claimed that it would be desirable to "work towards the 'intelligent tutor' concepts of O'Shea and Self

(1983) and Sleeman and Brown (1982)" in order to reflect "the interest currently in expert systems".

- Traditional research methods have not been able to provide solution algorithms for large, ill-structured decision problems (Bailey et al, 1989). This has led to an interest in the study of expert decision processes and attempts to automate these processes, as typified by Libby's (1981) review work on human information processing. Expert systems are implicated in the study of expertise and in the automation of expert decision processes for research purposes.
- There is significant interest in expert systems. The AICPA (1985) Future Issues Committee identified artificial intelligence and expert systems as one of the major issues significant to the future of the accounting profession. The UK accounting profession has similarly shown interest. Arthur Young and the ICAEW have supported research centred on Connell and Southampton University. This is reported by Connell (1987) and Edwards and Connell (1989). CIMA reflected its interest in expert systems by publishing "a thorough briefing on the current state of development of expert systems" as part of its management information system publication series (Dixon et al, 1988). More recently, a CIMA workshop, comprising 40 financial managers from throughout Europe, who met to discuss the possibility of developing a European accounting framework, placed a heavy emphasis on the use of expert systems (CIMA, 1991). Alan Sangster, of the University of Aberdeen, is currently engaged in CIMA sponsored research into the use of expert systems in management accountancy.
- The value of expert system development may be valuable in its own right. The process of expert system development may even be more valuable than the expert system itself (Edwards and Connell, 1989, pp. 91-92).

The value of expert systems to business and accountancy is reflected in a growing literature of substantial proportions. McMahon's (1990) bibliography of expert system publications in accounting, finance and management lists 1300 works. There is evidence that the number of works has grown exponentially. Based on the classification adopted by McMahon, the greatest expert system activity is in general management (228 citations), finance and banking (217 citations), auditing (151 citations), financial management (120 citations) and general business (105 citations).

1.4 Purpose of the research

The purpose of the research is to investigate the application of expert systems to management accountancy.

That an opportunity for valuable research exists has been suggested by Lin (1986), whose paper has been considered to be sufficiently important to be reprinted in at least two separate works (Wilson and Chua, 1988; Vasarhelyi, 1989) and cited as one of three "recent reviews" by O'Leary and Lin (1989). The evidence of other researchers taking up this opportunity is unfortunately scant. McMahon's (1990) bibliography lists eighteen works related to management accountancy out of a total list of 1300. On the issue of developing decision-improvement aids which reflect human decision-making or expertise, Libby (1981) finds that there is a literature which is "extensive and drawn from a variety of disciplines" but that "most accounting problems in managerial accounting ... have hardly been touched on". The majority of the literature relates to auditing and financial accounting. Libby's work more generally relates to human information processing and accountancy. Wilson and Chua (1993, pp. 403-404) list human information processing studies as one of the contemporary developments which "provide broader conceptual frameworks for the development of managerial accounting", but they only cite two works which illustrate contributions in this area. The most recent work cited, Ferguson (1988), explicitly claims that its purpose is solely to draw attention to the relevance of such research to the design of accounting information systems. It is clear that there is both a need and an opportunity to understand expert systems, and the broader area of human information processing, in relation to management accountancy, and vice versa.

The research reported here addresses a particular theory of human information processing which has been suggested by Newell and Simon (1972). The primary focus of any expert systems research project might be considered to be concern for a theory of a single expert's decision-making processes (Newell et al., 1958; Bailey et al, 1989). Newell and Simon's (1972) theory is potentially valuable in not only shedding light on management accounting expertise but also in providing a basis for the computerisation of that expertise through expert system technologies. Hence:

a) if Newell and Simon's theory of information processing is found to be adequate as an explanation of management accounting expertise, then it follows that expert systems can be developed for management accountancy;

OR

b) if the theory is found to be inadequate as an explanation of management accounting expertise, then the differences between management accountancy and the domains studied by Newell and Simon might provide new insights into management accountancy.

1.5 Statement of propositions

Given that the investigation of expert systems and management accountancy is a somewhat broad area to research, an attempt to define the boundaries of the research is necessary. A framework for research has been provided by an initial statement of propositions.

The main proposition is stated:

> The expertise of management accountancy can be beneficially represented in expert system form.

The main proposition directs a search for understanding about the nature of management accounting expertise and beneficial opportunities to represent that expertise in expert system form. The nature of management accounting expertise can be analysed in terms of the knowledge base and skills of the management accountant, following Vasarhelyi's (1989) analysis quoted earlier. This analysis leads to two propositions which provide the research with a focus:

Proposition 1

> The knowledge base of management accountancy can be fully described in expert system terms.

Proposition 2

> The skills base of management accountancy can be fully described in expert system terms.

The meaning of each of the terms "knowledge base" and "skills base" needs to be restricted. In particular, the term "knowledge base" has been widely used in recent years without any evidence of a widely accepted definition (Frost, 1986).

Harmon et al (1988) define knowledge as "a body of information about a particular topic that is organised to be useful". More specifically, the term "knowledge base" normally implies a collection of facts and rules (Frost, 1986; Harmon and King, 1985) and an implicit structure. This could also be true, however, of databases. A distinction is therefore drawn in the literature between knowledge bases and databases. A knowledge base is differentiated from a database by the proportion of facts to rules and the nature of their representation. Knowledge bases typically consist of explicitly stated rules and explicitly stated facts. Databases typically comprise a large number of explicitly stated facts together with a relatively small number of implicitly stored rules (Frost, 1986). A fuller discussion of the relationship between knowledge bases and databases is provided by McCarthy (1989).

The term "skills base" has not been defined by the expert system literature but it is possible to talk in expert system terms about inferencing mechanisms, implying that expert systems contribute the skill of inferencing. Similarly, the expert system literature is reasonably clear that expert systems should provide explanation facilities and it can be presumed that the skill of explanation is represented by such facilities. The skills base of inferencing and explanation can be compared and contrasted with the ways in which the knowledge base of management accountancy is used in problem solving situations.

The second element of the main proposition requires a contextual basis for investigating the beneficial representation of management accountancy in expert system form. Two areas have been selected for specific consideration; one related to the practice of management accountancy, the other to teaching. These two areas are represented by propositions three and four:

Proposition 3

Expert systems can be beneficially developed as practical management accounting decision aids.

Proposition 4

Expert systems can be beneficially developed for management accounting teaching and learning purposes.

The first of these two propositions is particularly linked to problem solving in ill-structured domains. This has been shown to be a value of expert system research (Bailey et al, 1989; Libby, 1981, referenced earlier). Teaching and learning have long been implicated with expert system applications and are claimed to be a feasible and valuable areas for research (Kaye, 1987; Lin, 1986, referenced earlier).

1.6 Limitations

The types of research method which have been adopted imply certain limitations which are more fully discussed in the chapter on research methodology. In particular, existing research methods tend to rely heavily on subjective interpretation and do not lead to conclusions which can be considered to be generalizable. This is generally accepted to endanger the reliability of the research but may provide benefits in terms of validity.

Care has been taken to mitigate as far as possible the limitations of the research methods used. Reliability can be improved by triangulation; the use of multiple research methods to extract important features from research data collected in a variety of ways. Every effort has been made to ground the research both in terms of theory and data collection. Data has been presented as fully, openly and objectively as possible in the appendices. References have been provided to similar findings made by other researchers. Key findings of the research have been subjected to peer review by means of publication in refereed journals.

Various elements of this thesis draw their understanding from management accounting research as a whole, from psychology, from sociology and from a number of areas of literature not traditionally associated with management accounting: artificial intelligence in general, intelligent computer assisted learning, expert systems, systems theory and information processing theory. While there have been numerous calls in the management accounting literature for research which is holistic, this itself provides a limitation. The author's limitations of time, resources and ability are the limitations of the research itself.

1.7 Value of the thesis

The thesis is potentially valuable to management accounting researchers, teachers and practitioners and to the accounting profession. In applying research methods in the pursuit of an under-researched area of concern, researchers may find a base for future research programmes. In describing the use of an expert system in classroom situations, the thesis may inspire other teachers to re-examine their approach to management accounting and possibly lead them to adopt expert systems in their own teaching. In dealing with the problems of developing an expert system based on practical problems, practitioners can decide for themselves whether it is appropriate for them to develop expert systems. Finally, by bridging educational and practical concerns of management accountancy, the thesis might be valuable for the accounting profession.

1.8 Structure of the thesis

The first four chapters establish the context of the research. Chapter 2 presents a literature review and finds the existing literature to be unconvincing, particularly because of its lack of a theoretical basis. Chapter 3 explains a theory of human information processing which is used to provide a theoretical grounding for the research reported here. Chapter 4 discusses the problems of establishing a research methodology for expert system research into management accountancy and explains the choices made for this particular research. This part of the thesis establishes the research basis and the theoretical basis of the thesis.

The next part of the thesis presents the research which was carried out. Chapter 5 presents a protocol analysis of experienced accountants, who were asked to respond to a small but open-ended management accounting case study. This chapter establishes two alternative views of management accounting expertise. Chapter 6 presents the findings of three case studies which investigated the practical problem-solving of managers and accountants for situations in which management accounting expert systems might have played a valuable role. Chapter 7 describes the development and use of an expert system in teaching. This part of the thesis establishes the data and data analysis basis of the thesis.

The final part of the thesis provides a synthesis of the material which precedes it. Chapter 8 provides an overall structure for the data collected from the three major research exercises. This is then developed to provide a framework to explain the research findings. Chapter 9 revisits the propositions stated earlier in this chapter and brings the thesis to an end.

1.9 Summary

The research reported here began with a single question: **can expert systems be beneficially applied to management accountancy?** There is evidence that published authorities are willing to assert that the answer is "yes" but little research to support or disclaim the assertion has been published. There is evidence that researching such a question has the potential to make a valuable contribution, either through the development of useful, practical decision aids and educational tools, or through the testing of theories of human information processing which might provide new insights into management accountancy. The thesis is grounded in a theory of human information processing and data taken from practical and teaching situations.

A main proposition has been developed:

> The expertise of management accountancy can be beneficially represented in expert system form.

This has been broken down into four propositions which will be investigated as part of a research process:

Proposition 1

> The knowledge base of management accountancy can be fully described in expert system terms.

Proposition 2

The skill base of management accountancy can be fully described in expert system terms.

Proposition 3

Expert systems can be beneficially developed as practical management decision aids.

Proposition 4

Expert systems can be beneficially developed for teaching and learning purposes.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The previous chapter provided a general introduction and included an initial definition of expert systems. This chapter takes the initial definition a little further and then reviews the literature which covers expert systems and management accountancy.

2.2 Definition of expert system

Muller (1988, pg.v) defines expert systems as systems which "replicate human expertise in a narrow domain". This definition carries two of the essential elements of expert systems. The first is that expert systems somehow embody the knowledge of the expert and can use that knowledge in a way that produces the conclusions that human experts would reach. This focuses attention on knowledge and how it might be represented and on the skills involved in converting that knowledge into conclusions. The second element has now become accepted by the conventional wisdom of expert systems; that expert systems cannot yet be developed for situations where a broad base of knowledge would need to be coded. Humphreys (1989, pg 22) claims that the success of expert systems "has been limited to handling low-level, well-structured problems, in which the decision maker has little, if any, discretion in formulating a policy for action".

Various knowledge representation schemes have been proposed by the general expert system literature, Indeed, given the variety of schemes which have been advanced, it is increasingly difficult to define precisely what differentiates an expert system from other forms of artificial intelligence. However, the most common form of knowledge representation in expert systems is the production system (Doukidis and Paul, 1990); one or more series of If ... Then rules which define the knowledge base.

Figure 2.1 provides examples of production rules taken from Demetrius (1986, pg. 238). This provides examples which he believes would be necessary to include in a financial structures module to be included in an expert system for Board Room decisions.

FIGURE 2.1 Examples of Production Rules

"IF leverage is beyond industry norms
THEN availability of loan funds is low

IF 'debt ratio' is outside set tolerances
OR 'times interest earned' is outside set tolerances
OR 'fixed charge coverage' is outside et tolerances
THEN leverage is beyond industry norms

IF voting control should not be devolved
THEN preference shares are preferred to ordinary shares"

To draw a conclusion, an inference must be made based on responses to questions which the expert system elicits from the human user. For instance, using Demetrius's (1986) rules, if the user provides responses which signify that the debt ratio is outside set tolerances, the expert system would return the conclusion that the availability of loan funds is low. The addition of extra rules might lead the system to conclude that preference shares are preferred when the user provides the additional response that voting control should not be devolved. The inference is drawn through means-ends reasoning which follows a reasoning chain from the IF part of one or more production rules through to a final THEN conclusion.

Dixon et al (1988, pg.8) summarise this by stating that an expert system is a two-fold "intelligent knowledge-based system" comprising the knowledge base and the inference engine. The knowledge base differs from conventional programming in that it comprises stand alone rules which are independent of the context other than when they are fired by the responses to questions or other rules. Additional rules can be introduced so that the expert system is more flexibly programmed than conventional programs. The inference mechanism is provided by the expert system environment itself, be it an expert system shell or an appropriate programming environment such as PROLOG or LISP. The programmer does not normally need to create the inferencing mechanism.

A summary of some of the leading issues and wider concerns of expert system development resulting from work over an extended period of time is provided by Hayes-Roth (1988, pg 4), quoted in full because of its excellent and controversial enunciation of many of the issues currently surrounding expert system development:

"An expert system is a knowledge-intensive program that performs problems which normally require human expertise. It performs many secondary functions, as an expert does, such as asking relevant questions and explaining its reasoning. Some characteristics common to expert systems include the following:

- *they can solve very difficult problems as well as or better than human experts,*
- *they reason heuristically, using what experts consider to be effective rules of thumb, and they interact with humans in appropriate ways, including natural language,*
- *they manipulate and reason about symbolic descriptions,*
- *they can function with data containing errors, using uncertain judgement rules,*
- *they can contemplate multiple, competing hypotheses simultaneously,*
- *they can explain why they are asking a question,*
- *they can justify their conclusions.*

Compared to a human expert, today's expert system appears narrow, shallow and brittle. It does not possess the same breadth of knowledge or understanding of first principles. It does not apparently think as a human does: perceiving significance, reaching conclusions intuitively, and examining a single issue from diverse perspectives. Rather, the expert system of today simulates an expert's thinking rather grossly. It reaches the same major decisions by elucidating many of the relevant criteria and making many of the same educated guesses that an expert would if forced to verbalise the thought *process. Unlike a human, however, the expert system does not resort to reasoning from first principles, drawing analogies, or relying on common sense; neither does it learn from experience."*

The final themes are particularly relevant; the role of principles, analogies, common sense and experience. The relevance to the present research is to consider whether these four themes have any sort of bearing on management accountancy. If Hayes-Roth is correct, then defining these four elements may provide important insights into the knowledge base of management accountancy. The extent to which they represent a proportion of the management accounting knowledge base will be implicated in judgements about the extent to which expert systems can be established for management accountancy.

Beyond a superficial definition of expert systems, the debate as to what exactly constitutes an expert system is somewhat difficult and can be protracted. For example, not all expert systems would include natural language processing or uncertainty reasoning. The debate is perhaps most fully related to financial expert systems by Edwards and Connell (1989).

Edwards and Connell (1989) draw the useful distinction between functional and architectural definitions of expert systems. From a functional perspective, an expert system is a system which mimics the human expert. As pointed out in the quotation from Hayes-Roth given above, current expert system are considered to be severely limited in this regard. One view might be that the functional perspective provides a target which is not achievable with the current technology. It does, however, provide a research objective; the simulation of expert behaviour using a narrow definition of expertise. From a management accounting expertise point of view, such a research objective may be valuable and certainly has not yet been greatly exploited.

The second perspective, the architectural definition, holds that an expert system comprises a knowledge base and an inference engine. Presumably any program written in an expert system shell or in an appropriate language such as PROLOG or LISP would be defined as an expert system under this definition. The research objective of coding knowledge in expert system form for management accountancy has the technological aim of establishing the feasibility of expressing management accounting knowledge in expert system form. A number of sub-systems of management accountancy have been claimed to have been coded in expert system form. Papers describing such systems are described later in this chapter.

2.3 The Relevance of expert systems to management accountancy

Much of the existing literature which purports to address the relevance of expert systems to management accountancy is disappointing in that it concentrates on the generalities of expert systems and not on the particulars of the appropriate use of expert systems in management accountancy. Typical are Akers et al (1986) and Shim and Rice (1988). These articles explain expert systems, provide some examples of existing systems, often taken from auditing and taxation fields, and provide a summary of pros and cons. They are valuable only as a brief introduction to the debate on whether expert systems should be applied to management accountancy.

In the absence of literature which directly addresses the relevance of expert systems to management accountancy, this section therefore considers three different lines of thought: Lin (1986) provides a list of appropriate topic areas where management accountants can use expert systems, Dixon et al (1988) suggest prerequisites for expert system development and Blanning (1989) suggests that there are three different areas where expert systems have been developed in the past, providing some examples of relevance to management accountancy. Lin's is a speculative approach, Dixon et al's a criteria based approach and Blanning's is an approach which builds on past experience. Finally, some of the views of O'Leary (1989) are presented to give an overview. O'Leary claims to address the issue of the relevance of expert systems to accounting in general and includes a limited assessment of management accountancy in particular. The choice of these publications is intended to be indicative of publications in the area and not a comprehensive review.

Lin (1986) states that "management accountants can use expert systems to solve the complex problems of capital budgeting, transfer pricing, variance analysis and investigation, performance evaluation, incentives and compensation systems, corporate planning and budgeting, product pricing, and information systems selection" and an expert system "can be used to train management accountants". Empirical evidence, or evidence of any kind, is lacking to substantiate these claims. The value of Lin is in providing a starting point. The drawback is that Lin's list is virtually all-embracing of topics within management accountancy and does not provide any guidance as to the types of task for which expert system development might prove beneficial, as well as those for which it might not.

Dixon et al (1988) is a significant piece of work in that it is the Chartered Institute of Management Accountant's published work in the area. In this respect, it is disappointing in not being more specifically related to management accountancy. Much of the publication is only general in its treatment of expert systems. The two chapters of potential importance to the present section, "Practical Considerations for Financial and Business Application" and "Expert Systems in Accountancy" are typical.

Of these two chapters, the first seems to be the most useful in providing a section headed "suitable areas for the potential expert system user". Four criteria for success in expert system development are given:

"*(i)* *There must be at least one human expert acknowledged to perform the task well.*

(ii) *The primary source of the expert's exceptional performance must be special knowledge, judgement and experience.*

(iii) *It must be possible to elicit the expert's special knowledge and experience and the methods used to apply them to particular problems.*

(iv) *The task must be a well-bounded domain of applications."*

Item (iv) implies the need for a narrow area of expertise noted earlier. The others are rather general and would seem to apply to virtually any area of management accountancy.

The remainder of the two chapters deal with a miscellany of topics: programming languages and shells, applications within finance and accounting in general (but, disappointingly, none in management accountancy in particular) and interested parties (listed as ALVEY, ICAEW and some individual companies and university departments).

Blanning (1989) lists three management areas as being significant in terms of past expert system developments: resource allocation, problem diagnosis and scheduling and assignment.

Under the heading of resource allocation, an early attempt to tackle the problem of capital investment decisions (Bohanek et al, 1983) is referred to. This system is not directly an expert system, but is a shell dedicated to the resolution of a particular type of decision. The user enters a set of rules in much the same way that a user of an expert system shell would enter a set of rules for any expert system application. The system was applied to a capital investment decision. The feasibility of using certainty factors and providing an explanation of an accept or reject recommendation was established. More recent expert systems for the capital investment decision are considered in a later section (section 2.5).

Problem diagnosis includes reference to an auditing system and to Bouwman's (1983) work in financial analysis. The only reference to management accountancy is a passing one to the importance of budget variance analysis in the manager's problem solving behaviour. Specific references to expert system development in this area are discussed in section 2.5.

Scheduling and Assignment involves applications not directly relevant to the management accountant. However, in raising the issue of factory scheduling and labour planning, the management accounting issues of stock and labour control are implicitly implicated in expert system development. Specific systems are again included in section 2.5.

The value of Blanning is in providing evidence of past systems which implicitly impinge on the work of the management accountant. The analysis is encouraging in agreeing with some of the suggestions of Lin, but is neither coherent nor comprehensive in addressing the relevance of expert systems to management accountancy. Since it does not claim to be either of these last two things, this section concludes with a publication which addresses the relevance of expert systems to accountancy in general.

O'Leary (1989, pg. 85) provides the following interesting and idiosyncratic definition of management accountancy:

"management accounting [planning and control systems] develops information to meet the needs of decision makers. As a result, management accounting is concerned with the expertise used in the development and maintenance of the planning and control systems."

O'Leary (1989, pg. 86) establishes that accountancy in general is a feasible domain for expert systems because accountancy is characterised by knowledge in the form of rules, accounting expertise is in short supply and is expensive and the distinction between the expert and non-expert can be designated through the existence of professional qualifications. Unfortunately, these points are not related directly to the view of management accountancy given above. The examples of rule-based accounting knowledge are drawn from areas not immediately associated with O'Leary's definition of management accountancy, for example, the work of the FASB. Similarly, the costs of developing and maintaining systems, central to O'Leary's conception of management accounting expertise, and which have a theoretical base in Information Economics (for instance, Scapens, 1991 provides a review), cannot be related to expertise in any simple or obvious manner. So, although O'Leary is probably correct in asserting that some aspects of accounting are rule based and some aspects of accounting are influenced by the expense and shortage of accounting expertise, these factors are not necessarily true of management accountancy.

O'Leary (1989, pp. 87-93) goes on to provide some useful general sections on expert systems, including a consideration of the limitations of expert systems. The limitations are worth noting (pg.93) because they all have a bearing on the findings of the present research. The limitations are based on two lists. The first is quoted from Messier and Hansen (1983):

"• *A substantial effort is required to build an expert system.*
• *The size of the knowledge base is limited by current technology.*
• *The development of expert systems must cope with the current languages, since computers are unable to understand natural language.*
• *The development of an expert system requires an expert to spend time developing and debugging the system."*

The third item, the lack of natural language capability, contradicts Hayes-Roth (1988), given above, and provides evidence of one of the ways in which definitions of expert systems differ at the margin of functionality. The second list is quoted from (McDermott, 1984):

- *"The systems do not have general knowledge to fall back on if the specific knowledge is insufficient.*
- *The systems do not learn from experience.*
- *The systems often provide a trace of the decision. However, often this is not a satisfactory explanation of the decision.*
- *The systems have little knowledge of their own scope and limitations."*

The first two items are the familiar themes of "common sense" and experience. The third again contradicts Hayes-Roth (1988) in that the supposed explanation facility offered by expert systems is called into question. The final item is idiosyncratic.

All in all, the lists show how some themes re-emerge in the expert system literature whilst some ideas are contradictory and others are idiosyncratic. Perhaps these are the marks of a discipline in its infancy.

Finally, O'Leary (1989) signals management accountancy as one area where few systems have been developed. The one system which is referenced (Reitman, 1985) is in the area of capital investment appraisal but is unfortunately an unpublished presentation.

This section has provided a flavour of the literature which relates management accountancy to expert systems. As can be seen, much of the material is general and no concrete picture emerges. The next section looks at publications which provides examples of specific management accounting expert systems to see if these shortcomings in the literature can be overcome.

2.4 Expert systems in management accountancy: an overview

This section reviews an article which provides a view of expert systems which are being used by companies, primarily in the USA. This provides an overview of the scope of use of expert systems in management accountancy which is then developed at a more detailed level in section 2.5.

Brown and Phillips (1990) review working systems which they claim are in use in the USA and elsewhere. These systems are grouped into five areas:

- Systems which emphasise long range planning. Brown and Phillips include two examples under this heading, both illustrating capital investment appraisal.
- Transfer pricing systems.
- Stock Control systems.
- Variance analysis systems.
- Performance measurement systems.

Companies referred to in the survey include IBM, Texas Instruments, EXXON and Digital Equipment Corporation. Systems vary from those which are claimed to be used by approaching 200 managers world-wide (Texas Instrument's system for capital investment appraisal) to a small business application (Arthur D. Little's variance analysis system which was developed for a high technology company with a turnover of $75 million). Functions offered by the systems include sensitivity analysis, integration with a spreadsheet, competitive and financial analysis together for justifications for recommendations made, and output in the form of reports which explain the reasoning behind a particular recommendation.

There is evidence that some systems are consistent with the functional definition of expert systems explained earlier, whilst others are consistent with the architectural definition. For instance, a stock control system implemented by Associated Grocers has captured the company's buyers' expertise in terms of the key factors of consumer preference trends, price trends, vendor distinctions, seasonality, mix and product distribution. This would seem to imply that the expert system is applying expertise previously applied by human experts in the field. The expertise is represented by a small number of rules coded in an expert system shell. Alternatively, Digital Equipment's BUCKS system, which has been used to measure performance of divisional projects in Europe, takes a small number of measures (revenue and contribution margin, comparing results with budget) and offers the facility of explaining the reasoning behind analysis and conclusions made. This appears to be using facilities offered by expert systems rather than claiming to replicate human expertise.

A variety of benefits are claimed. Texas Instruments' capital investment appraisal system is claimed to bring the knowledge of the most experienced people at TI to bear on decisions because the system is used at a higher level within the organisational hierarchy than the previous manual system. EXXON's transfer pricing system has reduced the delay in recording transfers from more than a month to a day or two and 90% of transactions are handled without human intervention. Manpower savings, cash flow improvements and better decisions are claimed by EXXON. Digital Equipment's performance measurement system is claimed to discover trends and underlying factors often overlooked by managers. It is also claimed to save management time and to improve the quality of decision making.

There is some cause for concern in the claims that are made. For instance, Associated Grocers stock control system uses only a limited number of rules and seems to gain its advantage because of the high number of stock items which have to be monitored. This might imply a repetitive, low level system for a highly structured task. It is not clear where human judgement and expertise are involved and it is also not clear whether other computing solutions would have been acceptable. Similarly, Digital Equipment's performance measurement system appears to consider so few variables that it is not clear why any computing solution could not have been equally adequate to the purpose. Texas Instrument's capital investment appraisal system includes payback and cash flow analysis but again it is not clear why other computer approaches were not adequate to the purpose. The difficulty with the description of these working expert systems is that the role of the knowledge base simply is not made clear. The article is a good introduction to WHAT expert systems might do but does not address the issues of WHY an expert system might be useful, as opposed to other forms of computing. Nor is the article particularly useful on the subject of HOW the systems were developed as expert systems.

2.5 Expert systems in management accountancy: specific systems

This section seeks answers to the WHY and HOW of management accounting expert systems in publications addressing particular areas. The structure follows the categorisation of management accounting expert systems provided by Brown and Phillips (1990), which was reviewed in section 2.4.

2.5.1 Planning and capital investment appraisal systems

Before moving onto the more solid publications that have emerged in the capital budgeting arena, the bewilderingly different approaches to planning are first briefly introduced.

The area of planning has produced a variety of papers which impinge on management accountancy, including general publications on "strategic planning" which claim directly or indirectly that expert systems can help in capital investment appraisal (Bidgoli and Attaran, 1988) and financial modelling (Smith, 1990), specific papers on approaches to planning with reasoning as their theme (Sullivan and Yates, 1988; Wise and Kosy, 1986a and 1986b), the preparation and evaluation of budgets (Hwang et al, 1987; Tonn et al, 1988; Lilien and Kijewski, 1987) and expert system approaches to forecasting (Whalen and Schott, 1983).

A number of these papers share an importance in presenting a novel concept but insufficient detail to provide material from which a thorough evaluation can be drawn. Bidgoli and Attaran (1988) describes the concept of integrating expert systems with Decision Support to assist strategic planning. Tonn et al (1988) describe an expert system which locates inconsistencies in budget submissions. Sullivan and Yates (1988) suggest the use of knowledge based systems to support reasoning based on investigating similar cases as part of business planning. Smith (1990) appears to apply an expert system approach to a financial modelling situation, although it is not clear how far beyond a conventional financial modelling approach the actual system goes. The system described by Lilien and Kijewski (1987) evaluates marketing budgets by reference to the spending levels thought necessary by experts to achieve specific marketing objectives. So far as details provided in the publications allow a judgement to be formed, none of these papers appear to suggest the use of conventional expert system programming approaches. Lilien and Kijewski (1987) is the most enigmatic in that the so-called expert system is made available in the form of a Lotus 1-2-3 spreadsheet. None of the systems described appear to be in practical use. A further difficulty with these papers is that the theoretical basis in management accountancy is unclear.

Whalen and Schott (1983) also present a "concept" paper lacking the detail from which an evaluation can be drawn. The concept is to use expert system technology to interact with a decision maker in the early stages of forecasting problem solving. The system provides an "intelligent index". The paper concentrates mostly on detailed and technical aspects related to expert systems and whilst useful in this regard, little insight is provided to benefit the present research aims.

Hwang et al (1987) overcome most of the deficiencies of the papers described in the previous two paragraphs and provide a genuine insight into the development of expert systems for management accountancy. Their application was very similar to that of Tonn et al (1988); budget submissions within the US Naval Sea Systems Command. Knowledge was elicited from a "budget analyst" by means of interviews which proceeded iteratively; follow up questions filled gaps in the coded knowledge base. Background information was gained through interviews with other significant individuals involved in the budgeting process. All interviews were transcribed and analysed to provide the necessary rule-based knowledge-base. The knowledge-base was coded in an expert system shell, GURU, which offered conventional expert system shell functions of rule entry and inferencing mechanisms, along with spreadsheet, form generation from the spreadsheet, database with SQL and a natural language interface, text editor, procedural language, business graphics and communications functions. Heuristics and procedures used by "budget analysts" were coded into the system's knowledge base. The prototype system allows "budget analysts" to maintain and update budgets and to create the necessary budget forms. The system asks questions of the "budget analyst" and stores data in spreadsheet form. Some rules apply validity checks upon the data at the input stage and suggest some remedies where problems emerge. The prototype was initially tested in 1987, the system modified and the final pilot test scheduled for July 1987. Unfortunately, the author of this thesis is unaware of any follow up publication providing the status of the system in 1992. The claimed benefits of the system include releasing the "budget analyst" from relatively mechanical budget preparation procedures so that "more productive tasks" (pg. 85) can be carried out, such as reviewing historical data, forecasting and providing "accurate and justified budget plans" (pg.85).

Hwang et al (1987) genuinely seem to make a contribution to our knowledge of expert systems in management accountancy but some doubts remain. Their paper is clear but relatively short. No sample rules are provided to illustrate the kinds of heuristic knowledge which is necessary to be coded into their expert system. The relationship of their system to theoretical budgeting systems, if any, is not explained. It is not entirely clear why an expert system was chosen as a solution to the problem they confronted. It might be that GURU provided the necessary and convenient computing functions. It does seem from a reading of the conventional wisdom of management accountancy, for instance as represented by Drury (1992), that much of budgeting is procedural; certain procedures need to be followed for the budget to be created. The role of expert systems in this process is not entirely clear. The one area where expert systems do seem to have a role to play is in the area of validating input data, where the use of rule of thumb comparisons with previous years might play a role. If this interpretation is valid, then the expert system component of Hwang et al's system would appear to be a part of a larger set of procedures which have been computerised and the expert system is playing a supportive role which is integrated with other modules within a larger computer system. This might imply that expertise is a part of the management accountant's knowledge base, along with other knowledge, including sets of procedures. If this is so, this adds to our knowledge of the contribution that expert systems have to play in management accountancy, but unfortunately the article only raises the questions and leaves doubts.

Wise and Kosy (1986,a) is fascinating in other respects to Hwang et al (1987) and confirms some implications suggested by a paper produced by Finlay and King (1989). Wise and Kosy began with a protocol analysis of a manufacturing plant manager as he reviewed several resource plans. The plans were displayed in spreadsheet form as a series of data in columns. The manager described the features of the plans which were expected and those which were odd, providing explanations of the oddities. Based on the protocol analysis, sixty three production rules were determined. For instance, a rule was established that if production increased then the number of employees should also increase. If that rule failed, then a check would be made to see if there was an explanation for the rule failure in terms of expenditure on plant and equipment. If no explanation could be found, increased production was placed on a list of questions to be taken up with the planner concerned.

Three problems were found in the specification of rules:

- Sixty three rules described the behaviour observed in the expert. However, the rules actually coded were only a small fraction of the rules which would be necessary to describe all cases that could arise.
- The rules appeared to represent more fundamental principles which were not directly stated within the knowledge base. For instance, the rule that stated that increased output should be associated with increased employees made assumptions about cost behaviour which existed at a more fundamental level of the distinction between variable and fixed cost. The danger is that in not representing the more fundamental principle, fundamental changes, such as changes in the managerial policies on the casualisation of labour or job-for-life would invalidate the rules as stated.
- The rules could not handle relationships which were simple for the human to handle. For instance, given three variables; A, B and C and a relationship such as A+B=C, expert system rules would need to be specified to cater for all eventualities, that is:

  A+B=C

  C-A=B

  C-B=A

  This increases the number of rules necessary to handle all situations which are likely to be encountered but also leads to many redundant questions and uncertain situations as the inference engine proceeds to manipulate a knowledge base.

The solution adopted by Wise and Kosy was to resort to a mathematical representation of the problem. They were able to show that the potentially large number of expert rules produced by their initial research could be most effectively managed by a general procedure and a model based on economic production functions. Finlay and King made a similar finding, showing that a knowledge base of over fifty rules which did not function effectively could be reduced to a significantly simpler, thirty rule knowledge base when mathematical modelling was applied. In other words, there may be simpler and more effective ways of reproducing human problem solving behaviours in computers than trying to represent that knowledge in production rule terms.

This seems to raise again the debate as to whether expert systems should be developed to provide descriptive validity, given the characteristics of human experts, or to make best use of the facilities offered by current technologies. The debate begins with the problem of defining expert systems. Is an expert system fundamentally a system which apes the human expert, or is it one which uses the facilities associated with expert systems to carry out tasks normally associated with human expertise? The extension provided by the discussion inspired by Wise and Kosy is that even where the latter, architectural definition of expert systems is adopted, it may be advantageous to think in terms of using the computer's overall facilities, rather than the potentially limiting facilities of expert systems alone, to automate expert tasks. Perhaps a numerical, rather than a symbolic, representation of expert knowledge makes more effective use of computer facilities. This debate therefore links to the problem of deciding upon a suitable knowledge representation for the task under consideration, where the present thesis initially defines knowledge representation in production rule terms whilst acknowledging that other forms of knowledge representation are available.

An area associated with budgeting and planning is the topic of production planning. For the sake of completeness, three papers will be briefly mentioned.

Rixhon (1986) is the "concept" paper in the collection. It establishes the possibility that expert systems might be used in production planning and scheduling, and, somewhat curiously, in the make or buy decision. The expert system development process is conceived as comprising problem definition, knowledge acquisition and system development phases. More usefully, it tries to justify an expert system approach to these applications in terms of the relative permanence of the expert system compared with the human expert (pg. 284: "not only the expert can be sick or on holiday ... he will surely retire"), the expert system is easy to duplicate and document whereas human expertise is difficult to transfer and reproduce, expert systems provides a "powerful training tool" and can achieve consistent decision making at a much smaller expense than through the human decision maker BUT expert systems lack the human decision maker's capacity to be creative.

Lee and Kang (1988) combine a mathematical modelling approach to planning, using linear programming, with qualitative factors provided in production rule form. For instance, a selection of rules concerning employees' morale includes the rules given in figure 2.2. The example rules should alert the reader to a concern for the theoretical underpinning of the implicit values contained within the knowledge base. Also, there are difficulties in understanding how the user is expected to make assessments about how "good" a particular working environment might be: "good" for whom, by which criteria and to what extent?

Figure 2.2 Sample of rules concerning employees' morale

```
Rule morale3
IF work_environment IS good
OR work_environment IS very_good
AND average_overtime = 9000
THEN status_of_overtime IS very_good

Rule morale32
IF status_of_overtime IS very_good
AND status_of_firing IS very_good
AND labour_condition IS good
OR labour_condition IS very_good
THEN morale IS very_good
```

The system operates as follows. The production planning situation is resolved in purely quantitative terms. If the quantitative solution is also acceptable in qualitative terms, then the solution is recommended. If the quantitative solution is not acceptable in qualitative terms, then there is a procedure by which the dilemma can be resolved.

The system is in prototype form and the authors concede that its knowledge base is incomplete. The paper provides useful detailed description of how the system works but little in the form of evaluation or insights into the relevance of the expert system approach to this particular problem.

Takkenberg (1983) does not claim to have developed an expert system solution to production planning but is valuable in the evaluation and insights that his work provides. Takkenberg shares with Lee and Kang a linear programming approach combined with an evaluation of the output of the optimising model in qualitative terms. Takkenberg attempted to model the human problem solving of a planner in order to programme the evaluation and explicitly references the work of Simon (1976) in his approach. Simon is a signicant contributor to theories of human information processing. Interviewing was used. Unfortunately, the details of the resulting knowledge base are not entirely clear. The important aspects of this paper are included in its evaluation of the work conducted, including:

- The emphasis is on supporting the resolution of ill-defined problems rather than on replacing the decision maker.
- The starting point for systems design is a descriptive approach but this must be meshed with a prescriptive approach at some stage.
- Expert systems are part of an overall information technology system comprising linear programming and database components.

This section concludes with a review of two papers concerned with expert systems in capital investment appraisal (or capital budgeting).

Myers (1988) describes a system which was begun in 1984 and released in December 1986. It has been sold to 20 companies despite a price tag of $66,000 and limitations on the computers that it can be operated on. The system takes as input figures of cash flow and produces output in the form of net present value and internal rate of return results. Input data can be varied using a relatively sophisticated man-machine interface to provide a kind of sensitivity analysis. Explanation facilities include an explanation of the net present value technique. One of the system's strongest features from a user's perspective is claimed to be a competitor analysis which introduces into the analysis the impacts of competitors' responses to acceptance of the investment proposal.

The Myers paper reveals a number of the themes already established in this chapter and some new ones. Expert system technology is integrated with other types of technology, including modelling. The analysis of competitor's responses is partly based on a model of competitive behaviour. Examples of production rules are:

IF NPV is negative and is still negative when S,G&A cost is set to zero, eliminate S,G&A cost from the sensitivity analysis

IF NPV is a downward sloping function of the discount rate at all positive discount rates, and if there is a positive IRR, then ignore any negative IRRs....

The second rule concerns the existence of multiple internal rates of return. Both rules are clearly highly technical and it is not made clear whether these are the heuristic rule of a human expert, the particular ideas of the authors or established theory in the area. The basis for knowledge elicitation for the application is therefore not clear. The system is claimed to help the user to build a bridge between managerial knowledge and discounted cash flow calculations to improve decision making. The expert system therefore adopts a supporting role in relation to the human decision maker. The author states that most of the numerical functions of the system could, with time, be replicated using a spreadsheet approach so that it is not entirely clear why an expert system approach was adopted.

The major addition to our existing themes concerns the problem of input. Myers signals this as the most time consuming aspect of system design. The problem is that users' cash flows could be presented in a wide variety of ways, from simple statements of total cash inflow and outflow to complex calculations incorporating data on cost of sales and expense, in either total cost or per unit terms. The system had to be designed to be flexible in its approach to data input and this phase is described as "moderately intelligent" (pg.27). The significance of this is that it may suggest that an important part of management accounting expertise is familiarisation with basic data or the acquisition of data as a preliminary stage. There is some support for the importance of familiarisation in expert behaviour in Libby (1981). If this can be shown to be an important part of management accountancy, this could be a significant finding since much of the existing literature is concerned with choosing correct techniques and with describing appropriate procedures once a technique has been selected. McAulay and Tomkins (1992) found that in the area of Transfer Pricing the existing literature is predominantly concerned with the selection of an appropriate transfer pricing mechanism (cost-based, market-based or negotiated price) and that information processing concerns, about how data might be input to a transfer pricing system and processed, have been neglected.

Dilts and Torowski (1989) describe a prototype capital investment system built using the VP Expert shell. This was chosen because VP Expert is "a very productive development environment... with a short learning curve" for the user (pg.196). The system considered the qualitative factors associated with a capital investment decision concerned with justifying new technology investment. This is an area which is known to be problematic in traditional, quantified accounting terms because it is often difficult to justify such technology on purely financial grounds and yet is thought to be absolutely essential to continued corporate development (for instance, Hayes and Abernathy, 1980 ; Hayes and Garvin, 1982; Iverson and Jorgensen, 1986 ; Kaplan, 1986; Kaplan and Atkinson, 1989). Dilts and Turowski use Porter as the basis for their expert system (Porter, 1980; Porter, 1985). The system is described and program code, together with part of a sample consultation with a user, is provided. No justification is given for using theory, rather than the heuristics of practitioners, as the basis for the system and this and other wider issues are not addressed. The paper is valuable in providing a carefully justified and described example of expert system development in expert system shell form to a prototype stage.

2.5.2 Transfer pricing systems

Freundlich (1990) provides evidence of the benefits of developing an expert system at Data General for prototyping purposes. His paper on a transfer pricing expert system addresses the issues of integrating expert systems into management information systems and also provides evidence on the benefits of expert systems. The paper provides a description of the system, including such company specific rules as "if the destination is NDG and the part is vendor purchased and the part is not I/C preconditioned, then the billing type is cost with adjustment five percent" (pg.58). This is interesting in throwing light on the practical problems confronting developers of transfer pricing systems, particularly in coming to terms with the detailed, company specific knowledge which must be handled by the system. It may be appropriate to investigate the time honoured problems of transfer pricing from the point of view of practical knowledge bases such as this. However, the major value of the paper is in casting light on the motivations behind the adoption of an expert system solution to management accounting problems. Freundlich states the benefits as follows:

1. Ease of modification. Some transfer pricing "policies" were amended after the expert system went into production and incorporating these changes "took a few days at the most" (pg. 61).
2. The prototyping advantage of gaining a clearer idea of the task to be performed.
3. The policy becomes explicit once it is coded in expert system terms and can be made available for examination by policy makers. An example is given of a slightly ambiguous element of "policy" which became apparent for the first time when tests were made of the expert system. This is similar to the finding made by King and Phythian (1992), where managers' understandings of the issues affecting a bidding decision were clarified through the development of an expert system.

A distinction is drawn between "difficult" problems which are interesting for artificial intelligence (and thus, possibly, expert systems) and "easy" problems of which this particular transfer pricing problem was an example. The curious situation seems to be that the "easy" ones reveal the benefits of expert systems and artificial intelligence but are possible to develop in more conventional ways; the transfer pricing system could be developed, and was originally developed, in Cobol. The advantages of using expert systems appear to be partly to do with prototyping (advantages 1 and 2 above) and partly to do with making knowledge explicit (advantage 3), an advantage also noted by Edwards and Connell (1989, pp 91-92) when they concluded their major work by stating that the process of expert system development might be more important than the expert system itself. Expert system development might be an important research methodology in its own right, even if it does not lead to the technological aim of developing useful systems.

By contrast with Freundlich's (1990) paper, which describes a particular company's coding of its transfer pricing knowledge base in expert system form, Kirsch et al (1991) describe a general purpose expert system which advises between the adoption of cost, market or negotiated prices and uses an expert system shell, VP Expert. The value of the paper is as a "concept" paper; in making explicit a portion of the problem space of transfer pricing, described in the form of a decision tree by the authors. For instance, one portion of the problem space, together with user responses and a final evaluation is provided in figure 2.3.

"Other responses" in figure 2.3 refers to other areas of the tree, representing wider aspects of the problem space to that illustrated by the sample consultation. The idea of representing the transfer pricing problem in problem space terms is an original and possibly valuable contribution. It is not a simple solution to the vexing difficulties posed by transfer pricing and grounding the problem space on theory is not entirely satisfactory because there are so many dimensions to consider. The dimensions are generally concerned with the purposes of transfer pricing, the choice of transfer pricing method and the information processing aspects of inputting and processing data necessary for the system to operate. Kirsch et al do not reflect on these difficulties and overcame the theoretical difficulties by using the knowledge base of a single expert. Their theoretical basis for the expert system appears to be incomplete and simplistic, therefore.

Figure 2.3 Part of Problem Space for Transfer Pricing

Domestic Profit Centre? ------------------------------ Other responses

|

yes

|

External Market? ------------------------------ Other responses

|

yes

|

Corporate Policy for Departmental Organisation? ------------------------------ Other responses

|

yes

|

Environmental situation ------------------------------ Other responses

|

Negotiate buy/sell economies

Advice: "Absent a perfectly competitive market for the intermediate product and aware of the limitations of cost-based pricing rules, a practical method for establishing a transfer price is through negotiations between managers of the two divisions. The negotiating process typically begins when ... " (pg.485)

2.5.3 Stock Control systems

Thorpe et al (1989) developed a system which inspects stock databases and detects errors. Ghiaseddin et al (1990) and Hosseini et al (1988) developed systems which act as an interface between managers and stock models to provide procurement advice (for instance, optimum order quantities using the conventional EOQ model). All three papers are concept papers in establishing that their chosen area is appropriate for further development. None of the papers provides a critical evaluation of the progress made and adds to the material so far presented.

2.5.4 Variance analysis systems

A further "concept" work is by Hollander (1987). Hollander developed an expert system for the investigation of variances problem. The system concerns materials and labour variances for standard costing. Hollander claims that the system provides benefits over existing approaches by incorporating qualitative reasons for investigating variances. Claimed achievements of the research are that the system devised is one of the first to apply its particular uncertainty reasoning method to variance analysis and the availability of a decision tool which is more thorough, systematic, consistent and timely than its human counterpart. Again, the work tends to be uncritical of expert system development.

By contrast, Shaoul and Smith (1988) is one of the only publications considered so far which takes a critical stance. Shaoul and Smith constructed an expert system which decided whether or not to investigate a particular variance. Their system was written in an expert system shell and interfaced with Lotus 1-2-3, which was used to calculate the variances. The grounds for their finding that expert systems can only be competent as opposed to "expert" are:

- Expert systems are based on rules. Only novices use rules to guide their decision making.
- Expertise is concerned with considering a situation in its entirety, and with matching the situation unconsciously or intuitively with similar past experience. Experience is concerned with continually adjusting action and is not the deliberate and rational selection made from a variety of alternatives codeable within an expert system.
- The expert manager would have taken corrective action long before the variances are calculated, let alone interpreted by the expert system as significant and requiring corrective action.

If nothing else, this evaluation shows the difficulty of expert system research. Shaoul and Smith use models of expertise and novice decision making in the first two points and models of management behaviour in the final point in order to provide their evaluation. The models they use could themselves be subjected to debate and research. The simplifications applied by Shaoul and Smith are clearly not sustainable without question but the point is that in order to evaluate expert systems, it seems to be necessary to form some kind of evaluation of the very things that expert systems are trying to do. Shaoul and Smith's conclusion is that it is only when the nature of expert decision making is understood that the capabilities of expert systems can be exploited. By the very nature of the present thesis, it must be said that the author has some sympathy with this view.

2.5.5 Performance measurement systems

Olave et al (1988) is yet another concept paper which establishes the feasibility of applying expert systems to management accountancy. This time the subject is the performance evaluation system used by the Pakistani Public Service. Demand for the system came because of difficulties experienced in a system which applied mathematical modelling to performance measurement. A bottle-neck had emerged with a system which applied weightings to a variety of factors to produce a single numerical measurement of performance. The bottle-neck arose from the need to redefine weightings when new factors were introduced to the performance measurement scheme. Given that the expert system was claimed to enjoy success, this experience is interesting when compared with Wise and Kosy (1986,a) and Finlay and King (1989) who found mathematical modelling to be a solution to particular problems of expert system design. A major benefit of creating the expert system for performance measurement was that the knowledge base used for performance measurement became explicit, providing a fresh insight into the knowledge used in the area. As seen before, the process of expert system development is presented as beneficial. Not surprisingly, Olave et al plan further work to improve their development.

2.5.6 Expert systems for Job Costing

A final and curious area for expert system development is in Job and Contract Costing. Doney (1987, 1988) provides a general treatment of expert systems and claims Cost Estimating as an appropriate area. The benefits, however, are the benefits which apply in general: making decision making more consistent, "productive" and timely, preserving expertise, improving understanding of the task under consideration and "providing for staff development" (1988, pg 69). A general statement of limitations is also provided. These are said to include: development costs, user acceptance, ability only to model a narrow knowledge base, incorrect or inconsistent knowledge bases leading to problems of expert system development and the difficulties associated with certain kinds of expert knowledge. The points raised by Doney are general, largely already covered within the expert system literature and do not provide any specific examples related either to Job Costing or Cost Estimation.

Herbsman and Wall (1987) do provide specific material on how expert systems might be applied to cost estimation. However, the paper is limited to speculation. It describes a system which might be built rather than experiences gained from putting ideas into practice. It is valuable as an example of how expert systems might be linked to databases as the foundation for a knowledge base upon which cost estimation could be built.

2.6 Evaluations of expert systems in management accountancy and finance

This section provides an antidote to the claims made by the majority of publications considered in section 2.5 by considering two works. Coats (1988) presents a bleak picture of expert system development in management accountancy and Stevenson (1989) challenges many of the conventional views about expert systems in the financial services sector. These two works provide alternative and critical perspectives to those so far considered and are representative of a class of literature which is increasingly emerging. They are not intended to be a complete representation of the critical literature.

Coats (1988) addresses the issue of why expert systems fail. The point is made that there are problems in making an evaluation of the existing literature because implementation problems and critical evaluations of products are almost never provided in the existing literature. The impression given by the existing literature is that attempts at expert system development are going to meet success. Yet, surprisingly, large numbers of the papers talk about additional work which is going to be done. Few claim commercial success. Many are merely concept papers, establishing that a particular area can be computerised in expert system form. Coats claims from private information that the reality is that there are 100 failed financial expert systems for every reported success. Coats concludes with the familiar theme that the process of expert system development might be more important than the systems themselves.

Amongst the potential problems of expert systems highlighted by Coats are some which do not appear to be mentioned by the literature previously described in this chapter and some which are familiar themes:

- Production Rules are "clumsy, resource hungry and unsuitable for complex applications" (pg 79).
- Adding rules to an existing knowledge base is difficult because it is necessary to understand how the new rule will interact with existing rules. This contradicts the ease of modification concept argued to be a benefit of expert systems.
- "Common sense" cannot be easily captured. Coats does not go into any detail as to what might constitute "common sense" in terms of the expert.
- Natural language interfaces between expert systems and human users are not materialising.

- Numerical calculations are not effectively handled by systems designed to process symbolic reasoning.
- The major bottle-neck in expert system development is in knowledge acquisition; "deciding what knowledge should be encoded into the knowledge base" (pg.81). Bouwman (for references, see chapter 5) is one of the few researchers in the area who has addressed the problem of extracting knowledge from financial experts. A number of the systems described earlier in the chapter relied on one or a few experts or one authority or an inadequate theoretical basis for the knowledge presented in the knowledge base.
- Financial expert systems are being "naively oversold and the resulting backlash has hindered progress" (pg 82).

Reasons for expert system failure include choosing the wrong problem to express in expert system form, cost and time, validation problems and lack of usefulness:

"*... a financial expert system that successfully runs the gauntlet of inadequate technology, cost, time, and validation, may have made so many concessions along the way that the results it produces are sufficiently trivial, general, or superficial as to have no real usefulness.*" (pg.83).

Stevenson (1989) categorises much of the existing literature as unsubstantiated optimism. Stevenson sought to establish the realities of expert system development in the Financial Services Sector through a combination of a mail survey, interviews, case studies and ethnographic observations. He found only a few experimental developments in reality and therefore much hype in the available literature. The expert system industry was characterised by the concept "cargo cult", in which the key players play different roles as cult chiefs, priests, pilots or followers. The cult of expert systems is not seen as an example of the rational application of a potential solution to finance problems but as an example of where myths, rituals, magic and cults best describe the application of expert systems , the argument (Cleverly, 1971) that:

"if we are to understand the people we deal with, to influence them and control them - to manage them - then the worst mistake we can make is to assume that the manager even in the twentieth century, is a rational being"

(Stevenson, 1989, pg. 298).

2.5 Assessment

The literature creates as many questions as it answers. It would appear that there are working systems in existence, but the reality of these systems may be more depressing than the hype which is customarily written up. We simply do not really know. The literature does not make it clear WHY the knowledge base of management accountancy is suitable for expert system development and WHY the inferencing skills of expert system are appropriate. If an aspect of expertise is concerned with general principles, common sense, experience and reasoning by analogy and that aspect of expertise is significant in management accountancy, then expert systems may not be valuable in areas where expertise, rather than limited, structured procedural knowledge, is important. The literature directly related to management accounting expert systems simply does not direct its attention to this and other fundamental issues. It seems to concentrate on saying WHAT systems expert systems have been applied to, together with limited material on HOW systems were developed, rather than WHY expert systems are appropriate in specific terms. It could just as easily be that expert systems represent an inappropriate technology and that better computer solutions are available. It is difficult to form a firm assessment from the material presented by the existing literature.

One point is reasonably clear. The literature is particularly disturbing in that it often fails to make explicit its theoretical basis in expert system theory, management accounting theory or research theory. No clear picture emerges as to why authors chose to represent the knowledge base of management accountancy in expert system form. It is not clear whether production systems, or other knowledge representation schemes associated with expert systems, provide an appropriate representation for the tasks considered. Similarly, systems which purport to represent topics such as transfer pricing, which is associated with a vast literature, could be expected to at least briefly mention the relationship of the literature to expert system development, even where the aim was to represent the expertise of a human decision maker. At best, an author may mention the research method that was adopted. For instance, the use of protocol analysis was explicitly stated as a research method adopted by Wise and Kosey (1986). However, even Wise and Kosey fail to discuss the limitations of their research approach.

The remainder of this thesis sets out to investigate the relevance of expert systems to management accountancy with this assessment in mind. Chapter 3 sets out a theory of human information processing which is used in the remainder of the thesis to provide a benchmark against which an assessment can be made of the relevance of representing management accounting knowledge in expert system form. Chapter 4 explains the research methodology that was adopted. Chapters 5, 6 and 7 make explicit the management accounting literature which underpins the investigations that were carried out.

CHAPTER 3

A THEORETICAL FRAMEWORK

3.1 Introduction

The previous chapter reviewed the existing literature and found it wanting. The literature fails to establish a convincing basis for assessing why expert systems might be appropriate, or inappropriate, to management accountancy. As stated at the end of the previous chapter, an important way in which the literature fails is that it does not make explicit a theory of expert systems against which an assessment might be made. In other words, the literature largely fails to ground its findings in theory.

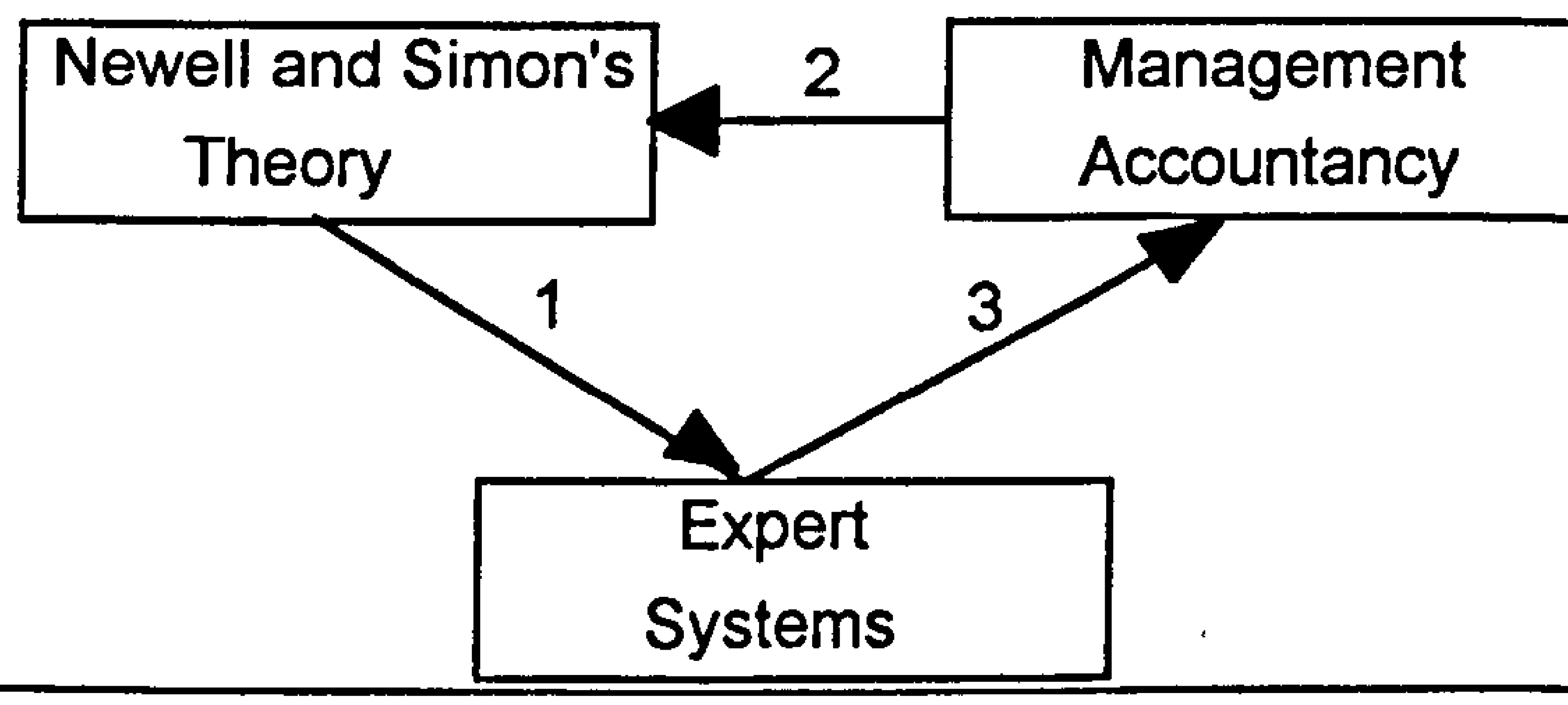
Since an expert system can be defined either as one which apes the human expert or one which takes advantage of the existing expert system technology, such a theory might possibly stem either from human information processing or from computer science. This chapter establishes a theoretical basis for the current research in human information processing terms. The theory of human information processing which is used, Newell and Simon (1972), is occasionally referred to in the wider expert system literature.

The purpose of adopting this theory as a basis for research is to ground the investigation in theory. It is not intended to imply that this particular theory is the only one which may be relevant to expert systems. It is intended to provide a focus for the research so that expert systems in management accountancy can be investigated in a reasonably rigorous fashion. This is important because all research implies a theoretical foundation or paradigm (Scapens, 1990; Smith, 1975), whether explicitly or implicitly stated, and theory is related to research method (Smith, 1975), which is the subject of the next chapter.

The basis for applying the theory is illustrated in figure 3.1. Figure 3.1 shows that the first stage, indicated by the line numbered one in the figure, is to determine whether Newell and Simon's theory is a relevant theory for expert systems. Newell and Simon show that human information processing can be represented in production system form. This directs attention to the production system as the prime knowledge representation for expert systems and therefore limits the scope of the definition of expert systems. An advantage of this is in reducing the ambiguity of the research process to manageable proportions. Allowing a range of knowledge representations to come within the definition of expert systems is consistent with the existing literature in general but may provide the danger, evident within the literature reviewed in the previous chapter, that virtually any computerised management accounting application might be called an expert system.

The second stage is to relate management accountancy to Newell and Simon's theory. Chapters 5 to 7 report the collection of data related to management accountancy, with Newell and Simon's theory providing a benchmark against which to assess findings. This provides a grounding for the research in data terms. The final chapter then provides an assessment of the research in terms of sub-propositions of the first proposition which was stated in chapter 1. The sub-propositions are developed within the present chapter and are based closely on Newell and Simon's theory. This allows the final chapter to close the triangle shown in figure 3.1 by addressing the issue of the relevance of expert systems to management accountancy.

Figure 3.1 Relationship of Newell and Simon (1972) to management accountancy and expert systems



To an extent, the single headed arrows in figure 3.1 should be double-headed because the relationships are inherently interactive. For instance, in relating Newell and Simon's theory to expert systems, not only is a restricted definition made available which is production systems based and which permits a grounded investigation of expert systems, but the availability of alternative forms of knowledge representation in expert system form itself comments on Newell and Simon. So, if research shows that expert systems which use alternative knowledge representations to the production system are shown to be valuable, then this either invalidates or extends Newell and Simon's theory.

This chapter sets out the background to Newell and Simon's theory, explains the concept of the problem space, which is arguably the most important aspect of the theory, sets out the theory itself and then provides an evaluation.

3.2 Simon's Human Problem Solving Theory; background

The research work of Herbert Simon and his associates during the 1940s, 1950s and 1960s has influenced management thinking in fundamental ways and continues to be influential. Perhaps the most evident influence of this work, bounded rationality (Simon, 1958), still appears in the accounting literature, the most recent citation known to the author at the time of writing being Northcott (1991).

The concept of bounded rationality establishes that there are limits to human problem solving capability which are given by the limits of computational capability of the human information processor. This suggests that the richness of reality does not always allow human problem solvers to follow the economic dictum "select that alternative, among those available, which will lead to the most complete achievement of your goals" (Newell and Simon, pg.889; Simon, 1947, pg.240). The notion of satisficing has therefore come to take the place of optimising in explaining some managerial behaviour. Managers may choose an action because it is presumed to provided satisfactory outcomes, even though such outcomes might be shown to be less than optimal.

The explanation of bounded rationality is presented by Simon as early as 1947 (Simon,1947). Following this, Simon's research drew him "more and more into the field of cognitive psychology and the related field of computer science (artificial intelligence)" (Simon, 1982, pg.xvii). It is within the scope of this latter preoccupation, and particularly a concern with the kinds of rationality which Simon categorises as "artificial" (Simon, 1981), that Newell and Simon's (1972) theory of human problem solving has emerged.

The theory of human problem solving is both a development from and a focusing of the more general concerns which a theory of organisational decision making might be concerned with. Simon (1986, pg.210) draws the distinction between a concern for rationality which can be equated with economics and that which can be equated with the other social sciences:

"In its treatment of rationality, neoclassical economics differs from the other social sciences in three main respects: [1]a) in its silence about the content of goals; [1]b) in its postulating global consistency of behaviour; and [1]c) in its postulating "one world" - that behaviour is objectively rational in relation to its total environment, including both present and future environments as the actor moves through time.

In contrast, the other social sciences, in their treatment of rationality, [2]a) seek to determine empirically the nature and origins of values and their changes with time and experience; [2]b) seek to determine the processes, individual and social, whereby selected aspects of reality are noticed and postulated as "given" (factual bases) for reasoning about action; [2]c) seek to determine the computational strategies that are used in reasoning, so that very limited information-processing capabilities can cope with complex realities; and [2]d) seek to describe and explain the ways in which non-rational processes (eg. motivations, emotions, and sensory stimuli) influence the focus of attention and the definition of the situation that set the factual givens for the rational processes."

While a complete theory of organisational decision making might wish to address all of these issues, the theory of human problem solving espoused by Newell and Simon (1972) very much concerns itself with a detailed consideration of items 2b) and 2c).

3.3 The Problem Space

Where bounded rationality is at the heart of Simon's earlier work, the concept of the problem space is at the heart of the theory of human information processing presented by Newell and Simon (1972). The problem space is defined, rather unhelpfully perhaps, as the "space in which [the problem solver's] problem solving activity takes place" (Newell and Simon, 1972, pg. 59). This space is intended to describe not only the problem solver's actual behaviours but the possible behaviours from which the set of actual behaviours is drawn. The behaviours considered should not only be overt behaviours but also those behaviours considered by the problem solver during the problem solving process.

This definition appears to place problem solving research within the context of psychological research and confronts the researcher with the difficult issues which this implies (a basic introduction to these difficulties is provided by, for instance, Dworetzky, 1991). As Newell and Simon (1972) point out, "This is not a space that can be pointed to and described as an objective fact for a human subject" (pg.59).

The problem space consists of:

1. A set of elements or symbol structures representing a *state of knowledge* about the task. For the game of chess, for instance, this represents the position of pieces at a particular time.

2. A *set of operators* which produce new states of knowledge from existing states of knowledge. For the game of chess, this comprises legal moves.

3. An *initial state of knowledge*, which is effectively a specific case of 1. For chess, it is the position of the pieces at the beginning of the game.

4. A *problem*, which is defined as the need to achieve a beneficial state of knowledge, as a final, desired state, by applying operators, as specified at 2. For the game of chess, this is a satisfactory conclusion to the game, presumably in the form of a won or drawn position.

5. The *total knowledge* available to the problem solver when in a given state of knowledge. For the game of chess, this might be knowledge that the opponent can take an important piece at their next move. We can suppose that some games of chess are lost because the losing player possessed a smaller set of available knowledge than the winning player, either in general or for a specific position.

Linking items 1 to 4 presupposes a means-ends rationality which assumes that the problem solver has a clear statement of objectives and a clear understanding of how goals might be achieved. This is a theme in Simon's thinking over the years, more recently expressed in the phrase (Simon, 1987, pg.209): "everyone agrees that people have reasons for what they do. They have motivation, and they use reason (well or badly) to respond to these motivations and reach their goals".

Item 5 is part of the bounded rationality argument; the problem solver may not arrive at an optimum solution because the total knowledge possessed by the problem solver may be less than is necessary for the task at hand. Newell and Simon's (1972) theory is explicit about how the total knowledge might be represented and the theory has been influential in psychology, postulating the existence of short term and long term memory. This particular theme will not be considered further in this thesis.

Newell and Simon (1972, pp.59-61) use an example to illustrate the concept of the problem space. This example is the fictitious game of number scrabble. Nine cards bearing the numbers 1-9 are placed face up on the table between two players. Players draw cards alternately from the set. The first player who draws three cards which total to 15 wins the game. If, for instance, the selection of cards proceeds 2,7,5,8,4,6,9, the first player now holds the set {2,5,4,9} and can achieve a total of 15 from the cards {2,4,9}. The sequence 5,2,8,6,7,3,1,9,4 produces a draw because neither of the sets {5,8,7,1,4},{2,6,3,9} provides a combination of three cards which total 15.

The *state of knowledge* at any one time can be represented by the set of cards held by each player, together with the set of cards remaining on the table.

The *operator* is taking an additional card from those remaining on the table.

The *initial state of knowledge* is nine cards placed between the two players, each of which are holding no cards.

The *problem* is for the player to hold a set of cards from which three cards total to 15.

The types of knowledge which might comprise total knowledge for the problem solver include:

a) set of cards in own hand;

b) set of cards in opponent's hand;

c) set of cards remaining between the players;

d) own competence: addition and subtraction

e) opponent's competence: addition and subtraction.

A game tree representation for number scrabble is shown in figure 3.2.

Figure 3.2 Problem Space for Number Scrabble adapted from Newell and Simon pg.61

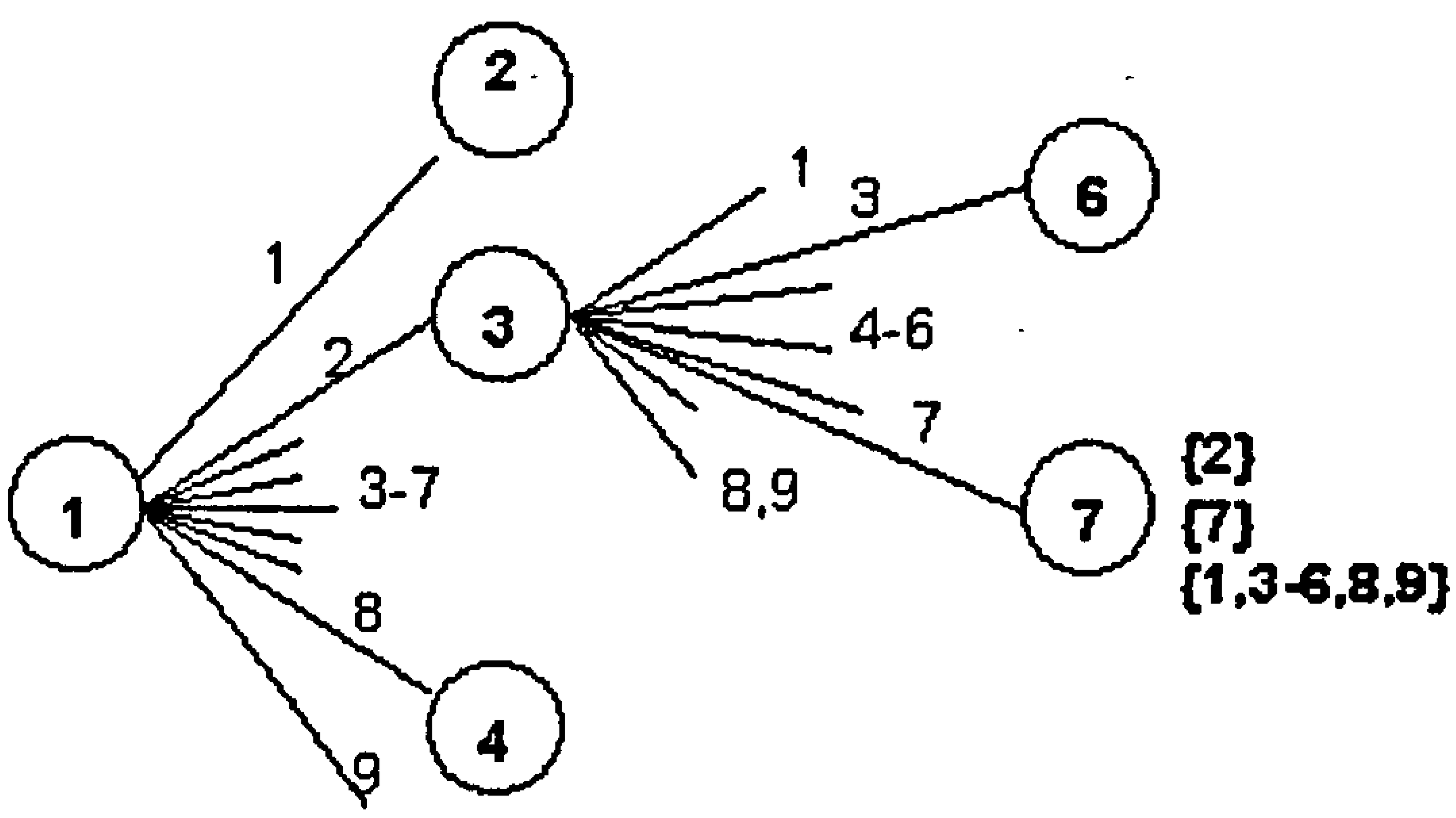


Figure 3.2 shows states of knowledge as nodes and operators as lines. A full representation of the state of knowledge for node 1 would show: player one {}, player two {}, cards on table {1,2,3,4,5,6,7,8,9}. The line connecting nodes 1 and 2 indicates the selection of the card bearing a number 1 by player 1. The state of knowledge for node 2 will therefore be: player one {1}, player two {}, cards on table

{2,3,4,5,6,7,8,9}. Node 7 shows a line of play and the state of knowledge resulting from player 1 choosing the number 2 and player 2 choosing the number 7. Similar states of knowledge could be provided for all seven nodes and all other nodes within the complete problem space.

3.4 The Research undertaken by Newell and Simon

Newell and Simon (1972) provide an account of extensive research conducted over seventeen years. The research programme centred on three problem solving tasks; cryptarithmetic, logic and chess. For each problem the task was analysed and the behaviour of human subjects was studied. Analysis of the task showed the value of a problem space representation. Having established the value of the problem space, the next stage was to consider the problem solving activity of a human problem solver using a method called protocol analysis, which is explained in chapter 4 of this thesis. Newell and Simon's research proceeded by taking an analysis for a single subject, following this up if appropriate with further analysis of additional subjects.

A focus for research was provided by asking four, initial and sequential questions (Newell and Simon, 1972, pp.163-164):

1. Is it possible to view the subject as working in some problem space?
2. If so, can the subject's problem space be specified to a suitable level of detail, consistent with that explored at the task level?

3. Does the subject use the same sort of problem solving strategies as defined by resolving the problem space for the task (most generally, search within the problem space)?
4. Can the subject's problem solving behaviour be simulated?

3.5 A theory of human problem solving

The shape of the theory of human information processing which derived from the research introduced in the previous section is given by four propositions (Newell and Simon, 1972, pp.788-789). Again, the propositions build as a logical sequence. The propositions are:

1. The characteristics of the human information processing system which are invariant both over task and problem solver are few in number.
2. These few characteristics determine that a task is represented in the information processing system as a problem space, and that problem solving takes place in a problem space (as a search).
3. The structure of the task determines the possible structure of the problem space.
4. The structure of the problem space determines the possible programs (either human or computer based) that can be used for problem solving.

Newell and Simon were able to show that their subjects worked within a problem space and further showed that the problem space could be defined as a production system which could be simulated by means of a computer program.

They did not claim that the computer simulation was an expert system nor do they use the term "expertise" in their work. However, the finding that a production system can be used to define human information processing is significant to the present research since production system representations can be computerised by means of expert systems. This provides a restricted, core working definition against which later findings can be assessed. In other words, Newell and Simon's value is in providing a structured approach to the present research by establishing a theoretical basis. This builds on the four Newell and Simon propositions and follows the following sequence:

1 can it be shown that management accountants work within a problem space?
2 if so, then can it be shown that Newell and Simon's theory is correct in suggesting that a production system can be used to computerise the problem space knowledge representation?
3 if the problem space can be computerised, then can it be shown that an expert system is a suitable computer representation?

This reasoning allows a sub-division of the first proposition stated in chapter 1. Adapting the propositions of Newell and Simon slightly, to match the particular needs of the present research, proposition 1 can be restated more fully as:

Proposition 1a: The problem space representation is a reasonable form of representation for management accounting tasks, implying the relevance of objectives, states of knowledge and operators.

Proposition 1b: The knowledge of the management accountant can be represented by a problem space for a particular management accounting task.

Proposition 1c: The structure of the task determines the structure of the problem space.

Proposition 1d: The structure of the problem space determines the possible programs (human or computer based) that can be used for problem solving and determines that an expert system is a suitable computer representation.

Proposition 1e: Problem solving takes place within the problem space as a search.

3.6 A simple experiment

Early in the life of the research reported here, the author used a simple problem solving experiment to explore Newell and Simon's human problem solving theory. This section briefly describes the experiment so as to provide a basis for an early assessment of the theory.

The problem, the "digits problem", concerns the possible existence of a number below 999 which decomposes over five multiplications to a single digit number, when the digits of the original number are multiplied together to give subsequent numbers whose digits are multiplied together. Figure 3.3 provides an example. In order to explore the task, the problem was solved in different ways and computer programmes were developed. Groups of students were then invited to solve the problem. The exercise has now been carried out with a wide range of students, including professional accounting students, undergraduates and MBA students.

Figure 3.3 Digits Problem Example

Example: The decomposition of the number 367:

367 ------ 3 x 6 x 7 = 126

1 x 2 x 6 = 12

1 x 2 = 2

The number 367 decomposes to a single digit through three multiplications

There appear to be four ways of finding a solution to the digits problem. The first, and most widely adopted by students, can be categorised as random search; think of a number and see if it meets the requirement. The second was only used by two accounting students, independently, and gave rise to the quickest solution and the only correct solution suggested by students in the time allowed (generally, fifteen minutes). It involves the heuristic "the answer must be a large, three digit number". The search therefore begins with 999 and proceeds quickly to one of the two correct solutions, 976 via 998,997,996, 988,987,986 and 977. The third approach, which has not been suggested by a student, is to test all numbers using an appropriate algorithm which can be computerised by means of a third generation language such as Basic, Pascal or C. The fourth and final approach, which has surprisingly been suggested by a small number of students in a range of different groups, is the problem space solution.

The problem space solution takes the initial knowledge state comprising single digits (the set {1,2,3,4,5,6,7,8,9}). Knowledge of factorisation is used as the operator to generate a tree of numbers beginning with each single digit. The problem is to find a branching of the tree with five multiplications as a characteristic. Figure 3.4 shows a part of the tree which includes one of the two possible solutions, allowing for the permutations of digits based on the two solutions.

Figure 3.4 Part of the Problem Space for the digits problem

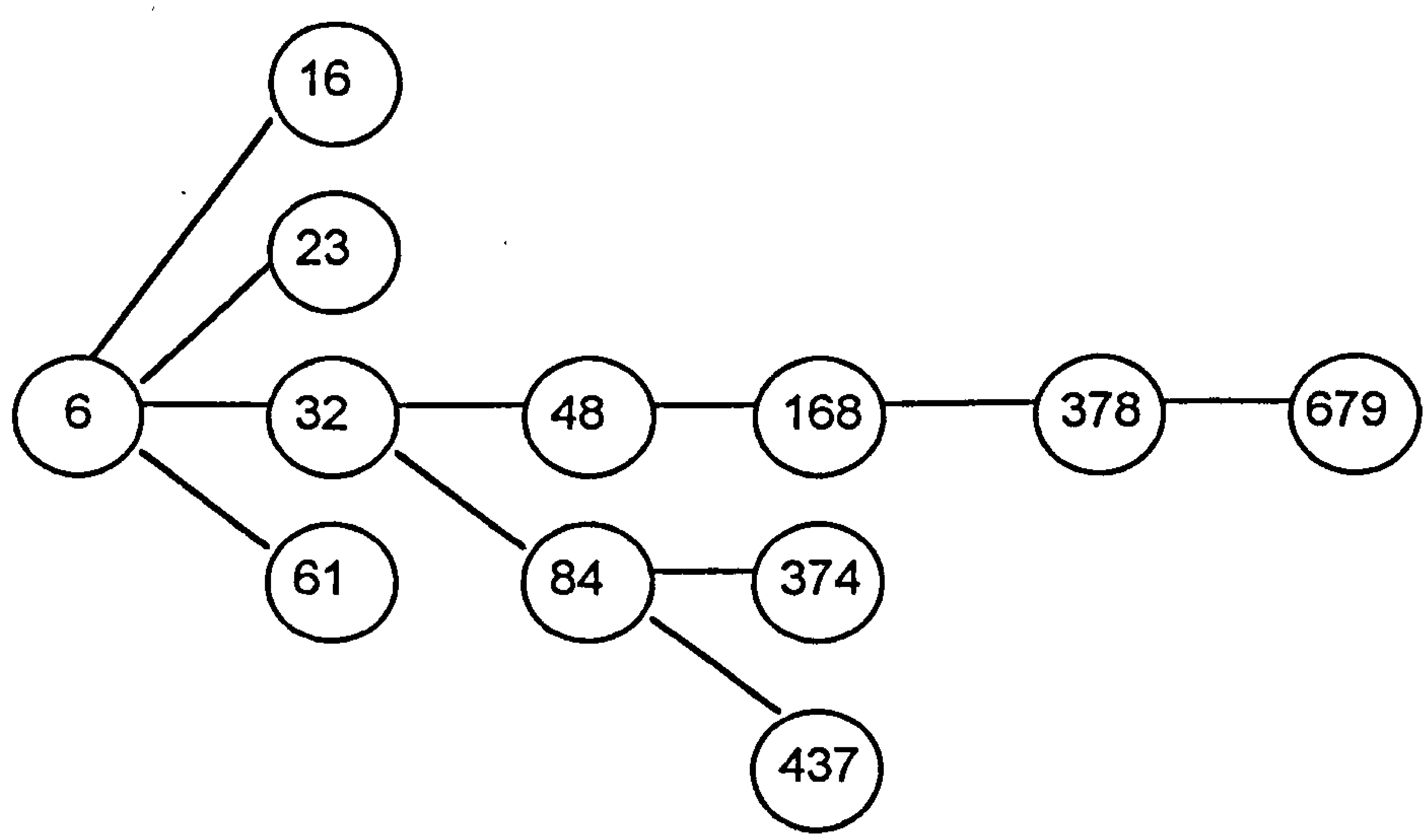


Figure 3.5 provides a Prolog program which can be used to produce a solution using the problem space approach outlined in the previous paragraph.

Figure 3.5 Prolog program for the digits problem

```
digit([1, 2, 3, 4, 5, 6, 7, 8, 9]).
given(Number) :-
        digit(List),
        member(Number, List).
determine(Snumber, Number) :-
        Number =< 81,
        factors(Number, D1, D2, D3),
        D1 = 1,
        Snumber is D2 * 10 + D3.
determine(Snumber, Number) :-
        factors(Number, D1, D2, D3),
        Snumber is D1 * 100 + D2 * 10 + D3.
go :-
        spy determine,
        given(N1),
        determine(N2, N1),
        determine(N3, N2),
        determine(N4, N3),
        determine(N5, N4),
        determine(N6, N5),
        cls,
        write(N6),
        nl,
        !.
factors(N, D1, D2, D3) :-
        digit(List),
        member(D1, List),
        member(D2, List),
        member(D3, List),
        N is D1 * D2 * D3.
member(Element, [Element|_]).
member(Element, [_|Tail]) :- member(Element, Tail).
```

The major production rule has been shaded. This states that if the factors of a number are D1, D2 and D3 then the subsequent number in the tree given in figure 3.4 is D1x100+D2x10+D3. The production rule therefore provides the operator which creates subsequent states of knowledge until a tree which is six nodes deep emerges. The problem is stated as the need to find a branching of the tree which is six nodes deep and this is coded as "go:- ...". The initial state of knowledge is that there are 9 digits, given by the code "digit(1,...). The exclusion of the digit 0 produces a simplification which is unfortunate because one of the two basic solutions to the problem degenerates through subsequent multiplications to 0. The program can therefore only find one of the two possible solutions. Once a solution is found the program stops and the solution is printed to the screen. The program uses non-standard code to do this (write and nl) due to convenience.

3.7 Evaluation

The digits problem shows that, even for simple tasks, a range of possible problem solving strategies is available, only one of which is the problem space. This may confound the first and second propositions of the Newell and Simon theory; that only a few gross characteristics are invariant over task and problem solver and that these characteristics determine that a task is represented as a problem space. Of course, it could be argued that the digits problem is a special case, and not a serious problem worthy of the human information processor. However, the line of argument does force us to consider the nature of the task in somewhat broader terms than that given by the problem space. It also shows that in computer terms a third generation or algorithmic representation may be sufficient to solve the problem. It finally makes it necessary to draw the distinction between the problem space for the task and the representation of the task considered by the problem solver.

The problem space represents every single alternative, good or bad, which can logically arise in carrying out the task. Computers can feasibly consider the complete task problem space in simple cases such as the digits problem or the number scrabble game described earlier. In fact, a minimax strategy (Newell and Simon, 1972, pg.60; Rich, 1983) would make a computer opponent competent at the game of number scrabble. Consistent with the theory of bounded rationality, it is believed that human problem solvers use heuristics (rules of thumb) to prune the tree to manageable proportions (Jacob et al, 1986) and so the human problem space can be considered to be somewhat smaller than the task problem space. So, for instance, human problem solvers may never choose to start with the selection of 1,2,3,8 or 9 for number scrabble, say. Similarly, for the game of chess, R.J.Fischer, a previous world champion, tended to play the opening move P-K4 and wrote: "I have never opened with the QP [the alternative major opening to P-K4] - on principle" (Fischer, 1972). This "tree pruning" operation can clearly be replicated within computer programming. The program which is presented in figure 3.5, for instance, was subsequently rewritten to improve its performance by stopping the expansion of branchings of the tree where such branchings were unlikely to produce a solution. For instance, if a number in excess of 500 appears at the fourth node, there is little chance that the solution would be found in subsequent branchings.

The human problem space may, however be more extensive than the task problem space. One case which is identified by Newell and Simon (1972,pg.60) is the case of illegal moves. Although the human problem solver may make mistakes and illegal moves, the problem space will never represent these kinds of states of knowledge whilst sensible and logical operators are employed. Factorisation errors made by human problem solvers would not be replicated by the program given in figure 3.5.

This distinction between the problem space which is represented in computer form and that which is representative of the human information processor is important to the present research and was to some extent reflected by the literature reviewed in the previous chapter. A beneficial management accounting expert system might alternatively be one which is determined by the requirements of the task or one which is the knowledge base one or more management accountant(s). It is important to be clear about the type of expert system which is to constructed. For the purpose of clarity within the present thesis the term "cognitive map" will be used to refer to the problem space for the human information processor and the term "problem space" will be reserved for the task problem space.

The term "cognitive map" has emerged since Newell and Simon's (1972) work. Cognitive mapping has increasingly been associated with action research and has been used to assist managers to model the complexities of their organisational problems for subsequent analysis and solution (Easterby-Smith et al, 1991). Just as a computer package has been developed to assist in the construction of problem spaces (Waterman and Newell, 1976), so a computer package, COPE, has been developed to assist in the construction of cognitive maps (Eden, 1988a, 1988b, 1989). Eden (1989, pg.37) states that COPE contains programme code for the creation of expert system specifications. More generally, there is growing appreciation of the value of cognitive mapping in the study of strategy (Huff, 1990). An example of a cognitive map is provided in figure 3.6.

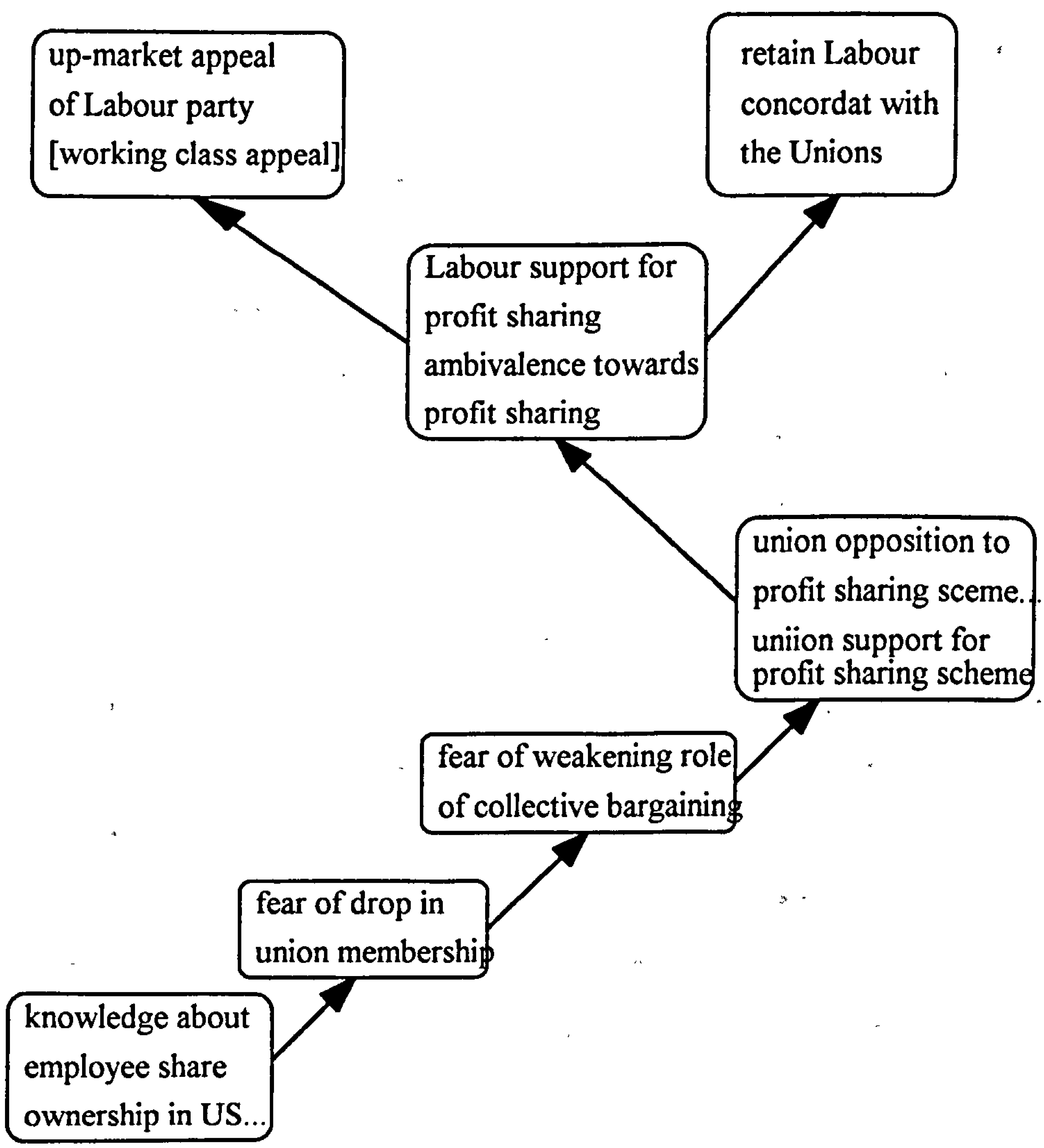
Figure 3.6 Small Cognitive Map (adapted, Eden, p.27-28)

Original Text

The latter day Labour party, aiming to appeal upmarket, is in a more ambivalent position. At a time when they are looking for a concordat with the unions, union opposition to profit sharing-because of the fear of weakening the role of collective bargaining-is hard to avoid. American experience with Employee Share Ownership Plans since the early 1980s has led to a drop in union membership in terms with these profit sharing schemes.

[Extract from the Guardian newspaper, 14 May 1986, slightly modified]

Map



It is difficult to see how figure 3.6 could be represented in problem space terms because it is unclear as to the problem being solved and the operator which is being used to generate the states of knowledge represented within the boxes connected by arrows. This might imply different forms of cognitive map, not all of which may be related to the problem space. Huff (1990) provides a valuable service in attempting an initial classification of cognitive mapping in the context of strategy and finds five mapping choices. In presenting one of the choices, "strategic argument mapping" (pp.33-35), Huff specifically refers to Newell and Simon and later in the same section provides a brief discussion of expert systems. Within Huff's typology, then, the present research starts out with a theory which is representative of one of a limited number of mapping approaches and therefore one of a limited number of available ways of representing human information processing.

The introduction of the term "cognitive map" has the advantage that it allows one of the sub-propositions stated earlier to be defined more specifically as follows:
Proposition 1b: The cognitive map of the management accountant can be represented by a problem space for a particular management accounting task.

The discussion about alternative forms of mapping raises the possibility that there may be more perspectives on human information processing than that postulated by Newell and Simon. Indeed, to some extent the quotation contrasting economic and social science approaches given earlier in the chapter implies that Newell and Simon might concede this point. The most recent argument known to the author which relates this possibility to management accountancy, is provided by Northcott (1991). Drawing on a range of ideas, including those contained in the works of

Simon, Northcott describes a range of interpretations of rationality. The context is capital budgeting. The major conclusion is (Northcott, 1991, pg.230):

"Researchers, for the most part, have demonstrated [an acceptance of the world view of economic rationality] and their research has therefore been 'blinkered'...Psychology and sociology literatures offer alternative perspectives on rationality that can enrich both the theoretical underpinnings and empirical research of both capital budgeting and many other aspects of accounting practice."

The basic argument is that in the past an economic model of rationality has constrained the world view of accounting researchers in an unhelpful way. One effect has been to dictate the use of survey methods in order to determine the techniques used by practitioners and to consider the gap between practised techniques and the "superior" or "correct" economic techniques. This may have led to accounting writers at times to seek to present the "one best way" of resolving management problems (Scapens, 1991, pg.4).

Different types of decision making might be taking place in organisations. For instance, Weber (1961) differentiated between rationality which concentrates on processes; the "value rationality" which entailed calculating the means necessary to achieve some non-calculable end, and that which concentrates on outcomes; the "purpose" rationality which is the means-ends analysis closest to economic rationality. Economic rationality implies the definition and prioritisation of goals, the ability to foresee alternatives in terms of courses of action and the effects of actions, and the ability to choose courses of action and that option which will be optimal in terms of the chosen goad (Lindblom, 1968). Both means and ends are calculated within purpose rationality, which Weber saw as the most rational type of action (Lee and Newby, 1983). Weber (1968) additionally found two non-rational decision making processes:

1. "traditional" action, based on custom or habit;
2. "affective" action, based on emotions.

Northcott (1991) argues for the use of case studies to throw more light on the decision making used in capital budgeting decisions and to broaden the world view traditionally associated with management accountancy.

A final aspect of Newell and Simon's theory is that where the major concept within their theory is the concept of the problem space, the major assumption is that the problem solver is a system (an information processing system) responding to the environment and specifically seeking to respond to the task. This is essentially a functionalist view. The strengths and weaknesses of the alternative sociological paradigms are too well rehearsed by Haralambas and Holborn (1990) to be fully repeated here. Walsh (1972), for instance, considers that whereas functionalists suggest that the social system is the active agent. Relating this to the present research, this implies that the task of management accounting determines subsequent human behaviour. In reality, it is argued, it is only human beings who act. The concept of social system is considered to be a reification of the social world (Walsh, 1972). It is a danger of research which seeks to simulate human problem solving in terms of the computer, such as Newell and Simon's, that the possibility of the self fulfilling prophesy will emerge that human information processing is computer like. The alternative view, that human beings are free to choose responses to problems which may be difficult or impossible to represent in computer form needs to be considered.

3.8 Summary

There is a theory of human problem solving which, if true for the management accountant, will allow the first proposition from chapter one to be investigated in a manner which is grounded in theory. This theory proposes human problem solving to be a means-end rational process and provides a way of exploring that rationality in terms of the problem space. The term problem space in general provides a way of representing task goals by means of changing states of knowledge according to a set of operators. A representation of the problem solving of management accountants can be provided by cognitive maps which may or may not coincide with the problem space for a particular task.

The theory allows the first research proposition to be more specifically defined as follows:

Proposition 1a: The problem space representation is a reasonable form of representation for management accounting tasks, implying the relevance of objectives, states of knowledge and operators.

Proposition 1b: The cognitive map of the management accountant can be represented by a problem space for a particular management accounting task.

Proposition 1c: The structure of the task determines the structure of the problem space.

Proposition 1d: The structure of the problem space determines the possible programs (human or computer based) that can be used for problem solving and determines that an expert system is a suitable computer representation.

Proposition 1e: Problem solving takes place within the problem space as a search.

If an investigation of management accountancy is able to reveal problem solving within a problem space, then it may be possible to state a theory of management accountancy with rationality at its heart. This finding may allow an assessment to be made of the value of expert systems to management accountancy.

Chapter 4

Research Strategy

4.1 Introduction

The previous chapter provided a theoretical foundation for research into expert systems in management accountancy and extended the propositions given in chapter 1 so as to provide a basis for systematic investigation. This chapter explains the research that was carried out to investigate the extended version of the propositions.

Given that expert systems have only been around for about 30 years (Liebowitz, 1990), or even less, the discipline of expert system research could be said to be in its infancy. Published works provide evidence of a range of research approaches. Many of these describe prototype systems, as chapter 2 showed, although some address wider issues such as the use of expert systems in practice and barriers to the adoption of expert systems. Few provide a theoretical basis for their findings and fewer still provide a systematic explanation of the research method adopted. This chapter begins by providing a general explanation of the research methods adopted and then moves to a discussion of the scientific basis for research into expert systems in management accountancy. It is anticipated that this approach might contribute to the development of expert system research as well as explaining the present research.

Detailied and specific descriptions of the research undertaken are provided in later chapters. Chapter 5 deals with a protocol analysis study, chapter 6 with case study research and chapter 7 with the development of an expert system for use in teaching and learning situations. Chapter 8 provides an analysis of the material presented in chapters 5 to 7 and uses triangulation to assess the extent to which findings are consistent across all three studies.

4.2 Research methods and triangulation

Three research methods were used to provide the material reported here. The first, protocol analysis, was the research method adopted by Newell and Simon (1972). The second method, the case study, was suggested by Northcott (1991) as an appropriate way of overcoming the limitations imposed by assuming economic rationality as a basis for management accounting research. Finally, the development of a working expert system provided findings which complemented the protocol analysis and case study methods. The section ends with a discussion of triangulation; a research concept which encourages the use of multiple research methods to overcome the deficiencies inherent in all research methods.

4.2.1 Protocol analysis

Verbal protocol analysis is a research method which is used to understand an individual's problem solving processes (Newell and Simon, 1972; Larcker and Lessig, 1983; Klersky and Mock, 1989). The approach is to present an expert with a problem and then to record the expert as he or she solves the problem while talking aloud. The verbal record is then analysed into individual protocols, or short statements representing individual thought episodes. A cognitive map is constructed based on an interpretation of the inter-relationships between the protocols.

Protocol analysis has already been used in finance and accounting research, if not in management accounting research. For instance, Bouwman (1984) used protocol analysis to derive a description of the difference in approach between experts and novices in evaluating the financial position of a company based on balance sheet, profit and loss, ratio and operational data. A "Problem Behaviour Graph" (presumably, a cognitive map) was developed to provide "structured pictures of decision making behaviour" (pg. 326). This was extended by Bouwman et al (1987) to provide a descriptive model of the financial screening process, including the types of knowledge and the rules that are required to make decisions on the basis of financial statements. Anderson (1988) used the literature on the decision making behaviour of financial analysts and stockbrokers to derive four hypotheses which were investigated within the Newell and Simon's (1972) problem space framework. The investigation of the hypotheses included statistical analysis of the knowledge applied and the time taken for professionals and non-professionals to reach a conclusion. In a thorough review of the use of protocol analysis research in auditing, Klersey and Mock (1989, pg.138) analysed the theoretical foundations of protocol studies into three: decision making behaviour (eg. Newell and Simon, 1972; Einhorn and Hogarth, 1981), knowledge acquisition for expert system development (Johnson et al, 1979; Johnson, 1984) and methodological issues. The ability to use protocol analysis at the difficult and critical knowledge acquisition stage of expert system development shows the relationship of protocol analysis to expert systems. Additionally , the use of protocol analysis to understand expert behaviour has led to working expert systems in finance and accountancy, including auditing (Johnson et al, 1989).

At the same time as protocol anlaysis has been proving its worth, its deficiencies have also become well established. Nisbett and Wilson (1977) claim that protocol analysis is unreliable and idiosyncratic, is not generalizable and does not promote our understanding of the performance of decision makers. Klersey and Mock (1989) counter this by arguing that these criticisms may be specific to the kind of protocol analysis considered by Nisbett and Wilson, an analysis of the retrospective reporting of decision making rather than the more customary accounting research approach which requires the expert to speak aloud whilst pursuing a particular decision. However, Klersey and Mock themeselves find three criticisms of general value:

- The effect of verbalisation argument: Boritz (1986, pg.344) concluded that the process of eliciting verbal responses may affect subjects' responses, as might a range of contextual factors (which might include the presence or non-presence of the researcher);
- The incompleteness argument: a portion of the information processed by the expert might not be verbalised (Klersey and Mock, 1989);
- The epiphenomenality argument: Ericsson and Simon (1984) indicate that the subject might report a parallel process which is independent of the thought process which is being used to carry out the problem solving exercise.

A final deficiency of protocol analysis is that it simply might not be able to account for the complexity of the real world. The problems and problem solving environments provided for experts during research programmes must be incomplete in terms of information and do not allow the kinds of discussions which customarily take place between experts (Bouwman et al, 1987). Protocol analysis may therefore lack external validity.

There are three responses to the deficiencies of protocol analysis. The first is that all research methods are deficient (Smith, 1975) and protocol analysis may be no more deficient than other approaches. The second is that protocol analysis has provided sufficiently interesting insights to warrant publication in prestigious journals, including Accounting, Organizations and Society. It has also led to the successful development of expert systems. For instance, Hansen and Messier (1986) built an expert system to assist computer audit specialists through a process of protocol analysis consistent with Newell and Simon (1972) supplemented by analysis suggested by Biggs and Mock (1983). The third response is to accept the criticisms and to apply other research methods to compare and contrast with protocol analysis findings before drawing conclusions. This third approach is the application of triangulation, which is explained below.

4.2.2 Case studies

Case study work implies field work study of practice in the context within which the practice takes place. In management accountancy, case study research is normally taken to be study in an organizational context and therefore draws from sociological perspectives (Scapens, 1990, pg.259), although some case study work implies theory taken from economics (Scapens, 1990, pg.259). It usually implies the study of a single unit such as a company (Scapens, 1990, pg.264). Its advantage is that it produces a rich picture (Scapens, 1990; Roslender, 1990). Its drawback is that it does not generate generalizeable theory (Scapens, 1990; Roslender, 1990).

The use of case studies is suggested by the major criticism of protocol analysis; that it does not allow the study of experts to proceed in context. Additionally, there has been a substantial call in recent years to study management accountancy in context and particularly through case study methods (Kaplan, 1986; Tomkins, 1986, Scapens, 1990; Northcott, 1991; McAulay and Tomkins, 1992). Perhaps the most visible contribution has been associated with Kaplan's call for field study based research to overcome the criticism that academic accountancy has lost its relevance to practitioners (Johnson and Kaplan, 1987; Kaplan, 1986), although the basis for the latter point has been challenged (Ezzamel et al, 1990; Drury, 1990). Case study research is also claimed to be beneficial because its intent is to view management accountancy, or the management process in general, holistically (Scapens, 1990; Gummesson, 1991). Of particular relevance to the present research is Northcott's (1991) call to study alternative notions of "rationality" via the case study method which is a "more appropriate research method" than traditional management accounting research.

It is arguable that case study research is "pre-scientific" (Scapens, 1990, pg.269), providing the observations which will later be transformed into theory. Alternatively, case study research may be interpreted as scientific in the sense that it is able to generate "explanatory" theory (Scapens, 1990, pg.270; Kjellen and Soderman, 1980), perhaps through replication (Scapens, 1990, pg.270) or through approaches such as grounded theory (Glaser and Strauss, 1967) which "'fits' and 'works' because it is derived from the concepts and categories used by social actors themselves to interpret and organize their worlds" (Jones, 1987, pg.25).

Two major issues emerge from Gummesson (1991) as relevant to the present work: access and taboos. The first represents the problem of gaining access to managerial decision making at a suitable level and with sufficient exposure to the knowledge processing activity. The danger is that the researcher will be exposed to the "rhetoric" of decision making rather than the decision making process itself. This might be particularly true when the researcher stands aside from the organization and relies upon accounts provided by the actors. The alternative is to participate in the decision making itself and risk biasing the problem solving process. In fact, this problem is well known to sociology and is not necessarily as problematic as it might first appear. There is a continuum between "unobtrusive observation", which might leave the observer completely outside the phenomena to be studied and thus unable to comment in an informed way, and "participant comprehension". Participant comprehension seems to be consistent with the action research approaches of Eden (1989), Checkland (1981, 1989) and Gummesson (1991), each of which need to confront the problem that they might create their own reality as a by-product of exploring the reality under investigation. However, Collins (1984, pg.68) argues that "each point on the continuum can be justified. The ideal-type model makes more apparent the nature of the compromises involved in most research decisions".

The problem of taboos (the issues which researchers do not write about in their case studies; issues such as personal relationships between members of the organisation) is a very real problem if the objective of holism is to be maintained. Indeed, it is difficult to see how holism can be more than an intention, unsustainable in the face of the reality of practical research. There simply are some facets of organisational reality which may not be spoken about or which cannot be presented in case study write-ups. This could be a drawback of case study work for which there may not be any genuine responses. However, it may equally be possible to ensure that in conducting a case study every effort is made to reduce barriers so that the influence of taboos in relation to the research objective are minimised.

As in the case of protocol analysis, there appear to be good reasons to adopt the research method of case study, whilst deficiencies are evident. Again, triangulation provides a way of benefiting from the advantages of the research method and minimising the effects of the drawbacks.

4.2.3 Expert system development

While much of the available expert system literature describes systems which have been developed, it is not at all clear that developing expert systems is a sound way of meeting research objectives. Steinbart and Gal (1989) are generally positive in their claims for the value of expert system development research and suggest that the research strategy of developing expert systems can overcome the problem that protocol analysis may lack external validity. Alternatively, Bailey et al (1987) distinguish between developmental activities and research activities. They suggest that the primary focus of expert system research is concern for theory and that "academics should concentrate on research while business pursues development" (pg 6). The points made in support of this view (pg.6) are:

- The practitioner is in a better position to pursue development than is the academic (Shpilberg and Graham, 1986).
- Scientific knowledge is not advanced by developing computer programmes (McCarthy, 1984, pg.7).

The first point became evident from the research presented here. Situations were encountered where it simply was not sensible for a researcher to commit time to systems development beyond a certain point. On many of these occasions, it was not sensible for the practitioner to commit resources either. The study of reasons for avoiding commitment to the development of expert system in fact constitute an important part of the findings presented in this thesis.

The second point raised by Bailey et al (1987), the issue of the advancement of science, is a more difficult issue which is left until section 4.4 below. This presents an initial response to the difficult arguments concerning the extent to which expert system research might constitute scientific research.

4.2.4 Triangulation

Triangulation encourages the use of multiple research methods. It is a term taken from navigation and surveying which describes the location of an object by means of three reference points (Smith, 1975; Easterby-Smith et al, 1991). By investigating a research problem from more than one point of view, it prevents a piece of research from becoming method bound (Abrahamson, 1983) and allows the counterbalancing of strengths and weaknesses of alternative research methods, none of which are ideal in practice (Easterby-Smith et al, 1991).

Triangulation can take a number of valuable forms (Smith, 1975). For the purpose of the present research, triangulation within and between methods was applied and the principle of investigator triangulation (Denzin, 1970; Smith, 1975) was additionally used. The use of both verbal protocol analysis and case study is triangulation between methods. Triangulation within methods was applied in the case of verbal protocol analysis; the results of a number of subjects were analysed so as to draw out common threads or themes which were given greater weight in subsequent synthesis than were the divergencies between subjects. Triangulation was also used within case study work. A number of cases was used to investigate proposition 3, which concerned the development of decision aids for practical use. Proposition 4 concerned the use of expert system in education and provides additional case study material to compare and contrast with experiences from practice. Finally, multiple observers were used on a number of occasions throughout the research. Some of the findings have also been subjected to peer group review through the journal refereeing process so that a number of authorities have provided opinions on the data presented here.

4.3 Expert systems in Management Accounting Research

A useful overview of research in general and management accountancy in particular is given by Tomkins and Groves (1983). Figure 4.1 provides an overview. Tomkins and Groves (1983) begin with the six views of reality suggested by Morgan and Smircich (1980). These are characterised in figure 4.1 by their ontological assumptions and given a type numbered from one to six. Abdel-khalik and Ajinka (1983) build on this by providing a diagram to summarise the six views and Covaleski and Dirsmith (1990) further build on the diagram to include a consideration of the role of information. Figure 4.1 is a combination of these works.

Figure 4.1 Overview of research

Type	Ontological Assumptions	Epistemology	Information
1	Concrete Structure	Scientific	Fully represents reality
2	Concrete Process	Scientific	Problematically obtained to represent quickly changing and causal relationships
3	Contextual Field of Information	Cybernetic	Viewed as altering relationships in an ever changing world where relations between phenomena are relative rather than fixed and real
4	Realm of symbolic discourse	Symbolic interactionism	Does not represent reality; it is reality. Reality rests in a system of meaningful action that renders itself rule-like. The world may be viewed as a pattern of symbolic relationships and meanings sustained through a process of human action and interaction.
5	Social Construction	Ethnomethodology	Is short-lived, individual rather than relationally orientated and a latent product of reality.
6	Projection of human imagination	Phenomenology	Is non-existent.

Figure 4.1 provides a contrast between scientific enquiry, typified by type 1 research at one extreme, and naturalistic enquiry, typified at the other extreme by type 6 research. Scientific, or positivist enquiry, is often associated with quantitative research and is typified by type 1 research at the extreme; the search for definitive "truth". The term "naturalistic" is used in the way adopted by Blumer (1969), Denzin (1978) and Abdel-khalik and Ajika (1979) to denote research carried out in its setting using qualitative methods. Type 6 research, at the extreme, suggests that "truth" is in the eye of the beholder and cannot be objectively determined.

The basic argument provided by Tomkins and Groves (1983) is that the majority of existing, rigorous accounting research is of the type 1 kind, involving the pursuit of scientific investigation in accordance with the positivist tradition. The model of science which is adopted stresses the prior determination of theory, appropriately expressed in terms of hypotheses for which measurable tests can be made during data collection. This is followed by statistical or mathematical analysis to validate or refute the hypotheses. Tomkins and Groves argue for a "fair sprinkling of accounting research effort all along [the scientific-naturalistic continuum]" (pg.373). The basis for the argument is that emphasising the positivist approach has provided accounting research with a very narrow foundation.

It would seem most natural for the present expert systems in management accounting research to fall in the type 3 (or cybernetic) view of the world. The essential points about type 3 assumptions of reality, for the purpose of the present research are that (Tomkins and Groves, 1983, pg.368):

1. Human beings are assumed to be continually processing information, learning and adapting.
2. The distinction between the subject and the environment is dropped.
3. The emphasis is on the holistic.

Item 1 is consistent with the thinking which underpins Newell and Simon's (1972) theory of human information processing. The theory of human problem solving assumes that the task determines the processing which takes place within the human problem solver. The task problem space should be entirely consistent with the cognitive map for all problem solvers and so, in a sense, any distinction between individual problem solvers and task is insignificant. In this way, the propositions developed in the previous chapter ensure that the research is consistent with item 2 above. Item 3 suggests that the present research should seek to be holistic in its intent. As mentioned earlier in this chapter, holism is consistent with case study aims.

4.4 Is there a Scientific Basis for Expert System Research?

Having determined that the present research is consistent with Tomkins and Groves (1983) type 3 research, this section assesses the extent to which expert system research might meet the requirements of scientific research. In other words, the question "can type 3 research be considered to be in any sense scientific" is explored. This question is developed firstly by suggesting that expert system research might be considered to be pre-scientific because its concern is for the symbolic rather than the quantified. An alternative perspective is then presented which suggests that expert system research of the kind presented here might be considered to be consistent with the soft system methodology which has itself been argued to be scientific (Checkland, 1981).

Section 4.3 stated that research of the type 1 kind involves the pursuit of scientific investigation in accordance with the positivist tradition. This stresses the prior determination of theory, expressed in hypothesis form, for which measurable tests can be made during data collection, followed by statistical or mathematical analysis to validate or refute the hypotheses. By contrast, expert systems are most commonly associated not with that which is measurable but with that which is symbolic. McMahon (1990), for instance, defines an expert system as "a computer-based system which uses symbolic reasoning to emulate the expertise and behaviour of a human expert in a particular area of knowledge or domain".

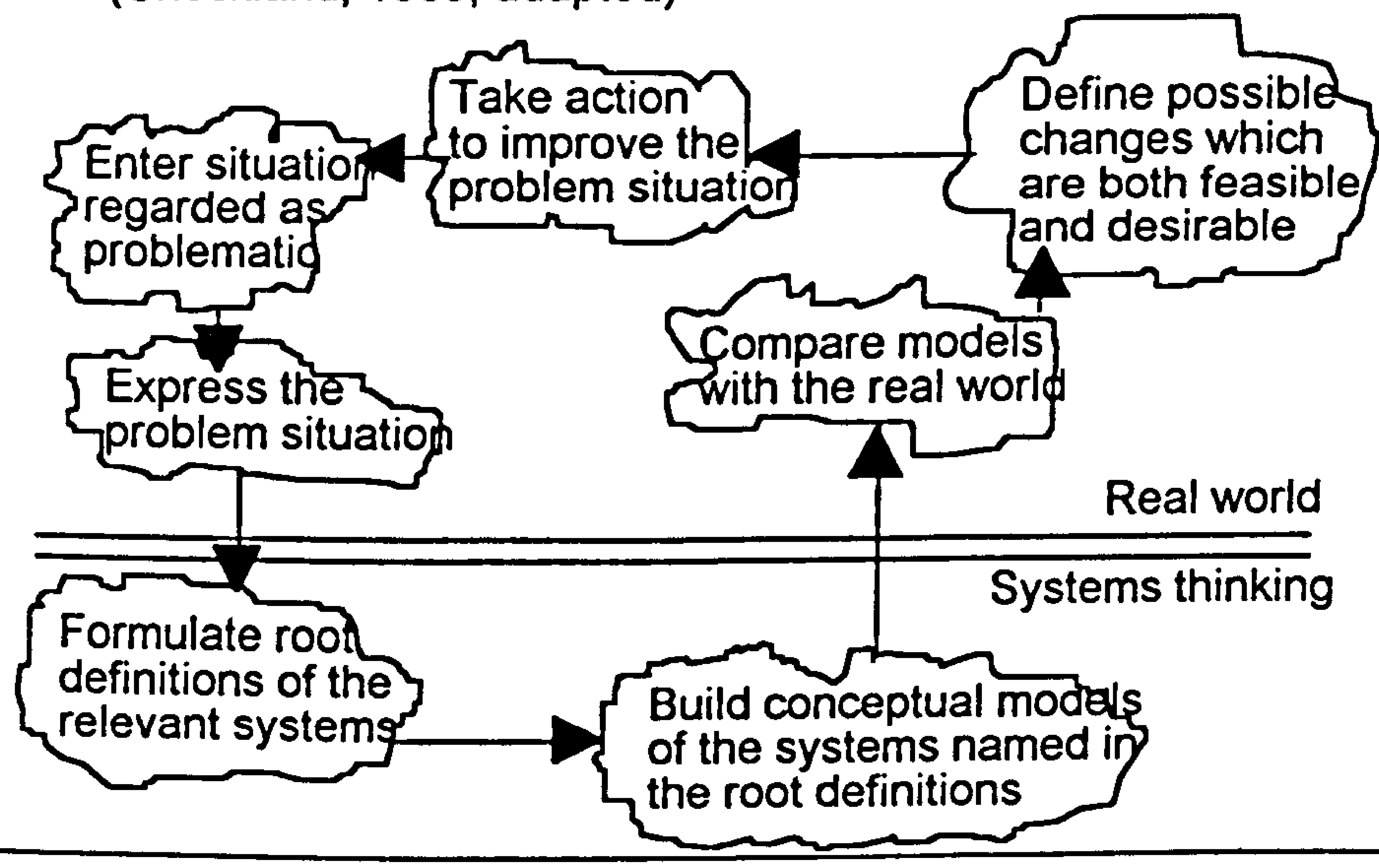
This concern for symbolic manipulation may be similar to a concern for concepts which Smith (1975) considers to be pre-scientific. Similarly, in an important contribution to management accounting research thinking, Kaplan (1986) includes an observation phase at the beginning of a description of a scientific model which clearly becomes positivist once it moves beyond the initital observation stage. The observation or description phase appears to be rather more naturalistic (in the sense used by Tomkins and Groves, 1983) in nature than would normally be accepted by positivists, being concerned with the concepts and symbols which are important to actors in the field.

However, Checkland's (1981, 1989) soft systems methodology would seem capable of including both that which is quantified and that which is symbolic. It has been argued to be scientific (Checkland, 1981). Soft systems methodology is arguably important to expert system research because it is a problem solving approach designed as a response to the failure of a structured approach to cope with the messy, ill-defined, changing problems facing managers (Checkland, 1989, pg.72). Abdolmohammadi (1987) draws the distinction between programmed tasks (Simon, 1960) or structured tasks (Keen and Scott-Morton, 1978) and non-programmable or unstructured tasks and confirm that it is the unstructured or semi-structured task which require expertise (Messier and Hansen, 1984).

Soft systems methodology grew from "hard systems thinking" (Checkland, 1981), which provides _the_ single approach traditionally associated with the alternative terms "operational research", "systems analysis" and "systems engineering" (Checkland, 1981, 1983, 1989). Thus, hard systems thinking is consistent with type 1 or type 2 research under Tomkins and Groves (1983) model. Hard systems thinking is teleological, in that it assumes that a system possesses an objective and that designing a solution should be consistent with and driven by that objective. In this respect, it could be argued to be consistent with Newell and Simon (1972). On the other hand, soft systems methodology recognises that, in practice, the statement of objectives is itself both problematic and a part of the problem which the management system is seeking to solve. In a formative experience for the evolution of Soft systems methodology, it was found that the objective of survival and finding a course of action from the alternatives available for a textile company facing difficulties were less than obvious; "these seemed very naive and simplistic questions in the face of the failings, fears and farce of the actual situation" (Checkland, 1989, pg.75).

In essence, the soft systems methodology demands that the designed solution is generated through systems thinking but is then taken back and tested in the real world. Figure 4.2 shows this in simplified form and is adapted from Checkland (1989). Soft systems methodology provides a way of thinking about the problem solving which generates the solution and presumes a philosophy of the world which is essentially qualitative in nature. The world is "messy", human beings bring perceptions to bear in understanding the mess, the human being makes evaluations based on perceptions of the mess and decides to act.

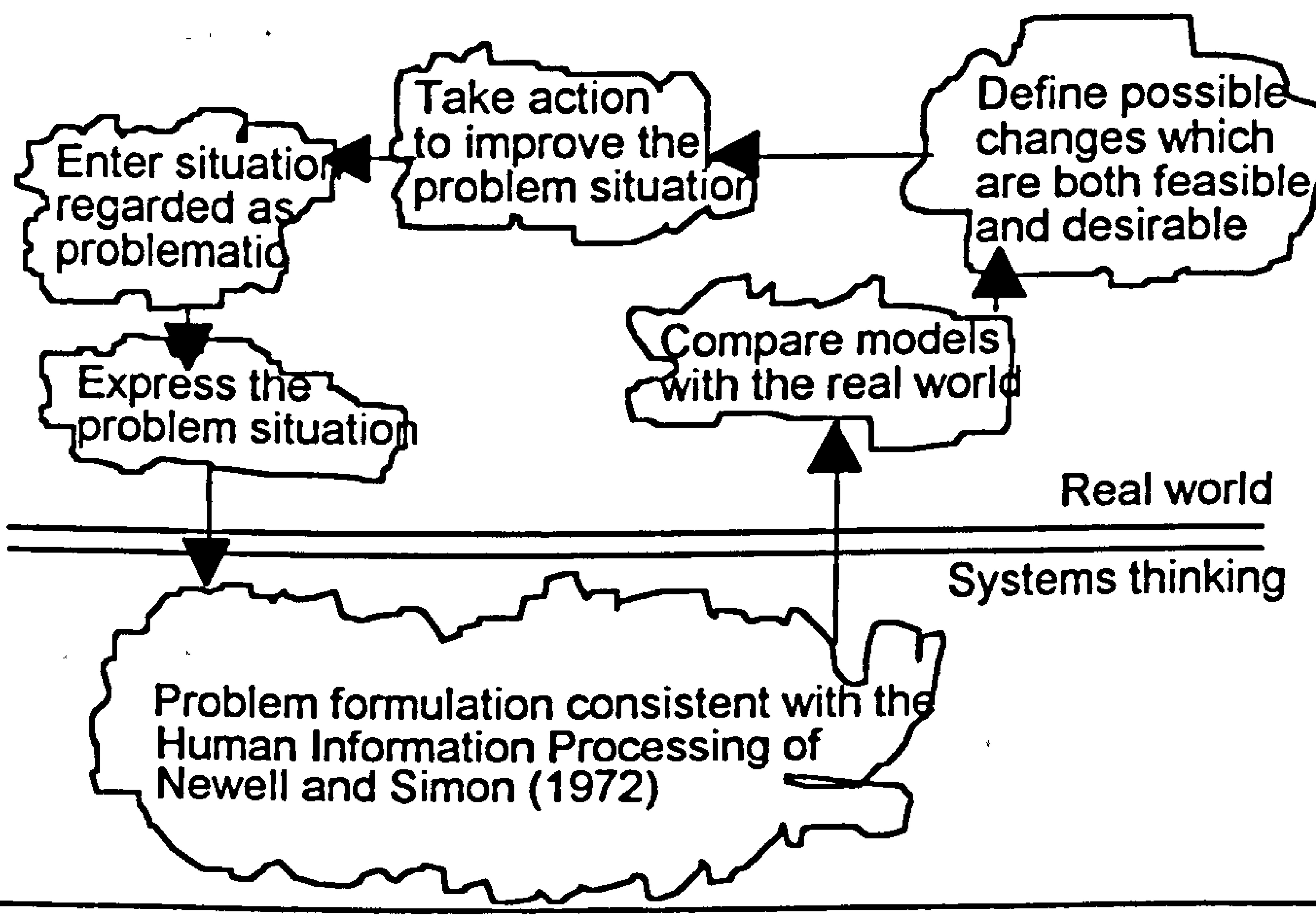
Figure 4.2 Soft Systems Methodology
(Checkland, 1989, adapted)



The soft systems methodology has been evaluated in terms of science in substantial detail by Checkland (1981). Soft systems methodology has arguably been shown to overcome some deficiencies of the scientific model in dealing with sociological situations whilst being a part of science. It might thus be possible to place expert system research within the scientific tradition by means of Checkland's evaluation, if expert system research can be shown to be consistent with the soft systems methodology.

Figure 4.3 illustrates how the soft systems methodology might be related to expert system research using Newell and Simon (1972) as a theoretical base. The real world, perceived in symbolic terms as a mess requiring to be structured before an expert system can result, is modelled in accordance with the theory of human information processing of Newell and Simon. Protocol analysis and case study research methods might, for instance, aim to provide data taken from the rich and messy real world of the expert. The modelling process applies systems thinking because Newell and Simon's theory is consistent with systems thinking. The objective is then to form a representation which can be shown to be consistent with the real world and which can be used to develop expert systems which can be used to solve problems in the real world. The development of a practical expert system is consistent with this aim.

Figure 4.3 Expert System Research Methodology



Soft systems methodology carries out the modelling exercise within a type 3 research context, as an application of systems thinking, but is able to take on board a type 4 view of the real world. In fact, because of the distinction between the real world and systems thinking, as shown in figures 4.2 and 4.3, soft systems methodology is potentially able to apply multiple views of reality. So, the development of an expert system can arguably lead the present research towards that which is scientific, thus moving it from an inherently type 3 form of research towards type 2 or type 1 research. It can also move it towards type 4 or type 5 research if necessary. Expert system research might begin with the rich and messy real world and seeks structure in that world in accordance with the soft systems methodology.

This is consistent with the concern about our knowledge of the functioning of accounting systems in terms of the social realities facing managers (Hopwood, 1978, 1979, 1983; Burchell et al, 1980; Scapens, 1984; Otley, 1984) because of the existence of complex social factors (Berry et al, 1985; Colville, 1981; Roberts and Scapens, 1985) which may need to be understood in terms of the significance of accounting from a symbolic viewpoint. The use of case studies particularly provides a way of meeting this concern. Expert systems may hold the opportunity of making the symbols amenable to analysis in a structured fashion which, if not absolutely positivist in approach, hold a reasonable semblance to science in providing a basis for objectivity.

In so far as Tomkins and Groves' (1983) argument is correct that accounting research should be sprinkled along the continuum, expert system research might have a valid role to play in management accounting research. In so far as the argument that positivist research has provided a restricting view of reality is true (see Chua, 1986; Demski, 1988; Whitley, 1988; Williams, 1989; Cooper and Hopper, 1990), then the fresh view provided by expert system research may well be welcomed.

4.4 Summary

As briefly mentioned in the previous chapter, Newell and Simon (1972) used a single research method, verbal protocol analysis. This provides the starting point for the present research report and the first research method. The second research method used a case study approach and providing the context of real managerial problem solving within which to investigate expertise in practice. A third project concerned the building of an expert system which was used in teaching. The three exercises together provide the potential to draw conclusions about the four propositions set out in the introduction. The use of multiple research methods finds a theoretical justification in the principle of triangulation.

It can be argued that the expert system research is either pre-scientific or else is alternatively consistent with scientific investigation. The present research provides an example of a way in which it might be considered to be scientific. It begins with the theoretical underpinning provided by Newell and Simon (1972) and proceeds by testing the theory by a series of observations. It can be linked to the soft systems methodology as illustrated by figure 4.3. The soft system methodology has been argued to be scientific. However, expert system research might not be thought to be scientific in the full sense of the positivist paradigm since the intent of expert system may be to manipulate symbols and to account for qualitative interactions rather than quantitative relationships. Expert system research may thus combine features of both scientific or quantitative research and naturalistic or qualitative research. That expert system research be valuable in extending our knowledge of management accountancy is suggested by the argument that positivism has failed to throw significant light on accounting realities by providing too narrow a world view.

Chapter 5

Protocol Analysis Study of Expert Behaviour

5.1 Introduction

One approach to exploring the possible role of expert systems in management accountancy is to capture the expertise of management accountants. One of the ways of capturing expertise in a way which is relevant to managerial problem domains is to apply protocol analysis (Kim and Courtney, 1988). Protocol analysis is particularly pertinent because it was used by Newell and Simon (1972) in their research and is therefore implicated in the theory which underpins the present research. It was also used by Bouwman et al (1987) to investigate the expertise of Financial Analysts and provided a model which has been claimed to be relevant to the development of financial expert systems (Bouwman et al, 1987, pg.26).

Bouwman's work over more than a ten year period has in fact refined a number of aspects of Newell and Simon's work and made it relevant to the investigation of financial expertise. This chapter therefore begins with a review of his contribution. The chapter then describes the present research exercise and draws up two alternative models of expert behaviour. The implications for future research are finally outlined.

5.2 Bouwman

5.2.1 Bouwman et al's (1987) research method

Bouwman has applied and developed Newell and Simon's (1972) work to financial analysis over at least a ten year period. His contribution is represented by Bouwman (1978), Bouwman (1983), Bouwman (1984), Bouwman (1985) and Bouwman et al (1987). Acceptance of this research by Accounting, Organisations and Society (Bouwman, 1984; Bouwman et al 1987), possibly the leading accounting journal in the United Kingdom, is mark of the esteem with which the research is held. Newell and Simon's work is extended by introducing certain context specific coding schemes to the research process and by considering the interaction between information and users so as to contribute to the literature in that area (as given by Biggs and Wild, 1985; Shields, 1980; Casey, 1980; Ricchiute, 1984; Stock and Watson, 1984; Govindarajan, 1980 and particularly Biggs, 1984).

The contribution to expert system development is provided by a model of expert behaviour which makes explicit the types of knowledge and the decision making processes adopted by practising financial experts. Bouwman et al (1987) claim that their process description of financial analysis expertise is valuable for expert system development. It is also claimed that human decision makers are "the richest source of information for the construction of expert systems" (pg.26). Some expert system literature is also referenced to support the view that expert system are developed for areas where mathematical models are not available (Hayes-Roth et al, 1983; Duda et al, 1979; Miller et al, 1982), although the relevance of this point to financial analysis is not explained.

Bouwman's research method evolved over a period of time. Bouwman et al (1987) represents the most recent and most developed description known to the author. The method involved asking subjects to speak aloud whilst a problem was being solved. Subjects were asked to consider a package of information concerning an undisguised but unfamiliar company listed on the New York Stock Exchange. Their problem was to "evaluate this security in the same manner and to the same point as you would in your normal practice" (Bouwman et al, pg. 7). Bouwman et al described these sessions as "interviews". Questions specific to the task were asked once the problem solving phase was completed and it was found that the package of information "seemed to be ample", with only one significant item of information being found to be missing. Data analysis of transcripts involved the isolation of individual protocols (consecutive phrases uttered by the subject which comprise a single idea), the coding of those protocols and the analysis of the coded protocols to provide episode summaries (consecutive protocols which pursue a single objective). A model of the decision process of individual analysts was produced on the basis of this analysis and a table of the information used during the problem solving process was developed. The overall impression is that few problems were encountered throughout the research.

5.2.2 Critical review of Bouwman et al's research method

It can be safely assumed that one or more interviewers sat with the subjects as they provided taped transcripts. Unfortunately, the detail of this, together with comments on the possible effects arising from the presence of the interviewer(s) and the tape machine, are not provided by Bouwman et al (1987).

The critical stages in analysis would appear to be the identification and coding of protocols. The subsequent analysis relies on the results of this. Bouwman et al (1987) imply that identification of protocols presented no difficulties whilst coding could be carried out objectively. The coding was carried out according to "strictly formalised rules" to avoid the introduction of researcher's interpretations which may vary with "experience and beliefs" (pg. 8). The presumption would therefore appear to be that the coding was objective. There is little in the protocol literature outside Bouwman to support these views. Libby (1981, pp 94-95) is particularly forceful:

"Questions concerning the objectivity of data-coding methods, in particular those related to verbal protocols, are so severe as to question the scientific status of the research. In fact, practitioners of the technique admit that this portion of protocol analysis is more of an art than a science. The choice of coding categories, the choice of the "short phrases" which serve as the unit of analysis, and the assignment of each phrase to a category are highly subjective and are often not even described in the research writeup.... Furthermore, alternative coding schemes which could as easily "fit" the data are usually readily available."

For this reason, attempts were made to contact Bouwman to analyse the protocol of one of his subjects in order to see how the problems posed by Libby had been overcome. Bouwman et al (1987) states as a footnote that a coded protocol analysis is available upon request. Unfortunately, Bouwman has so far not responded to this request.

5.2.3 Bouwman et al's findings

In essence, Bouwman et al (1987) found that expert behaviour could be explained by a combination of three types of behaviour: expert process, directed and non-directed behaviour and the application of templates.

Expert process involved a familiarisation phase, a scanning phase, the exploration of one or more themes and the formulation of a final evaluation. Familiarisation was concerned with the expert looking through the available data in order to gain familiarity with the details of the situation under review. For the issue of the exploration of one or more themes, an example of a theme is given and is presented in figure 5.1 (adapted from Bouwman et al, exhibit 8, page 15). The scanning phase, which was not apparent in the analysis of all subjects, again concerned the expert looking through the available data. The experts appeared to have a variety of motives for scanning, including looking for reasons to reject the company and ensuring that new or unexpected information was not missed. Bouwman et al's work is conspicuously silent on how the final evaluation is formed.

Figure 5.1 Example of a theme

The Theme is that profitability is weak and yet the share price is surprisingly good.

This leads to a search to explain the apparent anomaly. This search reveals big improvements in profits in the most recent three year period.

Looking further, it becomes clear that improvement in the last 3 years comes from a significant improvement in the plastics division.

The earnings in the plastics division can be explained by automobile downsizing.

The second issue raised by Bouwman et al (1987) is that behaviour can either be non-directed or directed. An example of non-directed behaviour is scanning the available data in case significant information has been ignored, as indicated towards the end of the previous paragraph. The most significant element of directed behaviour is the checklist, which Libby (1981, pg.88) explains in slightly different terms, as follows:

"After being faced with an initial diagnostic problem, experts appear to initiate information-search activity based on standard lists of questions. For example, physicians make extensive use of standard workup procedures,... financial analysts compute standard indicators... auditors use standard procedures for internal control evaluation..."

Bouwman's "checklist" is Libby's "standard list of questions", "workup", "standard list of indicators" or "standard procedures for evaluation".

The final element in Bouwman et al's (1987) findings is the application of templates. A template is a means by which a particular situation can be characterised in terms of a generalised situation. For instance, Bouwman et al gives an example by means of protocols uttered by one of the subjects which illustrates the way in which one of the subjects decided that the particular company under consideration was a "cyclical company" (pg. 22):

protocol 25: "And I see they have a container, and they have a machinery, and a heat treating division"

protocol 26 "and so I assume they are in somewhat cyclical type industries...."

The importance of the template is stressed as "a key component of expert screening behaviour" (pg.22).

5.2.4 Critical evaluation of Bouwman et al's findings

Bouwman et al (1987) fail to relate their findings to existing theories of human information processing. For instance, templates appear to be related to two heuristics observed by Tversky and Kahnemann: the representativeness heuristic (Kahnemann and Tversky, 1972) and the availability heuristic (Tversky and Kahnemann, 1973). Figure 5.2, which is adapted from Libby (1982) explains these important heuristics. This failure to address prior research is unfortunate, because the benefits and drawbacks of particular features of expert behaviour referred to by Bouwman et al have become fairly well understood. For instance, an heuristic allows the expert to reduce the space within which the search for a solution takes place but can introduce bias into the decision making process (Libby, 1982). This has implications for Bouwman et al's claim that their research provides important implications for the development of expert systems. For instance, developers of expert systems should be aware of the possible biases that can be introduced by the use of templates.

It would seem to be sensible to link templates and themes under the more general heading of modelling and to relate modelling to existing theory, including existing theories concerned with heuristics. One interpretation of themes is that they must be built on templates of some kind and would seem to be related to the representative and availability heuristics. By considering both under the heading of models provides a broader but potentially more coherent way of dealing with templates and themes.

Figure 5.2 Representative and Availability heuristics (Libby, 1982, adapted)

The representative heuristic operates by judging the particular problem under the assumption that it resembles a general problem for which the solution is familiar to the expert. Kahnemann and Tversky (1972) presented a group of undergraduate students with the following situation:

"A certain town is served by two hospitals. In the larger hospital about 45 babies are born each day, and in the smaller hospital about 15 babies are born each day. ... about 50 percent of babies are boys. However, the exact percentage varies from day to day. Sometimes it might be higher than 50 percent, sometimes lower.

For a period of one year, each hospital recorded the days on which more than 60 percent of the babies were boys. Which hospital recorded more such days?"

The majority of the undergraduates suggested that both hospitals were likely to record a similar number of days, suggesting that their judgement was influenced by the equal representativeness of the hospitals to the population as a whole. Going back to Bouwman et al, the use of knowledge of a type of company would influence judgements made about a specific company based on beliefs of the representativeness of the specific company in relation to the type of company.

The availability heuristic allows the expert to base a judgement on the ease with which similar events are called to mind. The concept can be illustrated by means of an experiment conducted by Lichtenstein et al (1978). Subjects were presented with two lists of the causes of death. The lists were paired, so that, for instance, accidental death from list A was paired with stroke from list B. Similarly, botulism (list A) was paired with lightning (list B). The subjects were then asked to judge which list provided the most common cause of death. The majority of subjects chose list A, even though list B was the correct choice. The interpretation given to this was that newspaper coverage of incidents such as botulism and accidental death was far more frequent than lightning or strokes so that the judgement of subjects was distorted by the knowledge they had available to them. Going back to Bouwman et al (1987), judgement based on templates is dependent upon the templates or situations with which experts are endowed.

There are two issues which have emerged as being important to understanding human reasoning which are not explicitly explored by Bouwman et al (1987). The first, which is described as being of "major importance in judgement and choice" (Einhorn and

Hogarth, 1981, pg. 5) is the cognitive representation of the task. Bouwman et al limit their discussion to the process of information processing which they discern from their subjects' behaviour. They therefore omit any consideration of cognitive mapping.

The second issue is implicit in some of the material presented by Bouwman et al but is not explicitly developed. This issue concerns the resolution of problems by means of hypothesis generation and the stage at which experts form hypotheses from which evaluations are subsequently drawn:

"A small number (usually less than seven) of hypothesized solutions which are most representative of the data gathered during the standard workup are retrieved from memory. Failure to retrieve the correct solution at this stage appears to be a major cause of decision error."

(Libby, pg. 88)

A consideration of the stage at which hypotheses are formed appears to be an important aspect of expert behaviour which needs to be addressed.

5.3 The Present Research

The present research followed Bouwman et al (1987). Appendix A presents tables of analysis, a guide to the data analysis and the complete transcript and analysis for one of the subjects in order to illustrate the research process. The complete analysis for all six subjects included in the research runs to nearly three hundred single spaced pages and has not been included. The stages in the research as a whole are presented in the following sub-sections.

5.3.1. Selection of case material.

Payne et al (1978) describe four types of research objective which can suitably be met through protocol analysis. Of these, the present research represents *exploratory* research, with the aim of applying triangulation to establish patterns of representative expert behaviour.

The accounting task presented to subjects was relatively short. The choice of topic was influenced by recent interest in product costing stimulated by Johnson and Kaplan (1987). Given that product costing requires a substantial volume of data in practical settings, it was decided to alert the subjects to the concern for product costing by means of short statements made by case actors. An additional statement was introduced and attributed to "an academic" in order to prompt a consideration of non-financial and qualitative measures considered by Emmanual et al (1990, pp 367-369) to be important to organisations facing dynamic change and uncertain futures.

The data that was provided was related to a University situation in order to provide experts with a situation they would not be fully familiar with but with which they might be able to relate. The case study, which is fictitious but based on a factual University Financial Report, is given as figure 5.3.

Figure 5.3 Case Study

The University of Tabh produces annual financial accounts. The most recent accounts reveal the following information:

	Year 3	Year 2	Year 1
	£'000	£'000	£'000
Income:			
Central Funding	21091	18712	16985
Academic Fees and Grants	5012	4439	3698
Endowments and Donations	590	213	146
Computer Board Grants	2264	1523	1198
Residences and Catering	3135	2831	2789
Other General Income	1059	684	595
Research Grants and Contracts	5559	5099	4414
Other Services Rendered	1386	1002	947
	-----	-----	-----
	40096	34503	30772
	-----	-----	-----
Expenditure			
Direct Academic Staff	13756	12913	12567
Academic Administration	3032	2867	2856
General Academic Exp.	539	501	485
Maintenance of Premises	4288	4179	4309
Admin. and Central Services	1933	1837	1472
Student and Staff Facilities	665	641	639
Residences and Catering	3007	2764	2509
Pensions	1029	333	638
Equipment and Furniture	4143	2417	3028
Miscellaneous	94	104	95
Research Grants and Contracts	5036	4688	4302
Other Services Rendered	907	853	960
	-----	-----	-----
	38429	34097	33860
	-----	-----	-----
Surplus/Deficit	1667	406	(3088)
	=====	=====	======
Number of students	4216	3948	3797
	=====	=====	======

The following conversation was recently minuted at a meeting of senior officials:

University Director: "Our costs have risen to £9,115 per student. There is little doubt that something will have to be done to improve our effectiveness and efficiency or the trauma of 1987 will be with us again. Are there any suggestions?"

Management Accountant: " We are actually in a strong position. Our relevant cost is only £3,263 per student and a number of departments are able to sell new courses at £4,000 per student. It is clear that all we have to do is to place all of our emphasis on making our courses relevant to Society."

Academic: "It is our role to further research and knowledge. Our value to Society is unquestionable. It is dangerous to play around with figures like this when our benefits to Society cannot be measured in the short term. Without a modern, high quality educational system, the whole future of our country is in jeopardy. It think it is clear that the only danger to this University is in attempting to make the measurements that are being suggested at this meeting."

5.3.2. Interview

Six subjects were interviewed. This compares with twelve subjects in Bouwman et al (1987). Interviewing stopped when it was felt by the interviewers that no new material was being generated. The time necessary to analyse transcripts places a practical constraint on the number of subjects who can be included in an individual exercise. By comparison, Bouwman (1984) used eight subjects, of whom five were students and three Qualified Accountants, and Johnson et al (1989) reported on the expertise of auditors once they had analysed the protocols of two subjects.

Subjects were selected because they met criteria established for the research. All subjects were qualified accountants and met Harmon and King's (1985) criteria for an expert as someone who has a combination of theoretical knowledge and ten years practical experience. The subjects held an average of approximately fifteen years experience (Bouwman et al, (1987); sixteen years). Given the relative seniority of some of the subjects, not all were primarily involved in their day to day working with specialist tasks specified by Wilson and Chua (1988) as constituting management accounting. However, all subjects were in some way involved with management accounting.

Subjects were provided with a copy of the case study in advance, the research study was explained to them and they were given the chance to refuse to take part in the study. In the event, no-one actually did refuse. Some of the subjects used the fact that they had received the case study to carry out analysis in advance of the interview. This factor does not appear to influence the findings presented here but created an interesting effect. There was a trade-off between witnessing a subject reason on the basis of prepared calculations deemed necessary by the subject to form an opinion, if the subject prepared in advance, and seeing a subject come to the case study with no prior notions, if the subject carried out no preparation.

Interviews were arranged at a location stipulated by the subjects. The aim was to minimise the effects that could have resulted from the subjects performing the task in unfamiliar surroundings. Three of the interviews were conducted by two interviewers to gain the benefits of investigator triangulation (Smith, 1972). There were no obvious effects across all subjects which could obviously be attributed to the interviewers beyond the effect caused by an interview process. However, it is possible that the existence of taping machinery and interviewers and the need to think aloud created an artificial situation.

Where Bouwman et al (1987, pg.7) experienced interview times of between 19 and 80 minutes, with an average of 52 minutes, the present research interviews lasted between 21 minutes and 72 minutes with an average of 49 minutes. Bouwman et al's subjects used a mean number of words of 4,300 with a range of 4,000 to 7,800. The present research subjects used a mean number of words of 5,800 with a range of 4,600 words to 8,500 words.

Subjects were initially asked to consider the case study data presented to them and to think aloud whilst they were doing this. All subjects eventually provided the evaluation that the financial health of the University was good. Since this provided a financial analysis focus, rather than a management accounting focus, for the evaluation, all subjects were then asked to provide an opinion on what the University should do if Central Funding became 40% of the total funding of the institution. Subjects responded with recommendations to change student numbers or to implement a cost reduction programme. These responses are consistent with management accountancy.

Table 5.1 summarises the interview process by giving details for each of the six subjects and showing number of interviewers, whether the case study had been studied by the subject prior to the interview session, the session time in minutes and the words used by each of the subjects.

Table 5.1 Interview details

Tape	Subject Ref	Number of interviewers	Case Study studied prior to session?	Session time, minutes	Words used by Subjects
1	S1	One	Yes	21	4600
2	S2	Two	No	68	5400
3	S3	Two	Yes	41	5900
4	S4	Two	No	72	8500
5	S5	One	No	50	5900
6	S6	One	Yes	40	4600

5..3.3 Transcription

The interview tapes were transcribed manually, typed and the typing was checked against the tapes before analysis began.

5.3.4 Identification of protocols

The identification of protocols proved to be an iterative process which was not finalised until the completion of stage 7, which is described in section 5.3.7. Given that Bouwman et al (1987) do not mention problems at this stage of the analysis, the present problems could have arisen because of the inexperience of the researcher or differences in the nature of the task. However, other researchers have found difficulties in being entirely objective at this stage in the analysis (Libby, 1981).

5.3.5 Coding of protocols

Bouwman et al's (1987) coding scheme was applied to the protocols. Coding of protocols raised difficulties which were again resolved by means of an iterative process. A series of rules were defined as necessary. Where possible, coding was interpreted to fit a prejudgement that the protocols could lead to expert system development.

5.3.6 Analysis of protocols

A comparative analysis of the protocol coding with Bouwman et al (1987) is given in table 5.2. In general, it the present study was roughly comparable to Bouwman et al in that the majority of protocols were coded as examination and reading or reasoning. The predominance of examination and reading codes in Bouwman et al's work probably reflects the large volume of data that subjects in that study needed to consider. They were also undertaking a relatively structured task which was very similar to their everyday work. By comparison, the subjects in the present study were provided with a relatively small amount of initial data but the data provided scope for a range of approaches to be adopted. The differences in this respect therefore appear to be task related. Other differences are difficult to interpret and the wide range reflected in the final column of table 5.2 for both studies might suggest that individual differences between subjects could be more influential in interpreting codes than the nature of the task or the nature of human information processing. The coding has little bearing on the findings presented in this chapter.

Table 5.2 Comparative analysis of Protocols

Bouwman et al (1987, pg.11), slightly adapted, Exhibit 5,

Activity	Frequency per subject	Mean	Median	Range
Examination and Reading	172	42%	43%	18-63%
Reasoning	98	24%	23%	16-24%
Formulating goals	42	10%	10%	4-16%
Memory retrieval	17	4%	4%	1-8%
Commenting	77	19%	10%	1-48%
Interaction with Interviewer	8	2%	2%	1-5%
Total	414	101%*		

* Rounding error

Present Study

Activity	Frequency	Mean	Median	Range
Examination and Reading	54	17%	18%	9-31%
Reasoning	186	58%	56%	48-71%
Formulating goals	11	3%	3%	1-11%
Memory retrieval	10	3%	4%	1-7%
Commenting	56	18%	12%	4-35%
Interaction with Interviewer	3	1%	-	0-4%
Total	320	100%		

Protocols were further analysed into episodes. The problems encountered with this analysis were again resolved as an iterative process and with the intention of fitting the data to a model of expertise consistent with expert systems wherever possible. Finally, episode summaries were produced. These were comparable to Bouwman et al in revealing familiarisation, scanning, the exploration of one or more themes and the formation of evaluations.

5.3.7 Interpretation

Stages 1 to 6 followed Bouwman et al (1987) as closely as possible. There was an initial presumption that expert systems could be developed from the transcripts and that the research should aim at a scientific basis, or move towards type 1 or type 2 forms of research (Tomkins and Groves, 1983). However, it soon became clear that alternative interpretations existed and in order to make explicit the naturalistic (Tomkins and Groves, 1983) dimension to the transcripts, an additional stage was added. This made explicit alternative interpretations of the transcripts. The alternative interpretations were created over a period of a number of months and were influenced by readings in the literature associated with human information processing and expertise in order to gain the benefits of theory triangulation (Smith, 1975). The interpretation was developed as a free flow of consciousness.

This interpretation was then itself subjected to data analysis consistent with grounded theory (Glaser and Strauss, 1967). Issues which emerged in the interpretation were summarised for each subject and then triangulation was applied to determine which issues appeared to be constant across all subjects. It is this analysis which is most influential in the findings reported in this chapter.

5.3.8 Cognitive Mapping and Analysis of Reasoning Chains

The final stage in the analysis was to draw cognitive maps for each of the subjects at the episode level. It was anticipated that drawing out the cognitive maps of the subjects would reveal a representation that would resemble a tree-like structure which could be interpreted in terms of the problem space. The intention was to draw out reasoning chains from the cognitive maps of each of the subjects. The reasoning chains were expected to give rise to a production system which would be a fair description of the expertise revealed during the interview session. Successful completion of this stage should thus have provided support for the propositions addressed by the thesis.

A major problem arose from the need to decide an appropriate level of analysis. Analysing maps and reasoning chains at the protocol level led to very complicated structures whilst analysing maps and reasoning chains at the episode level missed some of the richness evident at the protocol level. However, analysis at the level of the episode is adequate for the purposes of the present research and is significantly less time consuming.

5.4 Findings

Bouwman et al (1987) present findings by providing a detailed description and analysis of a representative expert and then comparing and contrasting that description and analysis to other experts in order to triangulate the findings. This would seem to be a consistent approach, if somewhat tedious from the point of view of the reader (Libby, 1981).

The present thesis does not seek to vary from this standard procedure except in that the findings differ somewhat from Bouwman et al's. A single expert is described and the findings are presented and interpreted in relation to Bouwman et al. However, since there are aspects of this expert's behaviour which are not consistent with Bouwman et al's findings, a contrasting picture of expert behaviour is developed using protocols and analyses of episodes developed from a triangulation of all of the subjects' responses.

5.4.1 Summary of an analysis of S1

S1 provides an analysis which is most consistent with the findings presented by Bouwman et al (1987). S1 is an academic who has worked as a Management Accountant, is a member of CIMA and is also a graduate. He has approximately ten years experience of management accountancy. His dominant interest is in strategy, thus making him a prime candidate for a current interest in management accountancy, strategic management accouning (Bromwich, 1990; Bromwich, 1992). His analysis required 21 minutes, which is 28 minutes less than the average. However, his use of the time was somewhat more efficient than any of the other subjects and he uttered 4,600 words, which is only 1,200 words less than the average.

His analysis begins with a familiarisation phase which is made explicit in the very first protocol:

protocol 1: "get the figures sorted out in a way which is meaningful"

Prior to the taping, S1 had prepared a report which matched income and expenditure items (table 1, appendix A, pg.35) and this report is the basis for early comments. This familiarisation, or acquisition of information phase, is known to be interdependent with evaluation (Einhorn and Hogarth, 1981). S1 reveals cue redundancy, a phenomena not mentioned by Bouwman et al (1987) but which Einhorn and Hogarth (1981) claim to be essential in order to develop a model of the search process in behavioural decision making. In this case, S1 calculated differences between year 1 and year 3 figures and expressed the differences as percentages. Cue redundancy describes the omission of year 2 figures from the familiarisation phase. An obvious explanation of this is given by one of the reasons posited by Einhorn et al (1979); the prevention of information overload.

Following on from the familiarisation phase, S1 determines that there are two propositions worthy of investigation:

protocol 33 "we seem to have two types of issues:"

protocol 34 "one is [an] issue of efficiency, perhaps cost control,"

protocol 35 "the other issue appears to be one of the choice of activities, which is more to do with allocation;"

These propositions appear to be similar to Bouwman et al's (1987) themes.

Having stated the themes, S1 returns to the case study in what can be considered to be a scanning process which is investigating the two propositions. There is no evidence that S1 is using a checklist during this phase of his analysis. This major difference with Bouwman is probably task dependent. Bouwman's subjects all tackled a financial analysis task which was structured and which would have been repetitious for the subjects he used in his research. The present research presented subjects with a task which was relatively ill structured, in that subjects were simply asked to think aloud as they considered the case study data presented to them. It was a task which was unfamiliar to them and which could have been approached in a variety of different ways. It could therefore not be expected that S1 would have developed a checklist to deal with the situation. Since this point applied equally to all the subjects in the present study, it would appear that Bouwman's theory of the checklist needs to be adapted to include a consideration of the nature of the task.

S1's scanning is at times unstructured, and therefore apparently non-directed, and at others sequential, and therefore directed. Again, any differences with Bouwman et al would appear to be task related.

S1 pauses in the course of his scanning process and integrates his observations to reason that the costs are well controlled (episode 15, appendix A, pg.22). Bouwman et al (1987, pg. 15) signal such episodes as "key" in directing subsequent behaviour. S1 appears to pursue a general cost control theme in the subsequent episodes and to broaden the finding that costs are under control to make the statement that efficiency is good. The data shows not only good cost control but also productivity improvements. This is a mainstream of reasoning which is included in S1's very final statement.

S1 then moves on to consider his second theme, which is the issue of choice of activities. He considers the Management Accountant's comments and applies cost behaviour analysis using both Account Classification (episode 29, appendix A, pg. 25) and High-Low Methods (episode 31, appendix A pg.26) (Kaplan and Atkinson, 1989; Drury, 1988; the Account Classification method is termed "Inspection of accounts" by Drury). He concludes that the relevant cost of increasing activity is between £3000 and £8000 (protocols 130 and 131, appendix A, pg.27) and that it is not therefore beneficial to increase students at a revenue of £4000 per student. He introduces concepts from activity based costing (Cooper and Kaplan, 1988; Cooper, 1988/9; Brimson and Fraser, 1991; Innes and Mitchell, 1991) and explains that the relevant cost included in his analysis is relevant as a long term measure. In the short term, he suggests that some courses would be viable at a revenue of £4000 because "a lot of these costs would in fact be relatively fixed" (protocol 137, appendix A, pg.27), giving a relevant cost approaching zero. This sequence of thinking terminates in a consideration of the marketing implications raised by the case study.

The next stage in the proceedings are determined by the need to consider the academic's comments. These are arrived at because they are the only item in the case study which has not so far been considered; S1 is processing the available data in a sequential rather than a directed manner. S1 concludes that "the academic is rather putting his head in the sand" (protocol 181, appendix A, pg.131) and returns to the issues of cost control and choice of activities (protocol 179, appendix A, pg.131), explaining that the academic could meet his goals if the financial and marketing issues are addressed.

S1 is finally asked to respond to the problem posed by a change in central funding to a 40% proportion of total funding. His response is consistent with his previous reasoning in that cost reduction is seen as a last resort based on the finding that the existing cost control is good. His solution is to find sources of new funds or to increase existing surpluses on items such as Research Grants and Contracts (protocol 195, appendix A, pg.32) for which Income items can be matched with Expenditure items within the case study data (episode 48, appendix A, pg. 34). The conclusions can be related back directly to previous episodes, as the cognitive map for S1 shows (appendix A, pg.16).

In important respects, Bouwman et al's work is sufficient to explain a part of the behaviour of S1. Throughout, S1 uses a range of templates to make evaluations. Bouwman et al (1987, pg. 22) refer to a limited type of template: "templates of typical companies are a key component of expert screening behaviour". If this is extended to other types of templates, such as the template representing the Account Classification method, then S1 is behaving in a way which largely accords with Bouwman et al. Other "key" elements of Bouwman et al's process description are evident; pausing to integrate observations, as discussed earlier, the use of familiarisation, scanning, and evaluation phases in the analysis. The only major part of Bouwman et al's scheme which was not evident is the use of the checklist, which was assessed to be a task specific issue earlier.

Further analysis of S1's reasoning chains leads to the specification of rules which might be suitable for expert system development. One such rule is presented in figure 5.4. This rule is based on an interpretation of cost behaviour and states that the level of cost which will change with major changes of activity in the long term exceeds the cost of academic staff. In other words, if, for example, increases in student numbers are major and a long term perspective is adopted then costs other than academic staff costs could be expected to rise.

Figure 5.4 Sample rule developed from analysis of S1

Rule: if time_span = long_term and
if activity_change = major
then variable_cost > academic_costs

It would seem to be possible to assert that Bouwman et al's claims for the benefits of their paper to expert system development are largely justified. However, the findings so far presented are only a part of the full story to emerge from the analysis. The next stage is to present other findings which have a bearing on the propositions under investigation. These are taken from an interpretation of a data analysis of all subjects.

5.4.2 Other aspects of expert behaviour

An expert system model of expert behaviour assumes a logical and means-ends reasoned approach to a problem based on a consistent and accurate processing of data which is complete as regards the requirements of the model. Although S1 was described as an expert who met these criteria, there are aspects of S1's behaviour which were not entirely consistent with this model. The behaviours of other subjects were to a greater or lesser degree more consistent with an alternative model of expertise which will be explored in this section.

All subjects revealed the ability to function in an uncertain world where incomplete information is a fact of life. Incomplete information, inconsistencies and inaccuracies, some inherent in the case study data and some created by the subjects themselves, presented no barriers to the subjects' ability to draw conclusions. The conclusions they drew were remarkably consistent despite a variety of differences in the detailed knowledge bases that were used.

S4 provides a good example. S4 was the most senior of the subjects and was the only subject who had detailed knowledge of the University system, gained from several years of experience in Higher Education. He was included in the sample to provide a benchmark against which to gauge the statements of knowledge of Higher Education provided by all the experts. Like S1, he involved himself in discussions related to the principles of Activity Based Costing. S4 takes a different approach to S1, discussing the information that would be required to produce different cost per student figures for different courses. Since the information necessary to carry out this analysis is not provided in the case study (nor could be conveniently be conveyed by any case study since the volume and the complexity of the data would be impractical in case study terms), S4 restricts his discussion to statements of how the activity based cost could be derived. The statements represent general intent and are incomplete in that they do not fully describe the necessary procedures. Having established that there are different costs for different courses, S4 states that the relevant cost per student is likely to be approximately £6000 based on an exercise carried out previously. This is inconsistent with the concept of different costs for different courses and is insupportable from the data provided within the case study. Further, S4 implies a relevant cost substantially less than £6000 when he recommends that it may be suitable to increase student activity at a revenue level of £4000 per student. So, S4 is able to recommend different costs for different courses, an overall cost of £6000 per student and a cost of less than £4000 without seeing any inconsistency in the knowledge provided. S4 additionally revealed a technical inaccuracy in his inability to differentiate cash flow and profit flow implications of reserves. Despite these specific shortcomings in his technical reasoning, which were unique to him, he was able to arrive at the same conclusions as the other subjects.

The major achievement of S4 was in conceptual model building or the ability to build pictures which he related to his reality. This provides the basis for the alternative model to the expert system model of expertise referred to at the beginning of this section. Possibly because of his familiarity with Higher Education, much of his transcript can be viewed as modelling or commenting on different situations which are implicit in the case study data provided. In so doing, a rich picture of issues of relevance to the case study are produced. Much of this is very detailed, for instance in relation to S4's view of academics:

protocol 130: "I know academics of old"

protocol 131: "there will always be a maverick"

protocol 133: "there will always be those who will want to do [research and consultancy] on the cheap"
protocol 134: "because they'd been conned into that by their industrial partner"
protocol 135 "and that's not too difficult in some cases"

Much of this conceptual modelling appears to be experience based.

The ability to draw intelligent connections between ideas presented by the case study appears to be an important part of the conceptual modelling process. Some of these connections are surprising and also unique to S4, for instance where he is discussing the role of research. He makes a connection between research, an interpretation of the statements made by two of the case actors and an interpretation of management of manufacturing industry:
protocol 309: "in all our academic costs, it's one thing to have a cost per student and reflecting that within any cost centre"
protocol 310: "but we ought to be looking at postgraduate research students, undergraduate students"
protocol 311: "and the efforts of academic staff pursuing their own research"
protocol 312: "the cost per student would be influenced by the research effort of any academic who was performing at that great and dizzy height"
protocol 313: "it comes back to the comment of the Director and of the Management Accountant"
protocol 314: "we are not trying to keep costs down"
protocol 315: "as we might on a factory production line in Wills Tobacco or wherever"

This behaviour might be particular to someone familiar with the specific circumstances of Higher Education and so it is necessary to consider a second subject. Almost any of the subjects provide supporting evidence so the choice is not significant. S6 provides an interesting example in that noticing a particular connection within the data prompts a model building exercise based on his personal experience. The example is also interesting because the implications of his statement are incorrect. His experience was not relevant to the University situation, being based on experiences of Further Education. Additionally, computerisation is raised and S6 states at one stage that his company is currently going through a computerisation process.

protocol 131: "... I've just noticed that the expenditure has increased from 1988 to 1989 with exactly the same percentage as central funding has increased"

protocol 132: "I don't know if there is some correlation between these two figures. I suppose there must be"

protocol 133: "if I can remember.... Central Funding is on an application basis and grants are submitted to the education authority and that would obviously be based on some sort of expenditure which would support their claim of a grant"

protocol 134: "I suspect that part of the Central Funding Grant would cover directly the increase in Furniture and Equipment"

protocol 135: "I suspect their might be some motive behind putting that equipment in"

protocol 136: "probably something to do with computers"

protocol 137: "or a laying out of laboratories or some expenditure like that"

So, the expert is one who looks for patterns in an uncertain world where accuracy, consistency and complete information are impracticable and therefore of lesser importance to the ability to relate the current problem to experience.

Three further aspects of the analysis are finally considered. The first extends the previous discussion on the types of modelling activity which the experts appear to be engaged in. The second looks at the familiarisation phase and addresses the issue of the stage at which a decision is taken about the problem. The final point returns to S6 and suggests an alternative form of representation to the problem space based on the premise that experts form intelligent connections.

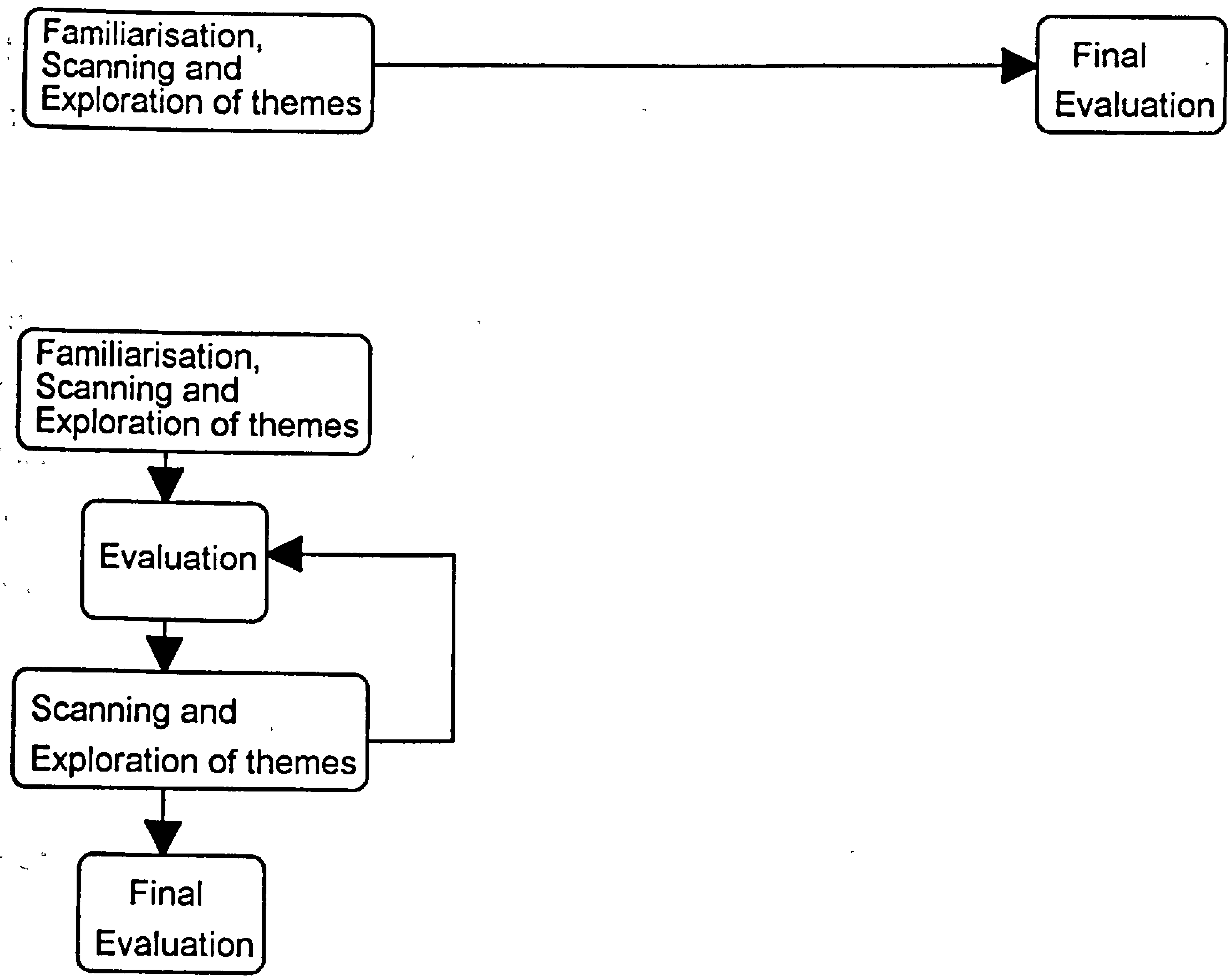
S1 applies modelling in three different ways:

- based on experience, without the support of data from the case study (for instance, at episode 38 (appendix A, pg. 29), where the assumption is that Engineering courses are expensive);
- based on argument or techniques which are included in text books, supported by case study data (for instance, the use of the High-Low method at episode 31 (appendix A, pg.26));
- based on argument which is available in text books, unsupported by case study data (for instance, episode 30 (appendix A, pg.26) combines the Marginal Costing argument, that relevant cost is the variable cost which changes with activity in the short term, and Kaplan's argument that all costs are variable in the long term).

This analysis of S1's modelling can be illustrated from the behaviour of other subjects and extends Bouwman et al's concepts of themes and templates. The analysis suggests that experts model either on the basis of experience or theory and may respond either on the basis of case study material, suggesting an empirical basis for the analysis, or on an a priori basis. It is difficult to take this point further on the basis of the data collected within the present exercise but the next chapter revisits the role of theory in the life of experts.

The second issue is concerned with the stage at which experts make their judgement, or evaluation to use Bouwman's coding. There are two possible models, as illustrated in figure 5.5.

Figure 5.5 Formation of Judgement



In the first model, a thorough acquisition phase results in a judgement which is based on the data processed through a familiarisation, scanning and exploration of themes process. In the second model, a preliminary phase of familiarisation, scanning and exploration of themes is followed by an evaluation. This is then followed by one or more iterations as further scanning and exploration occurs before the final judgement is expressed.

There is evidence in the protocol analysis study of experts using the second model, but not the first. Where an early judgement is made, a judgement of financial health is based on the organisation going from a deficit to a surplus position. S5 illustrates this more concisely than other subjects in an early protocol when he is still defining the problem to be resolved:

protocol 9: "I assume the nub of the issue is that the University of Tabh made a deficit on its Income and Expenditure account in 1987"

protocol 10: "the issue is how it's either improving that situation or whether that situation is worsening since 1987"

protocol 11: "I've only isolated that as the major issue because it is a key number in terms of the Income and Expenditure account; the Surplus and Deficit for the year"

protocol 22: "given where we need to start from ... we've got a deficit and it's pulled through ... a surplus to break-even in 1988 ... and then into a surplus in 1989"

This is translated into an evaluation later which takes this initial impression as its decisive argument:

Episode 28: Reason and evaluate:

-the financial position is encouraging

protocol 294: "I would be generally encouraged by what the University of Tabh financial statements seem to show"

protocol 295: "there isn't a balance sheet; I don't know what reserves the University of Tabh has to go with this; how long one could sustain the situation"

protocol 296: "having seen (a) deficit arising, one would want to look at it's sustainable future over ten to fifteen years"

In other words, the early impression that the University is doing well because it has moved from a deficit to a surplus position is upheld through an exploration of the case study data. The existence of the deficit causes S5 to be cautious in his final evaluation; it might happen again!

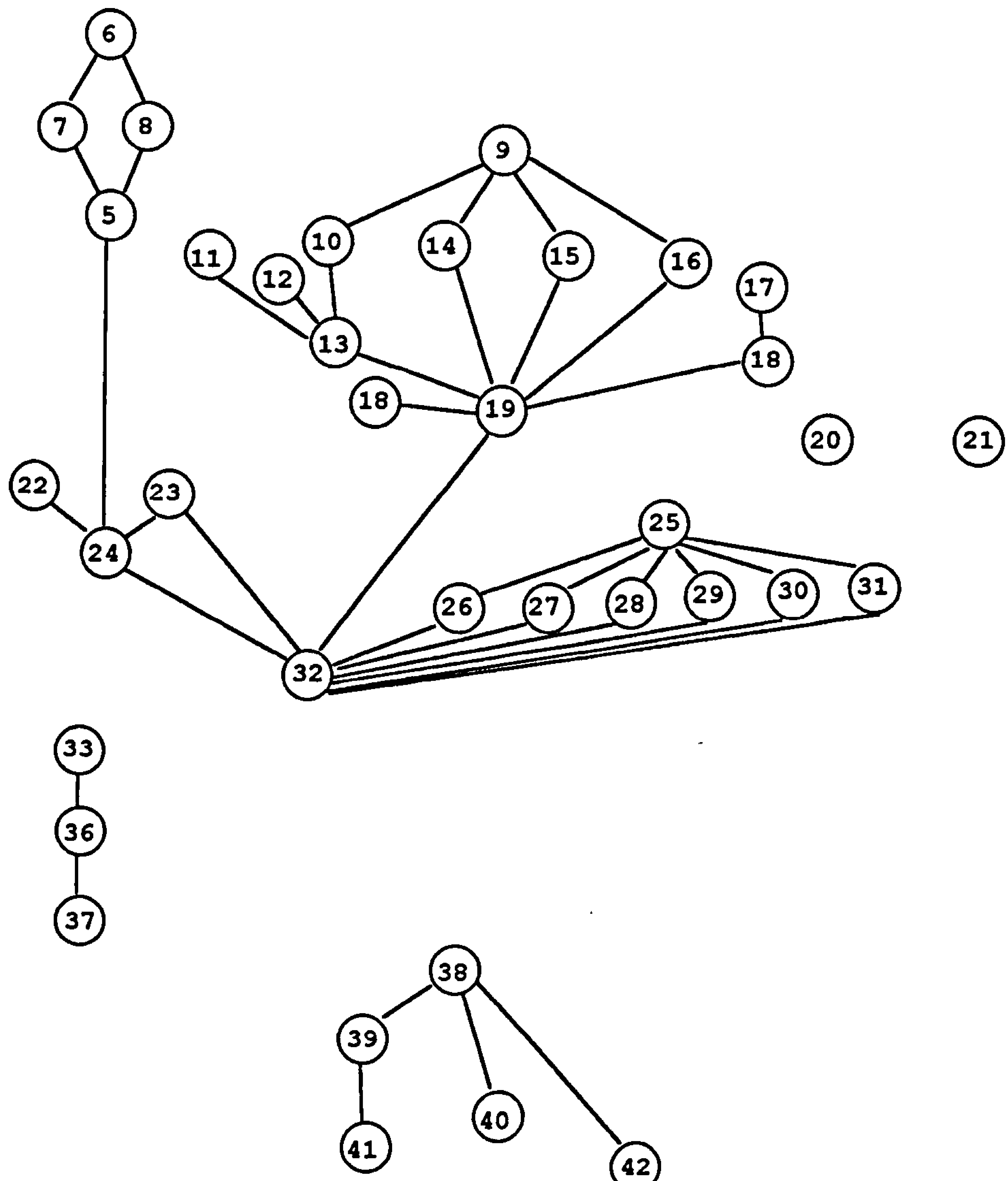
Where an early judgement is not evident, there is evidence of the experts suggesting possible solutions as their transcripts develop. The judgement is only changed when a change of funding scenario is posed so that new data drawn of a financial nature drawn from outside the initial case study changes the judgement. However, the new judgement is quickly formed. It is as though the experts know the situation already and know the recommendations they are likely to make. However, this analysis does not preclude the possibility of the expert behaving in accordance with the first model, that is leaving the judgement until after a complete acquisition of data is made. One of Bouwman et al's (1987) subjects appeared to do this.

The final issue to be raised concerns the way in which ideas interact within the subject's knowledge base. For instance, at episode 24 S6 rehearses three points, apparently from memory. These points are:

- The Management Accountant's assessment of variable cost is low (from episode 5);
- The providers of Central Funding could be expected to seek economies of scale (from episode 23);
- Central Funding and Academic Fees increase in line with inflation and with increases in student numbers (from episode 22).

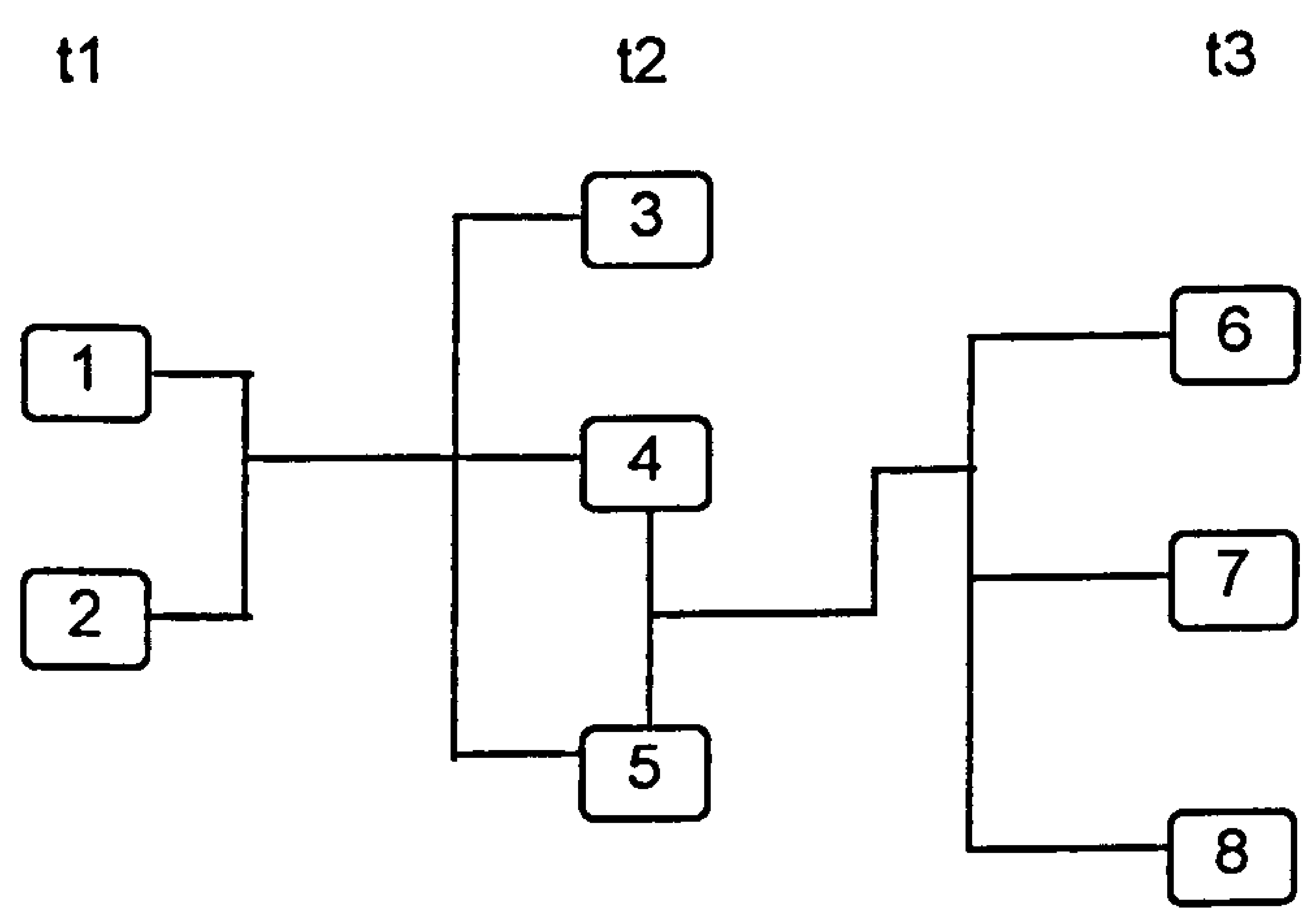
The collection of apparently unrelated items which appear at episode 24 suggests that S6 is taking stock. The collection is interesting because there is a contradiction between the second and third points. Maintaining costs so that they increase in line with inflation and increases in student numbers is not obviously consistent with a search for economies of scale. This apparent contradiction does not seem to be apparent to S6, even though they are juxtaposed in his verbalised line of reasoning. If the expert is one who looks for connections, then this is an example of an expert who is, at least temporarily, not drawing an apparently important connection.

Figure 5.6 Cognitive Map for S6



The cognitive map for S6, which is developed at the episode level so that the nodes refer to episode numbers, makes the point that ideas might ebb and flow as some kind of network, with ideas coming to be juxtaposed at various times as an expert takes stock. Figure 5.6 presents his cognitive map. Sometimes connections are drawn between nodes in the network. These connections may be used to support a new node or to develop new nodes. A generalised diagrammatic representation can be developed to show this hypothetically, as presented in figure 5.7.

Figure 5.7 General interpretation of the operation of networks within human information problem solving



Nodes connect and interconnect in a variety of ways. At time t_2, three new nodes or ideas are formed by drawing connections from ideas represented by nodes 1 and 2. An interconnection is drawn between nodes 4 and 5 and this gives rise to three new ideas. One of the ideas considered at time t_2, represented by node 3, does not continue but 4 and 5 together give rise to 6, 7 and 8 at time t_3.

This might suggest yet another alternative to reasoning chains to represent expert knowledge; neural networks. This might point to a useful avenue for future research. There is some evidence from the reasoning chains drawn from the subjects episode summaries that a network might more closely resemble the cognitive maps of the subjects than the tree like structure associated with the problem space.

5.5 Models of expert behaviour

The previous two sections provided interpretations from which two contrasting models of expert behaviour emerge. The first model might be consistent with expert system development and is largely drawn from evidence of problem solving provided by S1. This appears to adopt a means-ends approach which could be termed "rational". The second includes the accumulation of impressions and a reliance on experience which could be equated with Weber's (1968) "traditional" action based on custom or habit, which Weber categorises as "non-rational". These two models are described and contrasted in the next two subsections.

5.5.1 A Rational Model of Expertise

In this model, the expert is presumed to reason using a chain of rules which are fired according to answers to specific questions within a directed problem solving behaviour which can or cannot be framed within a checklist, depending on the type of task. The rules represent an expert's view of the world which can be established and coded, once access to the expert's knowledge bases has been gained. The knowledge bases determine the judgements that are made at the end of the consultation. Reasoning takes place within a problem space. The decision is reasoned and is an accurate and consistent inference based on a complete set of rules.

5.5.2 A Non-Rational Model of Expertise

This model presumes that the expert looks for patterns in an uncertain world. The patterns are based on experience and other modelling activities. The pattern seeking behaviour is geared to building a picture of the world from which judgements are made. The judgements are probably based on a decision taken early in the problem solving activity because the expert is one who is so familiar with the situation under consideration that he or she knows the appropriate responses at the beginning of the problem solving process. Reasoning takes place within an interacting network, not within a problem space. Impressions are accumulated, sometimes through a process of relating impressions to other impressions within the network, sometimes not. Accuracy, complete information and consistency do not appear to be important. What seems to matter is that the expert "feels comfortable" with the situation presented and is then able to express an opinion within a known "comfort factor". "Feeling comfortable" implies relating the situation to familiar models and experience. Familiar models and experience are rich and not easily coded because of that richness. Within the conceptual framework provided by Checkland (1981), the expert responds to a rich world by manipulating rich models and experience built up from that world.

5.8 Implications for future research

Protocol analysis appears to provide a valuable insight into the problem solving of management accounting experts confronted with a case study. The experts provided a range of views on both the case study and the nature of management accounting as well as revealing some aspects of their thought processes. There would seem to be sufficient encouragement from the present exercise to apply protocol analysis as a research method to other aspects of management accounting. For instance, McAulay and Tomkins (1992) have suggested that the perennial problem of transfer pricing might require more subtle methods of research in order to take knowledge further.

Protocol analysis, using perhaps the Birch Paper Company (1957) case study as a basis, might provide just such a research method.

A second area of research would be to feed back the findings of the present exercise into the type of research conducted by Bouwman to see if the present findings are task related. This recommendation envisages repeating Bouwman's work as closely as possible with new financial analysts to see the extent to which the non-rational model of expertise might be true of the decision making behaviour of Financial Analysts. It would be possible to ascertain whether Bouwman's transcripts could be subjected to alternative interpretations if Bouwman were prepared to release his working papers.

Finally, protocol analysis, for all its value, does not present subjects with problems which will affect their lives and therefore may not have the implicit penalties and payoffs which might affect everyday decision making. There does seem to be a merit in attempting to research decision making in context and the next chapter explores attempts to do just that.

Chapter 6

Case Studies

6.1 Introduction

Case study research allows the investigation of expertise to be conducted in context. The problem solvers in case studies are concerned with outcomes that will affect them directly and with problems which arise from everyday reality. The potentially artificial conditions that are imposed by protocol analysis studies such as the one described in the previous chapter are thus removed.

This chapter presents three case studies based on descriptions which are to be found in appendix B. The reasons for selection and justifications for the use of case study work are presented. The case studies are then described and the implications for knowledge representation drawn out. The chapter concludes with a brief assessment of the findings.

6.2 Case Study Selection

Three case studies are presented from several undertaken by the author in 1989 and 1990. The basis for the choice of these three is primarily that they all involved situations which were initially considered to be suitable for management accounting expert system development. The situations are all to be found on Lin's (1986) list of

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An earlier version of this paper has been published as King and McAulay, (1991), Barriers to adopting management expert systems: case studies of management accounting applications which failed, *Expert Systems*, 8 (3), 139-147.

suitable areas for management accounting expert system development. They can also be considered to be consistent with the types of situation that Murdoch (1990) has determined to be suitable for expert system development in general. The first case study presents a planning problem which concerns a decision on the transfer of production between divisions of a multinational company, the second concerns product pricing and the third concerns a budgeting decision. The case studies can be characterised as action research in that in all cases there was a motivation to provide a solution to a management problem posed by the host client. The author adopted the role of participant observer in all cases. The problem presented by the host provided the main point of contact between the case organisation and the author. In this respect, the ideas associated with the soft systems methodology (Checkland, 1981) are pertinent. The case organisation expected a computer solution from the commencement of the project in one of the cases and expert systems were explicitly discussed during the process of the research in two of the cases.

Case study reports have been validated. The first and second studies are based on material which has been written in full report form and which has been presented to the companies involved for their comment. The third study was partially written up in report form and the report was presented to the company. In no case did the company representatives question the validity of the contents of the reports. By selecting case studies where reporting and feedback from the company had occurred, a degree of validation is provided and the objectivity of the interpretation presented in this chapter can be assessed.

6.3 Case Descriptions

The case study organisations were extremely open in the data and information that they were prepared to reveal. Some of this data and information was highly sensitive either in personal or competitive terms. The confidentiality of the companies and individuals has therefore been very carefully respected. The descriptions which follow use the names company A, company B and company C to preserve anonymity.

6.3.1 Company A

Company A is a division of a major company which is based in the United States. It is a multinational with a very visible and highly regarded reputation for its strategy formation. This strategy actively seeks to involve people inside the organisation as a decentralised process. The world-wide company operates in the new technology sector and has manufacturing, marketing and product development capabilities.

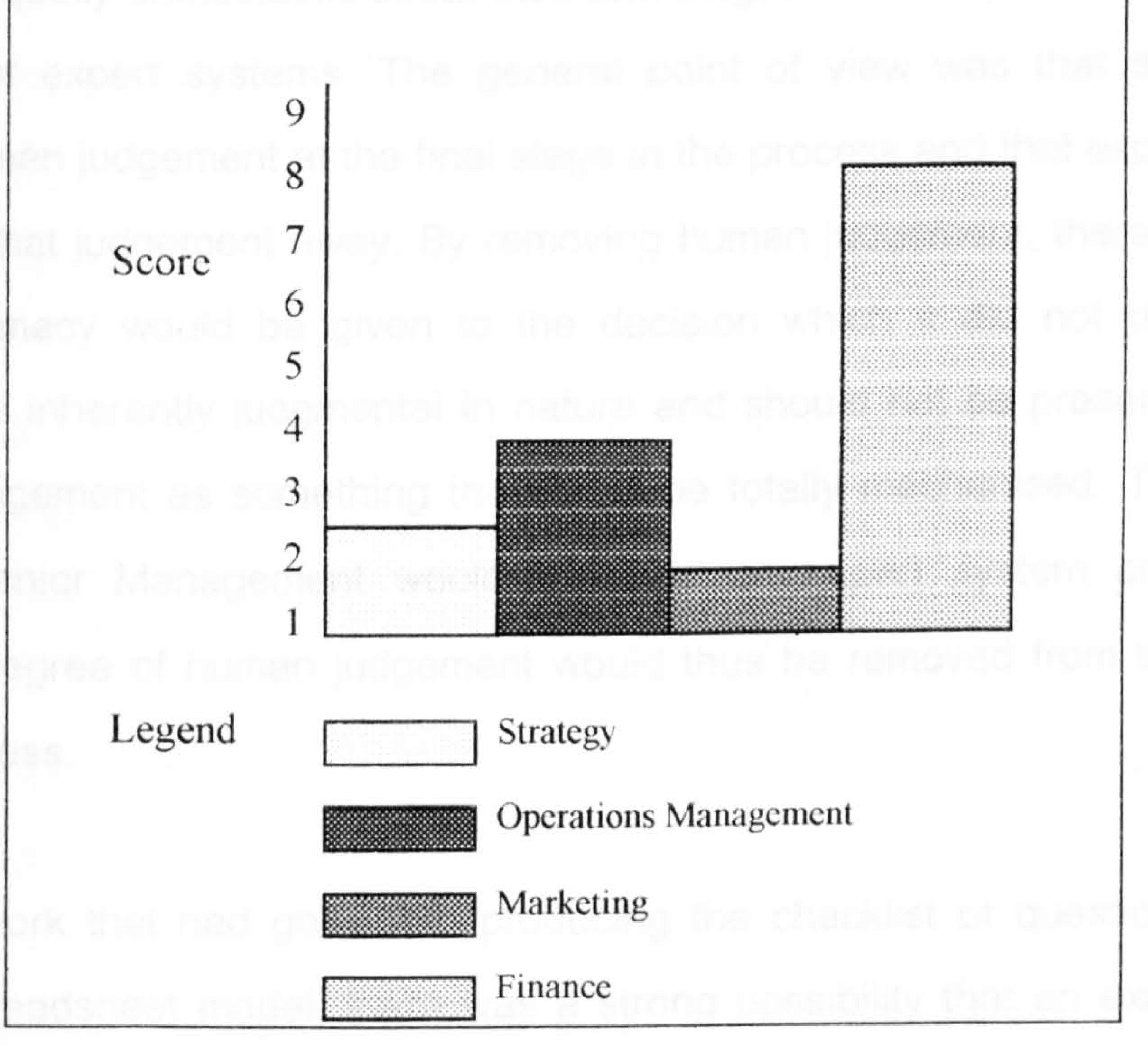
The problem posed by company A was to develop a systematic way of approaching a particular decision which had caused much debate both within the division and, so far as it was possible to tell, also within the world-wide company as a whole. The decision had previously been taken on an ad hoc basis which had not been considered to be satisfactory since little consistency had been evident. There was even some feeling that the decisions taken had needed to redefine strategy, rather than strategy influencing the decision, and this was not felt to be satisfactory.

The problem itself concerned the transfer of production responsibility between divisions. Divisions would develop a particular product and would assume responsibility for every aspect of the product's subsequent success. However, there were occasions when the transfer of the production operation to another part of the world could be beneficial to the group of companies as a whole. Where this was so, the division that wished to take on the production role was entrusted with the responsibility for developing a detailed and compelling proposal. The proposal would be submitted to the company which had originally developed the product and, if accepted, production would be transferred. The proposal involved the presentation and justification of plans for the transfer of production.

The company requested a project which could take advantage of the benefits of a fresh view of the problem which could be provided by an outside party. A computer solution was envisaged from the beginning of the project and the possibility of developing an expert system became evident early in the life of the research. The first part of the case study work involved investigating previous proposals and speaking to the many managers who were involved in transfer arrangements. The difficulties posed by this investigation and the way in which the difficulties were resolved has been reported by King et al (1991). The investigation led to the development of a systematic way of justifying each proposal which was tested on a transfer decision shortly before the end of the author's involvement with the company.

The solution to Company A's problem was presented partly as a systematic checklist of questions concerning three separate elements of the problem and partly as a spreadsheet model of the financial consequences of the transfer decision. The questions covered all the traditional management areas. The spreadsheet provided calculations of the revenue and cost implications of the transfer and followed many principles that are well known to product costing. It is possible to reduce the financial consequences of the transfer and the responses to checklist questions to a single score, although the company itself suggested the idea of a graphical presentation of results which uses scores for each of the separate elements of the problem. Figure 6.1 provides an example of a fictitious graph for a transfer which performs well in financial terms but relatively poorly in strategic, operations management and marketing terms. This graphical presentation has been given the title of strategic profile.

Figure 6.1 Hypothetical Strategic Profile



The hypothetical strategic profile shows composite scores for the separate elements in the decision. On strategic issues, based on a Likert scale response to a variety of strategic questions, the particular transfer shows a score of between two and three. The score is approximately eight for the financial assessment.

The profile allows the problem to be structured but retains the possibility of applying human judgement in the interpretation of the final result. The management of company A felt that this was important and were concerned that an expert system might take away this element in the decision making process. They were enthusiastic about the degree of structure imposed by the overall strategic profiling structure, stating that value had been added to the overall decision making process. They were equally enthusiastic about their unwillingness to computerise the process by means of expert systems. The general point of view was that the decision required human judgement at the final stage in the process and that expert systems would take that judgement away. By removing human judgement, there was a fear that a legitimacy would be given to the decision which it did not deserve; the problem was inherently judgmental in nature and should not be presented to very senior management as something that could be totally mechanised. There was a fear that Senior Management would "believe" an expert system and that the necessary degree of human judgement would thus be removed from the decision making process.

Given the work that had gone into producing the checklist of questions and the financial spreadsheet model, there was a strong possibility that an expert system could have been developed. The knowledge base that was applied to the transfer problem met the requirement of Partridge (1987) for expert system development.

The questions could have been developed into a series of more or less independent rules and the knowledge base would have been logical, structured and revealed means-ends rationality. Thus there was no technical reason why an expert system was not developed and could not have been beneficial. The point is that the adoption of an expert system by company A would have required social rather than technical acceptability.

The second lesson from this case concerns the role of the spreadsheet. Financial modelling was a vital part of the resolution of the transfer problem and spreadsheet technology met that need more than adequately. The overall problem would thus have been tackled using a combination of spreadsheet technology and expert system technology, had expert systems been acceptable to the management. The use of expert systems alone did not appear to be appropriate.

6.3.2 Company B

Company B is involved in direct marketing. It is a rapidly growing subsidiary of a UK marketing company and has a turnover of approximately £750,000 for the product which was investigated. This gives it the second highest market share behind the market leader. Its management is enthusiastic but not highly knowledgeable or skilled in management accounting terms. Management therefore rely on head office accounting support for systems development.

The problem posed by company B was to investigate the pricing system which had been inherited when the company was taken over by the parent company a few years ago. Normal practice was for company B to bid competitively in order to win contracts. The pricing system was set up as a procedure that was followed but that was little understood. The management requested that the system be reviewed and the project became partly a market research exercise and partly a product costing exercise. Of particular interest was how company B's prices compared with those quoted by competitors, how customers perceived prices and how contracts had performed in profit terms in the past.

Determining the profitability of individual contracts demanded a modelling exercise which shared with the company A investigation a reliance on the use of a modelling approach which had previously been applied to the teaching of operations research (Clark and Finlay, 1991; King, 1988; King, 1989). It combined with that modelling approach an overall objective of developing an activity based costing model (Cooper and Kaplan, 1988). The investigation involved a variety of exercises and interviews with management that led to a predominantly time based calculation of contract cost. Cost was compared with contract price to derive profitability figures.

Both the market research and the product costing exercises confirmed that company B had been under-pricing the majority of its contracts. This was surprising from a management point of view because it was generally believed that the company had been premium pricing to promote a quality image. With the availability of a systematic way of costing contracts, which was provided as part of the project, the company decided to change its pricing procedures. A product costing procedure was made available by means of spreadsheet technology.

There were two elements to all pricing decisions made by the company. The first was procedural and the spreadsheet was intended to replace the previous set of procedures in this respect. This element was largely quantitatively based. The second concerned various qualitative issues which the management collectively referred to as hassle. Hassle led to premium pricing.

Hassle was a term which was much used but which proved impossible to understand. This proved to be a barrier to expert system development because it was impossible to understand the principles by which hassle was converted into value terms. Management merely talked in terms of their feelings towards particular contracts and clients. It is possible that the availability of a more systematic pricing procedure, as provided by the spreadsheet, could lead to a better understanding of hassle in much the same way that Murdoch (1990) provides examples of general information technology to support expert system development. However, at the time of the project, hassle comprised an informal domain (Partridge, 1987) which was typified by interpretation in the light of experience and a personal framework based on subjective opinion. In other words, in the terms established earlier in this thesis, hassle was a non-rational response to managerial decision making.

The lesson to be taken from this case is that an expert system can be used in pricing decisions but will compete with alternative technologies until a greater understanding of the role and nature of qualitative issues in pricing can be forged. The Head Office Accountant was keen for expert systems to be introduced into company B. This would have allowed the necessary management accounting knowledge and skills to be introduced into the management process. However, a spreadsheet solution proved to be adequate. Only with greater understanding of the non-rational aspects of the decision process could an expert system be shown to be advantageous in comparison with a spreadsheet as a suitable application of information technology for this particular pricing decision.

6.3.3 Company C

Company C is a rapidly expanding small business with a turnover of £12 million. It imports timber and acts as a wholesaler for a variety of companies, including some national retail operations. It is largely family dominated, with the Managing Director being a forceful personality whose background has been in marketing. The company partly operates through a joint venture with a Canadian Company.

The Managing Director was confronted by a funding problem as part of a planning and budgeting exercise. The problem arose because the Managing Director was ambitious to expand and believed that expansion was limited only by the availability of funds. Four options to resolve the problem were available at the time the project began.

The first option involved the sale of a proportion of the shares in Company C to the Canadian Company with which Company C was involved in a joint venture. This alternative was attractive because the Canadian Company promised credible access to the Canadian banking system and virtually limitless funding. This alternative did not appear to endanger the independence of company C or its ability to retain its existing employees. However, the Managing Director had experienced difficulties in relationships with the Canadian Company during the operation of the joint venture.

The second option was to sell company C to an Irish Company which would appoint the Managing Director as Chief Executive of the new division which would be formed. This was attractive to the Managing Director in releasing him from personal financial responsibilities but infringed his autonomy and did not guarantee continued employment for the existing employees. Some of the employees had become personal friends of the Managing Director.

The third option was to maintain the company on its present basis and to expand through retained earnings. A financial model suggested that levels of expansion that were acceptable to the Managing Director could be achieved over a five year period. However, the Managing Director was most enthused by immediate expansion.

The final option was for the Managing Director to return to paid employment. This endangered personal autonomy but was attractive in releasing the Managing Director from personal financial responsibilities for operating at the level of operations which he was ambitious to achieve.

The project involved working through the alternatives with the Managing Director in a variety of structured ways. The following approaches were adopted:

- Financial Modelling was carried out to investigate a range of scenarios over a five year period.
- Sensitivity Analysis was applied as part of the modelling operation to determine the key success factors for the company.
- Strategic Profiles were developed for each of the alternatives and were discussed with the Managing Director.

The results of the project were presented to the Managing Director in report form.

In addition to using the report produced by the project, the Managing Director sought legal advice and the advice of one of the major UK accounting partnerships. The advice received from the latter will be discussed in more detail in the next section (section 6.4.3). A Financial Director was also appointed and played a decisive role in determining the outcome. This role will also be discussed more fully in the next section (section 6.4.1).

The basic problem for the Managing Director was that none of the alternatives could be considered entirely satisfactory or entirely unsatisfactory on rational terms. In a sense, the decision was arbitrary to an extent which is abnormal in everyday rational life. A similar situation has been noticed by Thomas (1980) in a technical management accounting problem which has not to this day been entirely satisfactorily resolved; the problem of allocating common costs (one-to-many allocations). Thomas writes (pg.3):

"One-to-many allocations are afflicted with exceptionally severe theoretical difficulties. .... any one-to-many allocation method is just as defensible (or indefensible) theoretically as any other. Because of this, all allocations within this range are incorrigible, a technical term signifying that they can neither be refuted nor verified.

Their incorrigibility renders one-to-many allocations arbitrary to a degree so extreme that we're unaccustomed to it in our ordinary intellectual lives. For it transpires that what's involved here isn't just an unfortunate weakness in the theory, but theory's complete breakdown - Chaos and Old Night."

In this quotation, Thomas is concerned with a procedure adopted within management accountancy rather than a problem confronting a manager and which emerged as part of a management accounting exercise. However, the points raised by Thomas appear to be just as applicable to the situation confronting the Managing Director of company C as they do to a management accountant trying to carry out a sensible allocation of costs. For the Managing Director, each of the alternatives was equally defensible or indefensible in rational terms. There was no possibility of verifying the advantages of one alternative over another or even of verifying the value of an alternative taken on its own terms. The decision became arbitrary to an unexpected degree. In fact, the Managing Director eventually found no basis for making the decision and relied entirely on the opinion of his Financial Director. In this way, the decision was incorrigible from the perspective of the Managing Director.

The type of knowledge used by the Financial Director can be linked back to the non-rational model of decision making developed in the previous chapter. The Financial Director accumulated impressions about the Canadian Company and finally came to a total belief in the advantage of the alternative which they offered. This belief survived the Managing Director's waning enthusiasm for the Canadian alternative. At the end of the project the legal arrangements for the sale of part of company C to the Canadian Company were concluded.

Hewitt (1985) relates the kinds of processes experienced by company B to the nature of open systems, which King and McAulay (1989) show to be one of the critical factors for the successful implementation of information technology in general. From a broader perspective, Tomkins (1991) has more recently provided a summary of the emerging knowledge of the different kinds of rationality which beset managerial decision making. Although the previous chapter developed a dichotomous model of rationality which appeared to fit the data well, it would seem that a broader view suggests a variety of rationalities. In some cases it may be possible that non rational problem solving provides the only basis for determining a course of action, as in the case of Company C. However, a type of rationality which is necessary to resolve a managerial problem may not be appropriate for expert system development.

6.4 Types of knowledge revealed by the case studies

The previous section suggested that there may be alternative forms of rationality which are pertinent to management accounting and suggested that the dichotomous model of expertise developed in the previous chapter might need to be further developed. This section takes the data provided by the cases as a basis for a model which seeks to expand the previously developed models of rationality. Different types of management accounting knowledge are considered.

Four types of knowledge emerge from an analysis of the case study data. These are given specific terms and connotations within the confines of this research and are each explained in the next subsections. The four types of knowledge observed in the case studies have been categorised as: *expert knowledge, facilitator knowledge, adviser knowledge and academic knowledge.*

6.4.1 Expert knowledge

Expert knowledge is that which is commonly discussed in the expert system literature in relation to the human expert. *Experts* manipulate substantial volumes of domain specific information (Harmon and King, 1985). The use of heuristics allows the substantial problem spaces which they confront to be reduced to manageable proportions (Rich, 1983). However, although they use heuristics to reduce the inherent problem space aspect of the tasks they confront, there is no evidence to conclusively show that their cognitive maps conform to problem space representations. Indeed, there is a literature which suggests that their behaviour is consistent with the non-rational model of expertise developed in chapter 5. *Experts* respond to problems through intuition and experience so that, as Dreyfus and Dreyfus (1986) suggest:

"when things are proceeding normally, experts don't solve problems and don't make decisions: they do what normally works. They don't rationalise "what normally works" but respond through intuition and personal experience."

The knowledge *experts* use could be said to be compiled (Black, 1986; Berliner, 1987) in the sense that computer programmes are compiled. The knowledge is efficient from the point of view of the user of the knowledge base but is opaque to outsiders. Black (1986) makes this point as follows:

"even where there is a complete scientific model of the underlying process, the expert does not need to apply the model process each time a diagnosis is required. The association between cause and consequence may be said to be compiled in the expert's mind."

Conceptual models are used in the form of scripts (knowledge of specific contexts, equivalent to the restaurant script, for instance, which is used by restaurant goers to direct their actions) and schema (mental models of the world). Lord and Foti (1986) relate scripts and schema to the broader aspects of managerial behaviour and Choo (1989) discusses scripts in an accounting context. Berliner (1987) addresses the issues of scripts and schema in a discussion of teaching expertise and adds that a part of expertise is concerned with knowing situations before they are met. Experience, scripts and schema allow the expert educator to almost know the group to be taught before meeting them. Unfortunately *expertise* is not without its drawbacks. As in the case of the representative and availability heuristics (chapter 5), *expertise* may be associated with bias (Macintosh, 1985; Jacob et al, 1986), as *experts* may apply preconceived biases when confronted with problems.

Company C provides an example of the types of scripts which can be used in management accounting situations. The Managing Director used a number of statements when reasoning through his funding problem. These statements included:

1 Do not enter into agreements with a 50:50 share of ownership.

2 Guaranteeing future employment for employees is secondary to securing the future of the business.

3 Supply depends on the ability to buy on a cash basis.

The Managing Director was unable to justify or explain such statements but was able to use them in negotiations with the Canadian and Irish companies. The statements resulted from a variety of contacts, including discussions with legal and financial advisers, suppliers and competitors.

The Financial Director of company C appeared to form his evaluation of the funding alternatives based on the accumulation of impressions. His justification for the selection of the Canadian alternative was difficult to obtain and the only statement that was forthcoming was as follows:

"The Canadian people are good, but we might do a deal with X, if he can find more money, because he is better. X can source more [commodity] before breakfast than the Canadians can manage in a day. But he hasn't got a backer."

This statement derived from a personal visit to Canada where the Financial Director met the Canadian company directors and others associated with the industry. For the Financial Director, the Canadians were significantly more impressive than the Irish Directors and were only less impressive than a third party who could not obtain the sort of funding that company C was looking for. The Financial Director was impressed by the ability of companies to secure access to, or source, the commodity.

Company A revealed a problem of *expert* knowledge in relation to knowledge elicitation. Interviews were used in the initial stages of the project in order to reach an understanding of the detail of the management problem. The difficulty was that these interviews produced a mass of detailed company specific knowledge which was opaque to the researcher. This appears to be reasonably typical of interviews with *experts* (O'Neill and Morris, 1989). It proved to be impossible to disentangle the knowledge states and linkages in the transcripts provided by the *experts* in company C without recourse to *academic knowledge*, as discussed later in section 6.4.4, so that a coherent picture in problem space terms failed to materialise at the initial interview stage. Given this finding, it would seem that *expert* knowledge provides a major challenge to the adoption of expert systems in management accounting.

6.4.2 Facilitator knowledge

One of the advantages of *expert* knowledge is that it creates actions. *Facilitator* knowledge shares this characteristic. *Facilitator* knowledge differs from *expert* knowledge in that it makes explicit the units of knowledge and linkages between units of knowledge. It might therefore be expressed in problem space terms.

The strategic profile developed for company A is an example of *facilitator* knowledge. Actions to accept or reject a transfer of production result directly from judgements indicated by the checklist of questions and financial analysis. The checklist comprises a knowledge base representing a knowledge state relevant to the transfer problem. Responses to the questions act as operators to transform the generalised series of questions into a specific series of measurements which are based on Likert scales and which are relevant to the particular decision.

The spreadsheet that was developed for company B also made a knowledge base relevant to the pricing decision transparent. The spreadsheet comprised *facilitator* knowledge because it too could be used to create actions, this time on pricing, once judgements had been applied. However, the knowledge base was somewhat different to that used in company A's strategic profiling for the reason that it was quantitative in nature. A spreadsheet solution to the quantitative aspects of pricing was a natural and effective response to the problem.

The strategic profile comprised a class of problem solving tool for which expert systems could be developed because the relevant states of knowledge and operators were explicit. However, the use of spreadsheet, third generation language or expert system appeared to be governed in this case by the way in which responses from the human user were to be solicited. For company A, responses were quantified by means of Likert scales. Qualitative and symbolic responses could have been built into the system and had this been done then the resultant system would have been suitably implemented in expert system form.

To process Likert scales required a weighting approach which can be theoretically related to multiple criteria decision making (Zeleny, 1982). To process symbolic responses required that the knowledge base be developed to include the combinations of questions and responses which would need to be stated in rule form. These grow as an exponential function. It is possibly not surprising therefore that the researcher chose to work with a relatively finite weighting scheme which was quickly implemented in a spreadsheet rather than determining the combinations of questions and responses which would be necessary to define the knowledge base in expert system form.

Thus *facilitator* knowledge could be expressed in problem space terms and could be coded by means of expert system technology. However, there were alternative ways of processing the knowledge states and in the case of company A the researcher found it more convenient to use multiple criteria decision making as a theoretical base. This particular debate is reflected in the contrasting works of Finlay and King (1989), Wise and Kosey (1986,a; 1986,b) considered in the literature survey (section 2.4.6). Finlay and King and Wise and Kosey found that it was more effective to state their knowledge base in multiple criteria decision making form when they experienced problems with a knowledge base in expert system form. Olave et al found it more convenient to convert to an expert system form because they claimed that determining weightings proved to be a bottleneck. The present research data based on company A suggests that in practice a multiple criteria decision making approach is more convenient than an expert system approach for *facilitator* knowledge.

6.4.3 Adviser knowledge

Adviser knowledge differs from both *expert* and *facilitator* knowledge in that it did not create actions. It provided a basis from which further knowledge could be developed which could itself direct actions. It shared with *expert* knowledge the use of compiled knowledge.

Company C provides an example. The financial adviser provided an input to the decision making process in the form of a report which gave a valuation of the company. The report began with a brief statement that alternative valuation bases were available. A single base was chosen, the P/E ratio approach, but no justification was provided for this choice. The link between the knowledge state which comprises the set of alternatives available and the alternative which was selected was therefore opaque. A relevant value of P/E was chosen using a table of normal P/E values for different industries and a series of calculations were presented which gave rise to a valuation. A part of the calculation indicated the use of a heuristic that reduced the value of the business by 25% because it was not listed on the stock exchange. This valuation procedure was used by the Irish Company in arriving at its offer price, but changes were made to the basic parameters used in the calculations. For instance, the Irish company used a P/E ratio of 6 where a P/E ratio of 8 was used in the original calculation. *Adviser* knowledge was therefore useful in so far as it could be followed by different parties and adapted to meet different requirements.

The lack of transparency in the linkages between knowledge states implies difficulties in generating explanations for the knowledge base of *adviser* knowledge. The human experts simply did not find it necessary to explain their own reasonings. The model of an expert system which suggests that the technology should be able to provide explanations, as shown in the literature chapter (section 2.2) may therefore be naive. Additionally, expert systems explanation facilities have been found to be lacking (Alty, 1987; O'Neill and Morris, 1989) so that the question of the importance of explanation facilities to the core definition of expert systems must be seriously questioned.

Additionally, the knowledge comprised quantitative elements and qualitative elements. The actual calculation could easily have been represented by a spreadsheet and there seem to be few reasons to incorporate such calculations into an expert system. An expert system might be appropriate for the selection of valuation basis, but *adviser* knowledge provided few insights to help in such a development because of the compiled nature of the knowledge that was applied.

There is evidence of expert systems which fulfil an advisory role in management and accountancy (eg. Connell, 1987; Ernst, 1988; Edwards and Connell, 1989). However, the evidence provided from the present research suggests that *adviser* expertise is not the most suitable source of knowledge for such systems. In fact, it was found that knowledge of the kind discussed in the next section could be a more sound basis for expert system development.

6.4.4 Academic knowledge

Academic knowledge shares with *facilitator* knowledge transparency of knowledge states and linkages. It differs from *facilitator* knowledge and shares with *adviser* knowledge the characteristic that it does not directly create actions.

When interviews failed to allow the researcher to make progress at company A, the problem of the transfer was related to a portion of the existing managerial literature (Anthony et al, 1984, Arnold and Hope, 1983; Emmanuel and Otley, 1985; Johnson and Scholes, 1988; Hill, 1983; Kotler, 1984; Porter, 1985; Sizer, 1989). This literature was used to frame basic questions concerning such matters as customers' requirements, economies of scale, flexibility to change, risk, market share, production capacities, quality and costs. Once the basic knowledge base was in place, the taped interviews with managers were reviewed and in this way *academic* knowledge was converted into *facilitator* knowledge.

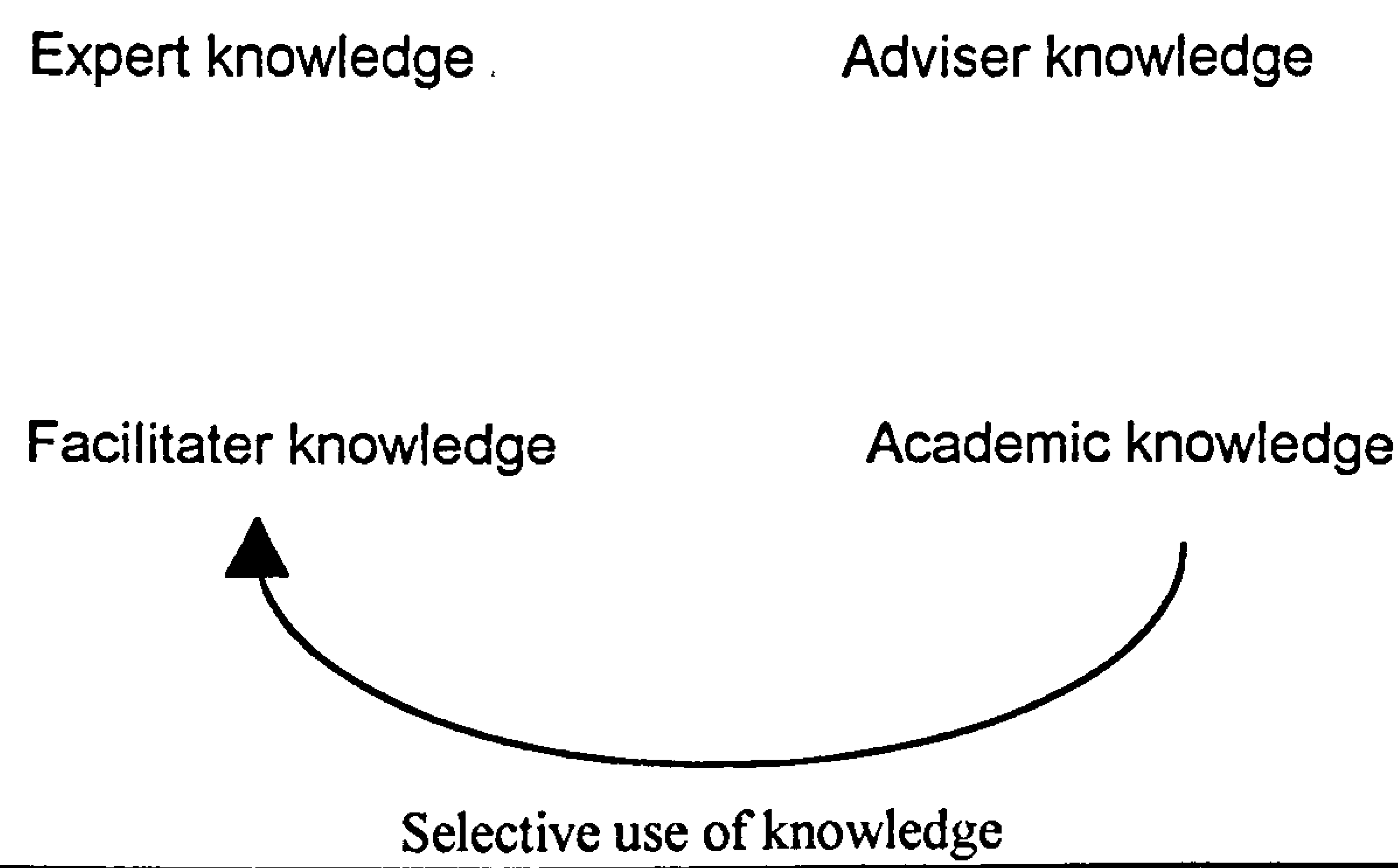
This process is illustrated in a general management example by Mockler (1989), who describes a problem of corporate strategy. An expert system was produced in this case. The expert system works on the basis that if specific industry type, company, competition and market conditions are present, then a certain type of strategy might be worthy of consideration. The expert system is based on Porter (1980), Porter (1985) and Hammermesh (1986). Similarly, a small amount of the literature on management accounting expert systems explicitly acknowledge the contribution of literature to their development (eg. Dilts and Turowski, 1989, section 2.4.2).

The evidence presented here therefore suggests that *academic* knowledge provides a suitable basis for the development of expert systems. Unfortunately, social factors and the availability of more convenient ways of processing knowledge states mitigated against the use of expert systems in the case of company A so further work is needed to provide more evidence on this finding. The next chapter develops this further.

6.5 Discussion

The lack of transparency in the knowledge states and operators given by the compiled nature of *expert* knowledge appears to suggest that there are more suitable types of expert knowledge which could be used as a basis for expert system development in management accountancy. Similarly, *adviser* knowledge presents difficulties because of the compiled nature of its knowledge base. Alternatively, it has been argued that *facilitator* and *academic* knowledge, by making knowledge states and operators transparent, can be represented in expert systems form assuming that no other barriers to the adoption of expert systems are evident. The evidence of case A suggests that *academic* knowledge can be converted into *facilitator* knowledge and that such knowledge could be presented in expert systems form. Figure 6.2 presents an interpretation of this.

Figure 6.2 Types of knowledge discerned from case studies



Expert knowledge and *adviser* knowledge are grouped horizontally because they share the characteristic of compiled knowledge. *Facilitator* knowledge and *academic* knowledge are grouped horizontally because they share the characteristic that they might be conveniently used to construct expert systems in management accounting. The arrow shows that for one of the cases a suitable system might have been developed where a selective use of *academic* knowledge was used to develop *facilitator* knowledge.

The horizontal grouping represents on the one hand compiled knowledge and on the other the characteristic that knowledge states are transparent and linkages between knowledge states can be drawn. A more convenient term exists for the second type of knowledge and is provided by Wenger (1987). Wenger (1987) suggest the term articulated knowledge, which he contrasts with compiled knowledge.

The vertical grouping also provides a contrast in that *expert* and *facilitator* knowledge types are actionable whilst *adviser* and *academic* knowledge need to be adapted in order to create actions. Figure 6.3 shows this relationship between the four types of knowledge.

Figure 6.3 Grid to show the knowledge types

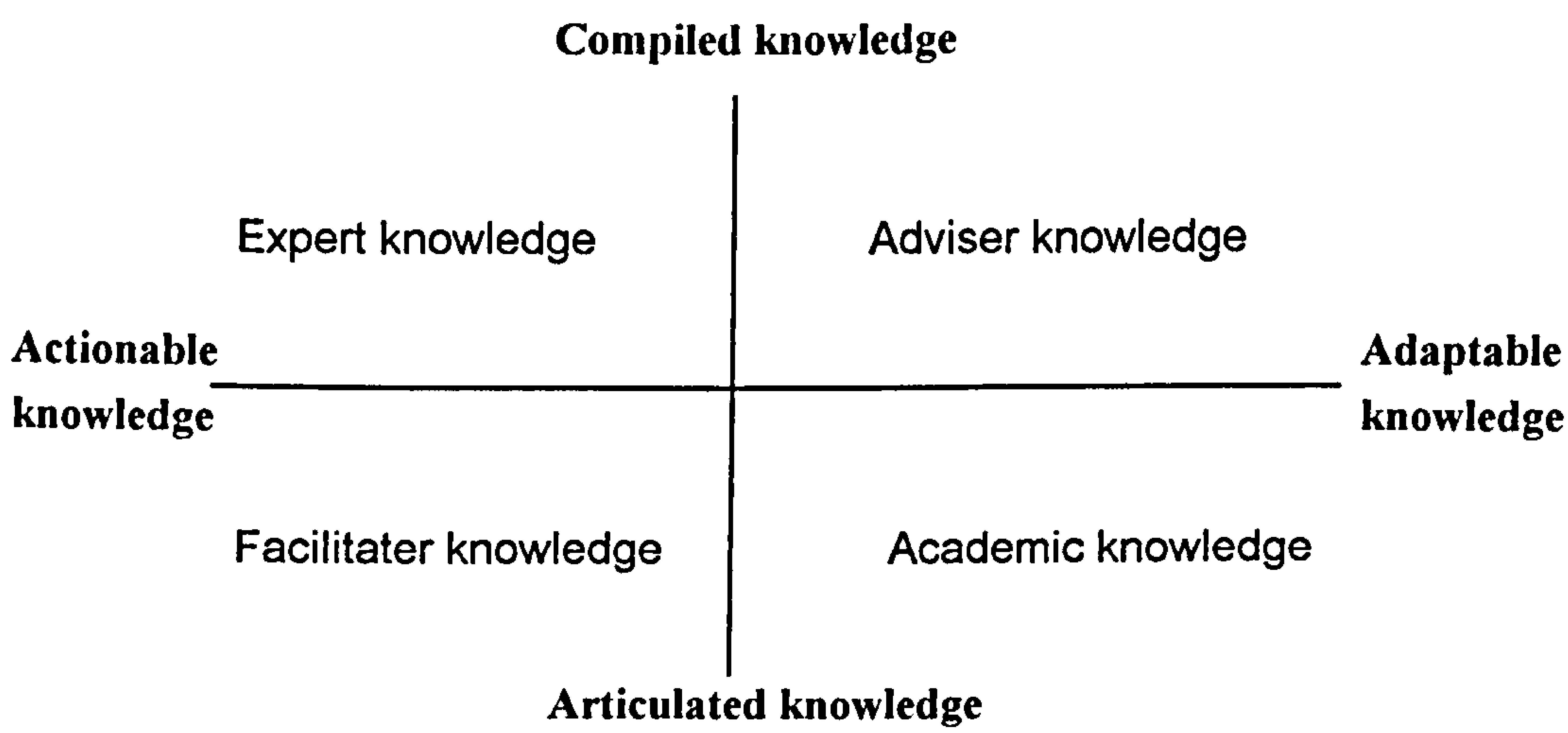


Figure 6.3 shows *expert* knowledge to be diametrically opposite to *academic* knowledge. *Expert* knowledge appears to be closely related to the non rational model of expertise that was developed in the previous chapter. *Academic* knowledge may be close to the rational model of expertise. The grid therefore explains the four types of knowledge discerned in the case studies and appears to provide some consistency with the model developed in the previous chapter. The case study work therefore provides findings which are consistent with and extend the findings of the protocol analysis work.

Expert knowledge was related earlier to the existing literature of expert systems and was shown to be consistent with the non rational model of management accounting expertise. So far, it has been suggested that *academic* knowledge might be related to the rational model of expertise but this idea has not been particularly fully developed either in terms of relating the case study findings to literature of to the protocol analysis findings. The reason for this is the difficulty of relating a large and varied body of academic knowledge to the development of expert systems in a convincing way. The next chapter takes a specific area of management accountancy and describes the findings made when an expert system was developed from *academic* knowledge.

Chapter 7

Building an Expert system

7.1 Introduction

The previous chapter reported on the different kinds of knowledge found in a case study of management accounting expertise. Various barriers to the development of expert systems as problem solving tools were encountered. However, some encouragement was provided by the possibility that some kinds of management accounting expertise might yield expert systems. This chapter explores that possibility by reporting on the experiences of converting *academic* knowledge into a working expert system.

The previous chapter showed that there are a variety of reasons for the non-adoption of expert systems in organisational contexts. It is also initially difficult to see how an expert system could be developed for management accounting as a whole, especially given that the available literature shows the development of systems for specific topics. In addition, the general literature on expert systems suggests that expert systems succeed where a narrow area of expertise is

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King, M. and McAulay, L., (1991), 'Experiments with Expert Systems in Management Education', Journal of Information Technology, 6, 34-38.

King, M. and McAulay, L., (1991), 'A Standard Costing Knowledge Base: Building and Using Expert Systems in Management Accounting Education', Issues in Accounting Education, 6(1), 97-111.

King, M. and McAulay, L., (1992), 'Simple Expert Systems for Computer Assisted Instruction', in G.I. Doukidis and R.J. Paul, (Editors), Artificial Intelligence in Operational Research, Basingstoke: Macmillan, pp. 105-114.

addressed. The starting point for the system reported here was therefore to focus on a specific aspect of management accountancy and to choose a context where the system could feasibly provide benefits. Having shown the experiences gained from developing a system for a narrow area of management accountancy, the aim will then be to attempt to relate those experiences to management accountancy as a whole.

This chapter explains the choice of application, establishes a framework for the application in terms of *academic* knowledge and then proceeds to describe the expert system that was developed. The findings are presented and a final section discusses the experience gained from this part of the research.

7.2 Selection of application

The application context is that of education. The initial chapter suggested that expert systems could be valuable in education and established a proposition calling for investigation in this area. Education is an interesting applications area which has produced a debate in the expert system literature. Duchastel and Imbeau (1988) and Beech (1986) are enthusiastic about the potential of expert systems to make a contribution to education whilst Ramsden (1987) suggests that there is more to learning than asking students to replicate expert processes. Clancey (1988) supports this, stating that "expert systems often reflect the expert's automatic way of thinking, without the articulation and abstraction ... useful in teaching". There seems to be scope to take advantage of the finding that experts, possibly including lecturers, can build expert systems for themselves (Harmon and King, 1985; King, 1989), a point which is important to gain acceptance of technology in the classroom

(Coleman, 1985). Within the context of Intelligent Computer Assisted Learning, expert systems may have a role to play in one of the four interacting modules outlined by Barr and Feigenbaum (1982); knowledge of the domain to be taught.

The initial location for the research was Derbyshire College of Higher Education. An opportunity arose to develop and use an expert system at the College for one of the areas of management accountancy for which expert systems have been developed, standard costing. The literature survey chapter showed that the investigation of variances problem, one aspect of standard costing, is an application which has received attention (section 2.4.5). Observation of lecturers at the College showed that two out of four aspects of the knowledge domain module defined by Bumbaka (1988) were evident in teaching expertise: knowledge was imparted to students and problems were generated and the correctness of student's responses were assessed. Therefore, the research project set out to develop an expert system for the teaching of standard costing by allowing students to improve their knowledge and to have access to problems and solutions.

7.3 Standard costing: an analysis of *Academic* knowledge

Scapens (1991) has coined the term "conventional wisdom" to describe text book knowledge of management accountancy. The term conventional wisdom will therefore be considered to embrace *academic* knowledge of standard costing.

There is agreement within the conventional wisdom on the general scope and nature of standard costing. Conventional wisdom sees standard costing as a negative feedback or cybernetic control system. There are three elements to standard costing: standard product costs are ascertained, variances are calculated and some variances are investigated with the intention of taking corrective action where necessary. Standard product costs are established to show projected or target costings for products in a particular range and can be incorporated into budgeting. Actual results are extracted from financial records and are compared with the standards to provide a calculation of variances, or differences between actual results and targets determined in accordance with standards. Variances are interpreted in the light of possible causes and decisions are taken to investigate certain variances, with the pay-off of correcting a process operation where it is out of control.

Standard product costing is generally considered to be straightforward for the expert accountant (Pizzey, 1987; Emmanuel and Otley, 1985), although a minority of authorities see some difficulties in this area (eg. Corcoran, 1978). Product costs can only be developed in one of two ways, the engineering estimate or through historical data analysis (Morse, 1978, Kollaritsch, 1979). The alternative approaches are therefore limited in number. Standards are not revised often (Matz and Usry, 1976, Corcoran 1978). There does not appear to be any interest in developing expert systems to assist in the development of standard product costs and the experience of product costings reflected in the case studies suggested that spreadsheets would be entirely appropriate for this largely quantitatively based task.

There are some choices about the way in which variances can be calculated, for instance, in relation to overheads (Solomons, 1972) or the point at which the price variance is extracted (Hartley, 1983), but in basic terms, the variance calculation is well understood within the conventional wisdom. The conventional wisdom adopts a number of approaches to the representation of knowledge of standard costing variance analysis calculations, as summarised in figure 7.1., which shows the approaches used by a range of standard texts available in libraries in Higher Education.

Figure 7.1 shows that there are four basic ways of representing knowledge about variance calculations. The four methods, represented by headings in the figure, comprise a formula approach, a general methodology (this term is used by Horngren, one of the authorities listed in the figure), a mathematical approach and a graphical approach. The majority of authors present knowledge according to a formula approach or a general analysis approach.

Figure 7.2 shows an example to illustrate these four different approaches to the representation of knowledge. The figure shows the same basic example being used to create the same solution in four different ways. The method which at first sight provides a different answer is the mathematical analysis method. However, by combining terms, the same price and usage variances result if the figure of £50 adverse is combined with the figure of £250 favourable.

Figure 7.1 Analysis of approaches to the explanation of variance analysis provided by the conventional wisdom

	Formula	General Analysis	Maths. Analysis	Diagram. Analysis
Batty, 1974	*			
Corcoran, 1978			*	
Crowningshield and Gorman, 1979	*			
Dopuch, Birnberg and Demski, 1982		*		*
Drury, 1992	*			
Glautier and Underdown, 1988		*		
Hartley, 1983	*	*		*
Horngren, 1974	*	*		
Horngren, 1982	*	*		
Horngren, 1984	*	*		
Horngren and Foster, 1987	*	*		*
Inman, 1988	*			
Kaplan, 1982	*			
Killough and Leininger, 1977	*			
Kollaritsch, 1979	*	*		
Layne and Rickwood, 1984		*		
Leininger and Killough, 1984	*			
Louderback and Dominiak, 1978	*	*		
Louderback and Hirsch, 1982	*			
Magee, 1986			*	
Matz and Usry, 1976		*		
Moore, Jaedicke and Anderson, 1984	*			
Montgomery, 1979	*			
Morse, 1978		*		*
Morse, Davis and Hartgraves, 1984	*	*		*
Murphy, 1985	*			
Nelson and Miller, 1977	*			*
Norgaard, 1985	*	*		
Owler and Brown, 1978	*			
Pizzey, 1987	*			
Schattke and Jensen, 1981		*		
Schmiedicke and Nagy, 1983		*		
Simpson, 1979	*	*		
Thacker and Ellis, 1981	*			
Thornton, 1978	*			*
Titard, 1983		*		
Tubb, 1979	*			
Wald, 1978	*			*
Wilson and Chua, 1993	*			

Figure 7.2 Variance analysis example to illustrate the different forms of knowledge representation provided by the conventional wisdom.

Example: One unit of production requires 3kg of raw materials priced at £2 per kg. During last month, 1,000 units were produced, using 2,900 kg of raw material at £2.50 per kg.

Formula approach:

Price variance = 2,900 (2 - 2.50) = £1,450 adverse.
Usage variance = 2 (3,000 - 2,900) = £200 favourable.

General analysis approach:

Inputs: Raw material cost	2,900 kg @ £2.50/kg	£7,250
Raw materials at standard prices	2,900 kg @ £2.00/kg	£ 5,800
Output: Production at standard cost:	1,000 units x 3kg @ £2/kg	£6,000

Variances: Price variance (5,800 - 7,250) £1,450 adv.
Usage variance (6,000 - 5,800) £200 fav.

Mathematical analysis approach:

let p = price paid
q = quantity used

vp = variance in price

vq = variance in quantity

then: materials cost = p x q

standard materials cost = (p + vp)(q + vq)

materials cost variance = (p + vp)(q + vq) - p x q

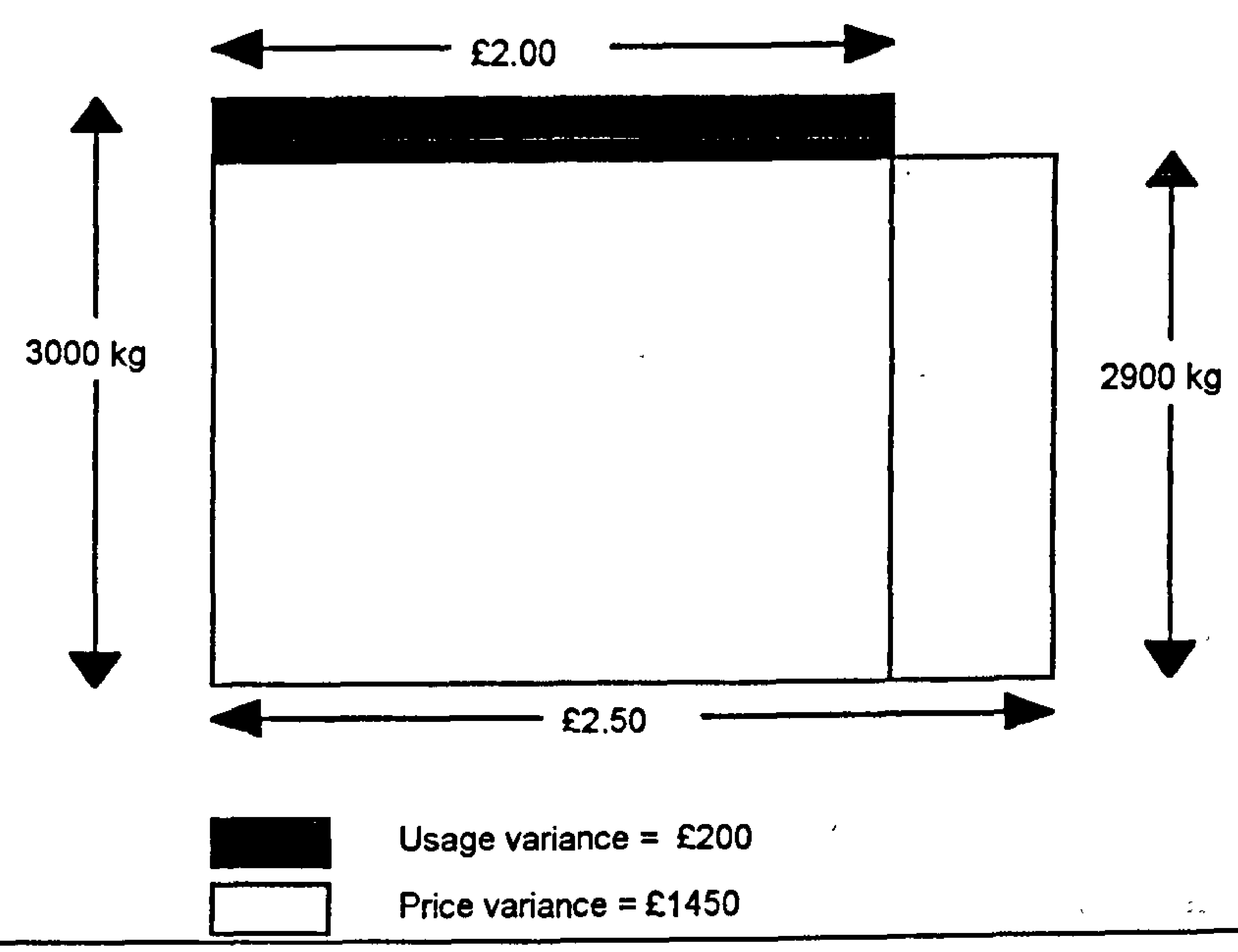
= p x vq + q x vp + vp x vq

substituting values from the example:

materials cost variance = 2.50x100 + 2900x -0.50 + 100x -0.50

= 250 fav. + 1,450adv. + 50adv.

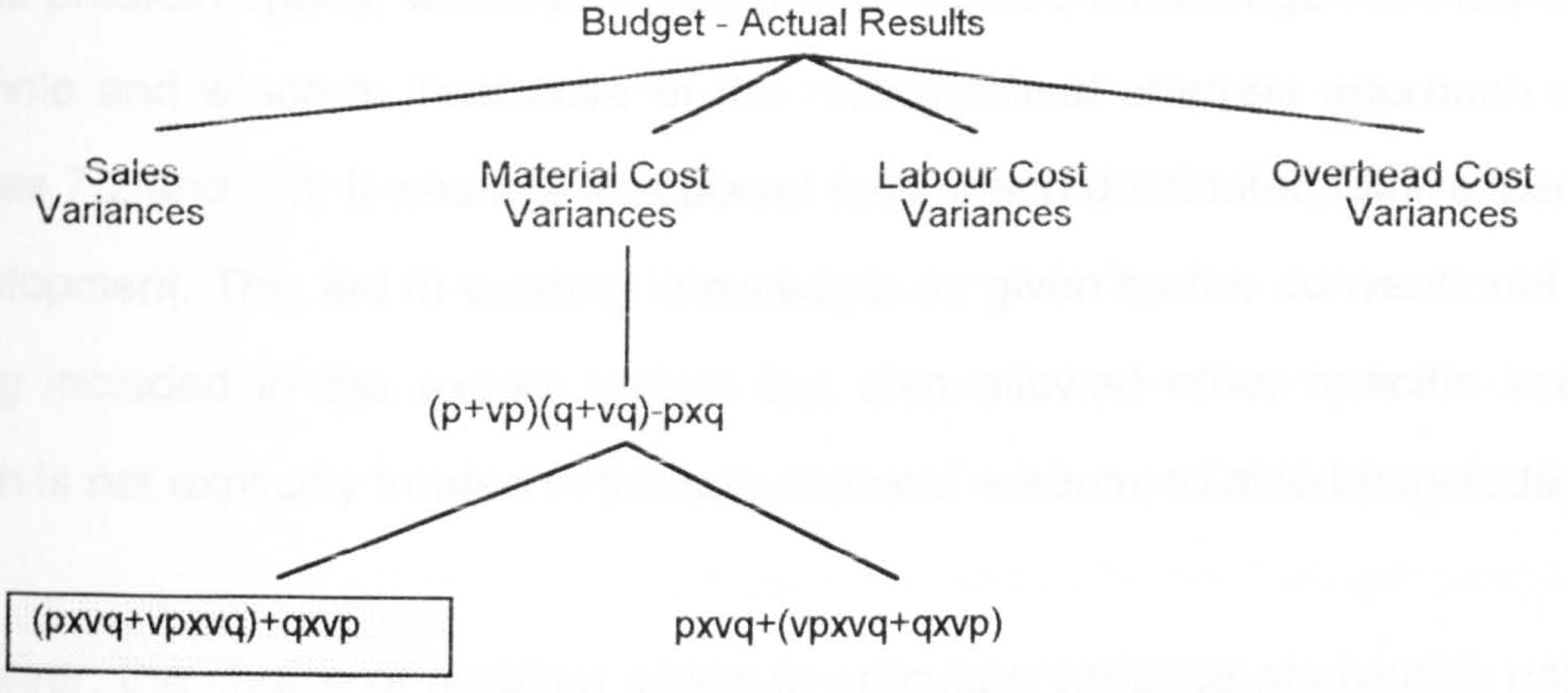
Diagrammatic analysis approach:



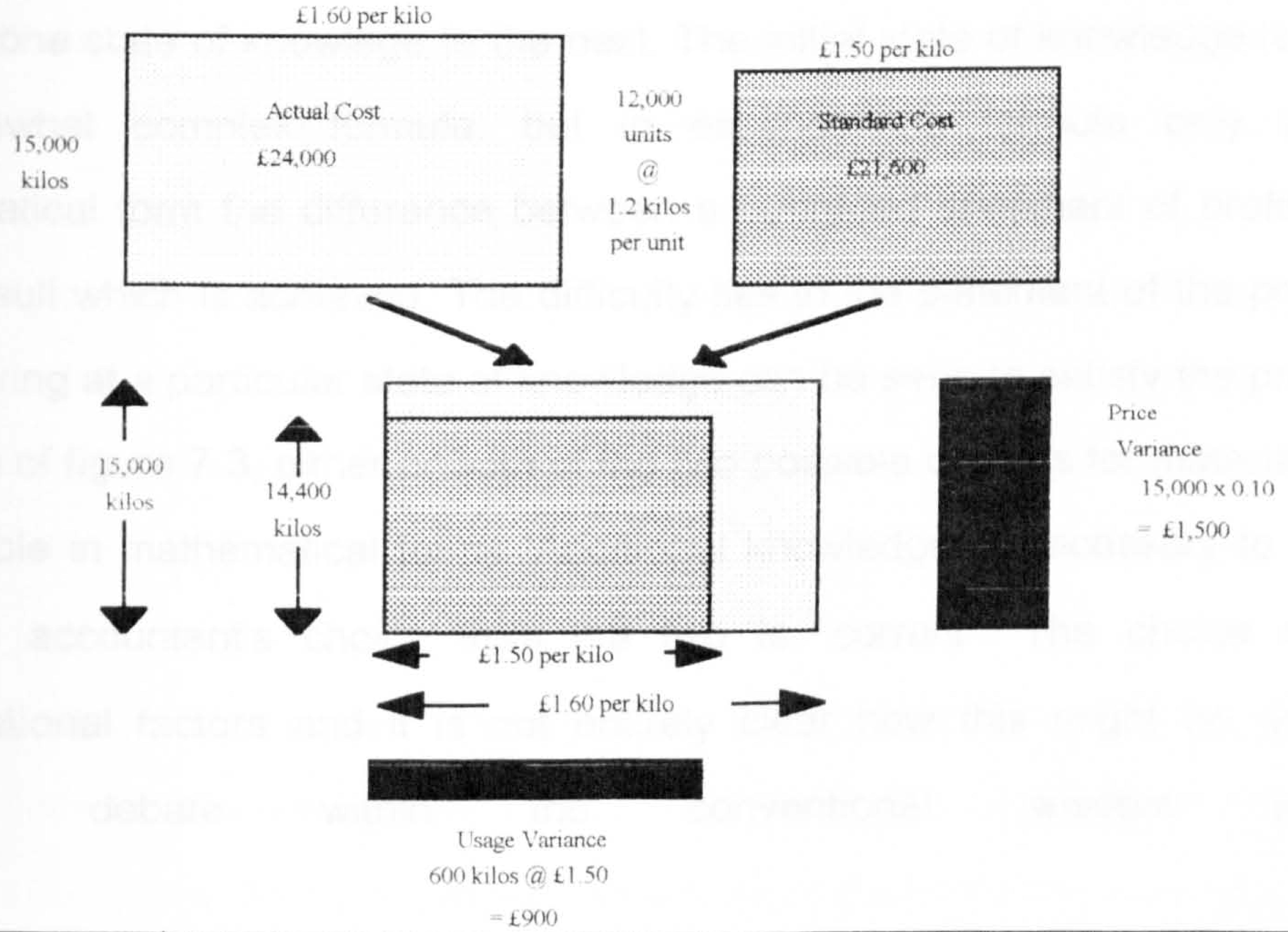
Analysis carried out by the author has revealed that mathematical analysis for the complete knowledge base of variance analysis can be expressed in problem space terms. The initial state of knowledge is given by financial profit and loss relationships between financial accounting results, budgeted profit statements and standard product costs. The initial state can be stated in mathematical terms. Mathematical operators are used to define the problem space. The problem space itself contains the traditional variances as shown in the conventional wisdom of management accounting and others. Some of the other variances are potentially valuable but many would simply be taken by accountants to be erroneous. The problem space is interesting in making explicit a broader range of knowledge than that revealed by the conventional wisdom. The process of articulating the problem space for variance analysis is illustrated in the working papers in appendix C and is illustrated in a simplfied form in figure 7.3.

The general point, that variance analysis can be expressed in problem space terms, is the point of concern. The value in adopting the rigour that a problem space construction requires is making explicit a variety of assumptions that are often taken for granted in the conventional wisdom of management accountancy. So, for instance, the "corner problem" which is explicitly accounted for by considering the two ways of combining terms for the mathematical derivation of material costs and which is evident in the diagramatic representation given in figure 7.3 is easily missed in the treatments illustrated in figure 7.2. There are other, more technical management accounting problems which become apparent upon a very close reading of the working papers in appendix C. The value of the problem space representation becomes more evident when the numerous relationships associated with multi-product, multi-resourse situations which include stock complications are considered.

Figure 7.3 The problem space of variance analysis for a single product



In diagrammatic form, using the example of a actual cost of 15,000 kilos @ £1.60 per kilo and a standard cost of 12,000 kilos @ £1.50 per kilo, the management accountant's solution, which is shaded in the problem space above, can be shown as:



In fact, it can be shown that the formulae and general methodology forms of knowledge representation as illustrated in figure 7.2 are merely compiled versions of the problem space, which provides the articulated knowledge for the problem as a whole and which is illustrative of the mathematical analysis approach shown in figures 7.2 and 7.3. It was this articulated form which dominated later expert system development. This led to existing knowledge, as given by the conventional wisdom, being included in the expert system but also allowed other specific knowledge, which is not explicitly treated in the conventional wisdom, to also be included.

However, the choice of problem space to articulate variance analysis is not without its difficulties. A problem space imples a problem, states of knowledge and operators. The states of knowledge within the problem space of variance analysis are clear, as is the fact that basic mathematics can represent the operators which change one state of knowlege to the next. The initial state of knowledge is given by a somewhat complex formula, but in essence the formula only states in mathematical form the difference between a budgeted statement of profit and the profit result which is achieved. The difficulty lies in the statement of the problem so that arriving at a particular state of knowledge can be seen to satisfy the problem. In the case of figure 7.3, either or both of the two possible choices for materials cost is acceptable in mathematical terms. Additional knowledge is necessary to establish that the accountant's choice from the two is "correct". The choice relies on organisational factors and it is not entirely clear how this might be done. The detailed debate within the conventional wisdom is not entirely convincing to the author and will not be persued further here, other than illustrating the issue by quoting the way in which Drury (1993, pp.518-519) explains this issue:

"[The price variance] *is of little consequence if the excess purchase price has been paid only for a small number of units of purchases. But the consequences are important if the excess purchase price has been paid for a large number of units, since the effect on the variance will be greater. The difference between the standard material price and the actual material price per unit should therefore be multiplied by the quantity of materials purchased. .... Should the standard material price per kg. or the actual material price per kg. be used to calculate the* [usage] *variance? The variance is the standard price. If the actual material price is used, the usage variance will be affected by the efficiency of the purchasing department, since any excess purchase price will be assigned to the excess usage."*

The calculation of variances is not an obvious choice for expert system development because it is largely quantitatively based. However, the conventional wisdom addresses this aspect of standard costing more fully than any other and the availability of alternative ways of representing the knowledge base of the area made it an interesting topic to follow up. Additionally, variance analysis is a difficult subject area for students (Schank and Churchill, 1982) and might be an area where students would appreciate additional support.

The final stage in standard costing is to take corrective action based on an interpretation and investigation of the variances. A variety of techniques are available (Scapens, 1985). An expert system might therefore be developed to select an appropriate technique. However, the existing literature has concentrated on isolating variances which are worthy of investigation rather than making a recommendation for the choice of technique (section 2.4.5). The investigation of variances and particularly the decision as to which variances to investigate is clearly an area where expert system development could proceed.

7.4 Pre-development findings

Appendix C is the working papers and the printed text files of programme code which was generated for the project. The appendix contains details of the pre-development work that was carried out. This includes:

- The completion of a questionnaire by professional accounting students to assess their attitudes towards the expertise of accounting teaching.
- The development of a knowledge base which presents the results of variance analysis calculations and provides an explanation facility for use by students. The knowledge base was coded in Prolog.
- The development of a knowledge base which provides an interpretation of the results of variance calculations. The knowledge base was coded in two expert systems shell: VP Expert and Savoir.
- An abortive attempt to adopt LPA Prolog in order to gain advantage of the input/output facilities offered by the package.

Detailed considerations are presented in the appendix.

In general, the results of this series of preliminary investigations suggested that there was interest from both students and lecturers in a system which could present the solutions to variance analysis examination questions. Somewhat surprisingly, there was absolutely no interest from lecturers in a system which could interpret variances, the area where prior expert system development had occurred. For this reason, further work in this area was abandoned and efforts were concentrated on developing an expert system which might assist students by providing support in calculating variances.

7.5 Description of the expert system variance analysis prototype

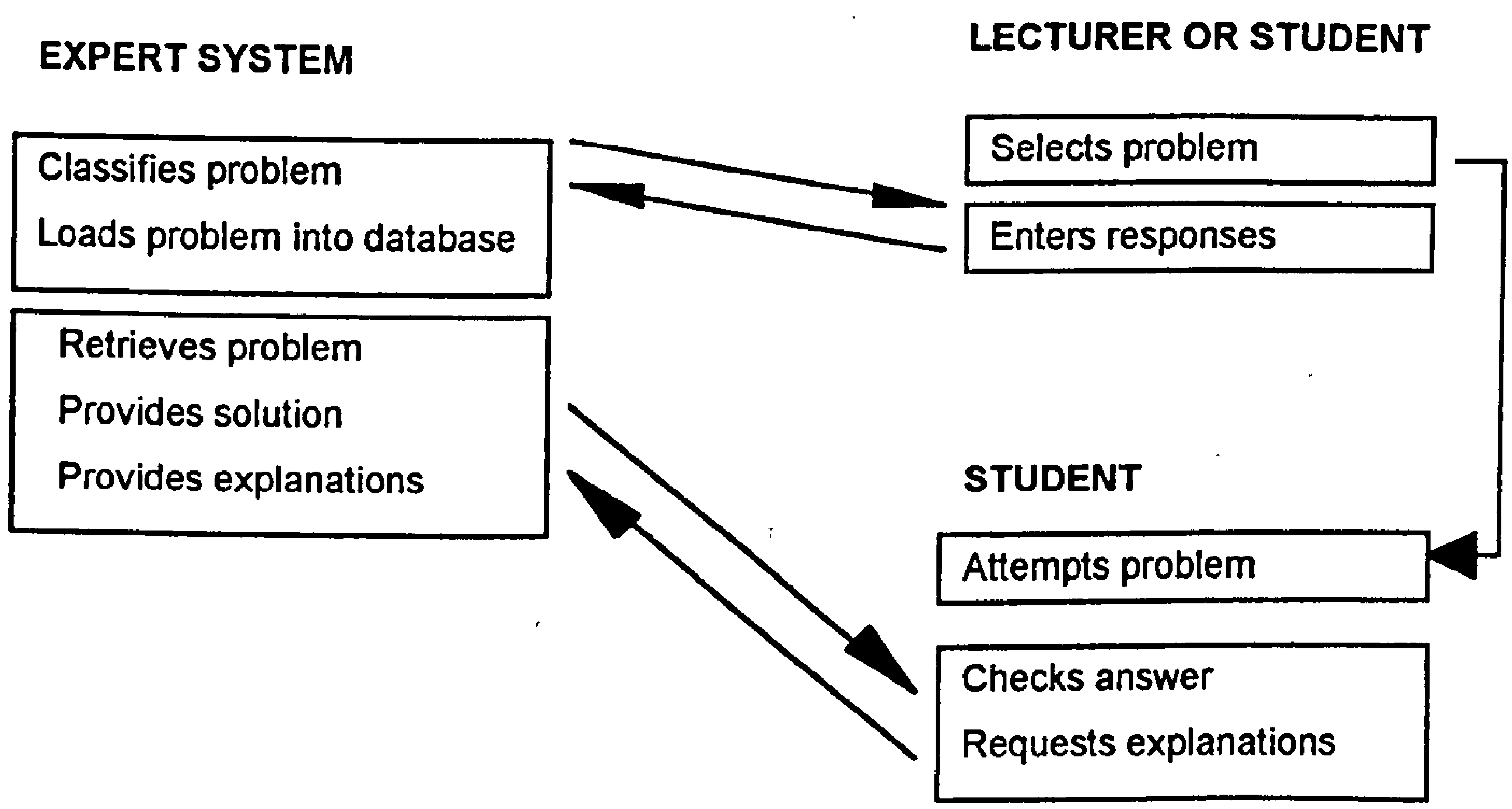
An expert system variance analysis prototype was developed from the pre-development phase because a reasonable chance of successful expert system development was apparent. Using the well established criteria for expert system success, including Wolfgram et al (1987), the project proceeded for the following specific reasons:

- *Academic* knowledge had been established to the point at which a good consensus seemed to exist. This does not appear to be true of all areas of management accountancy.
- A useful and relatively limited area could be initially defined for development with the prospect that the knowledge coded could expand.
- Groups of students existed for whom the product could expect to be valuable.
- Lecturers appeared to be enthusiastic about the potential time savings that could be made by using the product so that benefits were readilty apparent.

Prolog was used in the first stage of the programme because of the facilities it provides and the ability to prototype rapidly (Sugaya, 1987; Bratko, 1986; Hammond, 1987). It posed some problems, particularly in terms of its relatively unattractive and unnecessarily difficult input/output demands. An expert system shell was eventually preferred. However, it was the Prolog version that was used in classroom situations and was used by students in independent study. King and McAulay (1991) provides full details. The level of available resources affect the adoption of computing into the curriculum in general (Borthwick and Clark, 1987) and resources were limited at the research site. Of the shells that were available, VP Expert was chosen. VP Expert is a relatively simple shell and the trade-off between complexity and simplicity discussed by Garson (1987) was influential in the choice. According to Garson (1987), less powerful software may actually be more effective in learning situations where specific and limited objectives have been determined, which was the present case. Based on the experience gained in the preliminary stage of the research, VP Expert appeared to be more than adequate for the purpose of the research.

The prototype is summarised in figure 7.4. The expert system begins by asking the user a series of questions from which a classification of the specific type of examination question is made. This classification controls the way in which data for the examination question is acquired and stored in the database file which is written to and read by the expert system. The availability of data also affects the way in which explanations are provided later in the consultation process. Once a classification has been made, the expert system asks a series of questions to prompt the user to provide data from the examination question. This data is then loaded into the database file. This phase is largely concerned with classification, which is a common application of an expert system approach (Pollitzer and Jenkins, 1985).

Figure 7.4 Operation of the variance analysis expert system prototype



The second facility offered by the expert system is to present a solution to the examination problem and to provide an explanation if so requested. This facility can be operated independently of the first data acquisition phase so that students can consult problems for which data has previously been loaded. The student is expected to have attempted the problem before consulting the expert system and begins by requesting a solution to the examination question The expert system retrieves data from the database file, calculates the variances that are relevant to the particular problem and displays a solution. A calculative element is not a customary element in expert systems design (Wolfgram et al, 1987) and Shaoul and

Smith (1988) integrated their variance investigation expert system with a spreadsheet to carry out calculations. Two levels of explanation are currently available. Both are provided in such a way as to overcome deficiencies in the explanation facilities offered by VP Expert and expert systems in general (Alty, 1987). Both were influenced by observations and discussions with lecturers at the research and other sites. The first level provides a detailed breakdown of the data used in the calculation and the way in which the variance results from the data. The second level provides a general level of explanation which recalls text files to assist students in certain topics. Topics were chosen which were known from prior experience to be common causes of misunderstanding in the variance calculation. A third level is envisaged for future development and will use the hypertext facility made available by recent releases of VP Expert. Behr (1988) suggests the necessity to offer explanation facilities at different levels in this way.

7.6 Findings

A basis for expert system development in *academic* knowledge proved to be only partially acceptable. *Academic* knowledge paints a surprisingly simplistic picture of the wide variety of ways that data can be acquired. Examination problems provide a significant variety of ways in which basic data can be presented to students. To take a restricted example, the price of raw materials is presumed by *academic* knowledge to be easily available. In examination questions, the price might be presented in a narrative form which describes the general context within which the variance calculations are to be made, it might be presented in a table along with other data for use in solving the problem, it might be made available in a table showing stock control data or it might not be directly presented. In the last case, the examination problem would provide data from which the price could be calculated, possibly the total purchase value and quantity of purchases made. The price might be the purchase value or might be the issues value. In some cases, the issues value might be provided along with the purchase value and there is a line of reasoning which needs to be applied in order to decide whether to use the purchase or the issues basis. This variety is significant for students and presents difficulties in phrasing expert systems questions so that students can extract correct data from examination problems. It is also challenging in terms of providing explanations which can clearly be related to the examination question data in a way that is satisfactory from a student point of view.

The evidence of observations taken at Derbyshire College suggest that the issue of acquiring data is less significant for the expert than it is for the student or for the expert system. Experts appear to build up experience of the ways in which data can be extracted from examination problems and concentrate their efforts on explaining the knowledge representation of the calculation. Curiously, students seem to be more interested in "where the figure comes from" than in the calculation itself. It seems that the gap between the knowledge representation of the calculation and the variety of ways in which data is presented is filled by students who develop experience of different types of examination problem in much the same way as lecturers. This is particularly true of professional accounting students. For undergraduates at the University of Bath, a fairly common comment is that confusion is caused by presenting variance analysis problems in different ways. It is the manner of presentation of examination data which causes difficulty rather than the calculation itself.

Collins (1987) has suggested a classification scheme for expert systems based on the extent to which knowledge can be coded into the expert system. Potentially successful applications are those where there is a negligible gap between the knowledge that can be coded into the expert system and the knowledge which is necessary to deal with the application. Collins basic point is very similar to the general point to emerge from the previous paragraph. Experts use experience to respond to the context of each individual situation they meet. Data is extracted without difficulty depending on the context in a way which is challenging when it is necessary to specify all of the permutations which may arise. Given the problem of coding every eventuality for the presentation of data that examiners may use, expert systems for variance analysis could be classified as ones for which there is little chance of total success in Collins' terms.

The analysis of *academic* knowledge presented in figure 7.1 has additional implications for the way in which explanations of calculations were laid out for students. Unfortunately, students and lecturers brought with them a bias in favour of a particular approach to explanation. Biases differed as between both students and lecturers. Figure 7.1 shows that *academic* authors primarily choose between the formulae or general methodology approach but there is significant variation. At one extreme, some authors do not discuss variance analysis calculations. At the other extreme, some authors present three different methods. Between these extremes, the majority select a particular approach. Perhaps an expert system should be able to present the calculation in the way that meets the demands of the lecturer or the student and future developments will address this possibility. Resolving this difficulty for the prototype involved developing a fifth way of presenting the calculations, as shown in figure 7.4. Figure 7.4 uses the data provided in the example provided for figure 7.2.

Figure 7.4 Expert system prototype explanation format

Actual Price Paid for the raw materials	£2.50
Standard Price	£2.00
This gives a difference of	£0.50 adverse
The quantity involved was	2900 kilos
This gives a variance of	£1,450 adverse

Explanation frames of the kind illustrated in figure 7.4 are driven by the classification of examination problem determined at the first stage in the consultation. At present, some compromises have been made in the wording of the explanation because the number of necessary explanation frames grows exponentially as new examination problems are encountered. An expert system is helpful in that additional rules can be readily introduced but the system grows quickly which leads to memory problems for the existing technology. The impossibility of pre-determining a full and ideal range of explanation formats is further evidence of the significance of Collins' (1987) concept of the gap between codeable and necessary knowledge.

Despite these problems, the initial use of the expert system was encouraging. Perhaps this should not be surprising, given that initial student reaction to the use of computer intitiatives in the classroom has been traditionally good (Earle, 1985). However, subsequent testing was less encouraging. The expert system has now been used with over two hundred students, partly at Derbyshire College of Higher

Education and partly at the University of Bath. Evaluation is problematic (Borthick and Clark, 1987) in general and much of the basis for the judgement that results were initially encouraging and later less encouraging is based on informal evaluation methods. Formal methods, including questionnaires and focus groups (one of which was organised with the assistance and involvement of a researcher whose main form of research is the focus group) were not successful in terms of response rates from students. Informal discussions with students revealed that they calculated the value of completing a questionnaire or attending a focus group on the basis of self interest. Attempts to carry out formal evaluation additionally met with distrust; an attitude that seemed ot prevail was: "what is in it for the lecturer that he should take an interest in us in this way". So, most of the evaluation was based on informal discussions with students when the opportunity naturally presented itself. Opportunities presented themselves often because the author systematically set about developing a reputation for approachability and, occasionally, sociability. This proves to be expensive in time commitment terms but valuable in terms of reaching a greater understanding of students' attitudes. The other useful form of evaluation was observation, including the simple device of counting the numbers of students actively participating in particular activities. So, in the case of undergraduates at the University of Bath, less than 10% of the relevant student cohort attempted to use the expert system during the time formally set aside for its use. Of those 10%, only one student used the system as directed by a handout given out during the lecture which led to the expert system's use. The remainder came to the session unprepared. This was not exceptional behaviour for this particular year group of students since other lecturers experienced similar responses and it is most likely that evaluation primarily reflected the characteristics of the student group. The results of evaluation have therefore been mixed and attempts to evaluate on a rigorous basis have met with difficulties. In summary, however, it seems reasonable to state that professional students seemed to welcome the expert system but undergraduate students appeared to be incapable or unwilling to use the system as intended.

This is difficult to explain with any degree of rigour, as indicated in the discussion provided in the previous paragraph. As stated, educational evaluation of computer initiatives in the classroom is difficult (Borthick and Clark, 1987). However, a possible explanation is provided by a model of learning in accountancy which is suggested by Ryan and Simpson (1988). Their framework presents a description of the learning cycle in five phases:

1. The disposition phase, concerned with motivating the students to learn.
2. The recollection phase, concerned with the student recalling facts and rehearsing concepts as a mental exercise.
3. The instructional phase, concerned with presenting the students with new material.

4 and 5. The practice and review phases which involves the student working with new examination questions in order to rehearse skills.

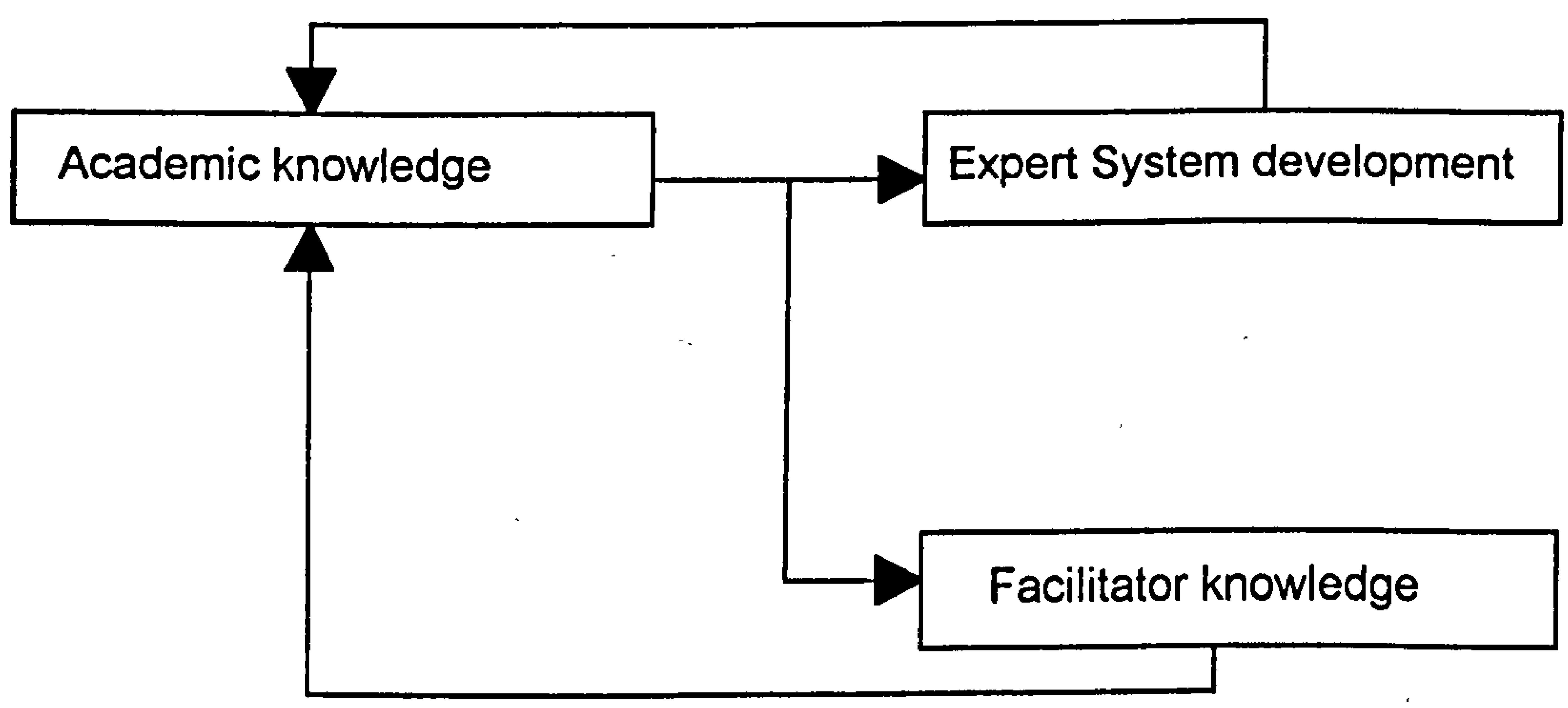
Professional accounting students experienced high class contact times and were accustomed to the learning cycle suggested by Ryan and Simpson. For these groups of students, the expert system provided a fresh and new approach to the final two phases. The use of an expert system was valuable in allowing students to work at their own pace and the expert system was tireless in presenting explanations. However, the undergraduate group brought a somewhat unhelpful learning cycle which largely omitted the final two phases. In general, the first phase became the province of one hour lectures. The second phase became the province of one hour classes and, particularly, assessment material. The third phase was informally postponed until the revision period between the final class and the end of year examinations. Attempts were made to encourage students to address the third, fourth and fifth phases of the learning cycle as the management accounting course progressed but these attempts seem so far to be unsuccessful. Intitial investigations suggest that this pattern of learning was successful for the students in previous studies and so there is no perceived need for change.

7.7 Discussion

One of the major benefits to be gained from writing expert systems appears to be the insight into the knowledge area which this process provides for the lecturer. It was this benefit that was singled out by accounting journal referees. Coding knowledge is difficult (du Boulay and Sloman, 1988; Lidtke, 1988; Quere, 1985). Overcoming difficulties, developing a problem space representation and coding knowledge in computer form challenges the lecturer's beliefs about the substance of the knowledge base to be conveyed to students and provides insights not revealed by the existing *academic* knowledge. Indeed, it is not easy to see how existing literature could conveniently convey the many alternatives which can even possibly be coded in expert system form. Expert systems can thus provide a way of extending *academic* knowledge as an iterative research process. This is similar to the process which Bailey et al (1986) has argued could provide a justification in scientific terms for the technological motivation of developing expert systems .

Figure 7.5 shows the process. *Academic* knowledge is used to define the knowledge base to be coded in expert system form. The process of developing expert systems in management accountancy redefines or extends *academic* knowledge. Additionally, *academic* knowledge can be converted into *facilitator* knowledge to provide decision aid tools as described in the previous chapter. The process of doing this may also enhance our understanding of *academic* knowledge. The implicit loops are similar to the loops that are evident in Checkland's (1982) soft system methodology discussed in the Research Methodology chapter (section 4.4). In this way, expert systems development almost becomes a research method in its own right. This argument is an extention of the point made by Edwards and Connell (1989) that the process of developing expert systems might be more important than the expert systems themselves.

Figure 7.5 The interacting roles of expert systems and expert knowledge



Although variance analysis calculations are not an obvious choice for expert systems development, because they are inherently quantitative rather than symbolic in nature, the use of expert systems in learning situations appears to be beneficial in some ways. The classification of examination problems and the subsequent flexibility in presenting explanations could not as easily have been offered in ways which would provide natural responses to calculations, such as third generation languages and spreadsheets. This process seems to be largely symbolic in nature. The ability to rapidly prototype was a further advantage. This ability is important in establishing whether there are benefits to be gained from computerising a particular management accounting application. Future work may adopt a third generation language to overcome technical problems such as the memory problems caused by expanding the knowledge base. However, for prototyping and establishing the benefits to be gained from a particular initiative, expert systems do appear to be beneficial.

Some problems were encountered related to the acquisition of data by students and by the expert system. Wright and Ayton (1987) suggest that "it is precisely this knowledge of 'what to look for' in reaching a decision that is the province of the expert". This point appears to be largely overlooked by the existing conventional wisdom of management accounting, which seems to concentrate on the description and selection of techniques, largely concentrating on the issue of how data might be processed rather than how data might be acquired. It is also easy to overlook this critical point in considering the application of expert systems to management accounting. Myers (1988) was the only work to raise this as an issue in the literature addressed by the literature survey (section 2.5.1). The ability of the expert system to acquire data in a particular context appears from the present research to be central to successful implementation.

The final point is that in considering the problem of data acquisition, it became apparent that knowledge could come from a number of management accounting knowledge bases, not just that related to variance calculations. The example given earlier of the raw materials price suggested that a stock control table might be provided. Stock control is covered by a knowledge base which in the conventional wisdom is separate to variance calculations. Although an examination problem might set out to predominantly test students' knowledge of standard costing variance calculations, it may very well test knowledge of other areas of management accountancy. In many ways, management accounting knowledge comprises an interacting range of knowledge bases which must be understood holistically if examination problems set for any one knowledge base are to be tackled competently.

Chapter 8

Implications for management accounting expert system development

8.1 Introduction

The research strategy given in chapter 4 proposed the application of triangulation to determine the common elements in the three projects presented in chapters 5, 6 and 7. This chapter begins by reporting the results of triangulation. The findings reported in the previous three chapters are then presented and brought together into a common framework. The next and final chapter relates this framework to the propositions developed in the earlier chapters of the thesis.

8.2 Review of Research Projects

This section provides a summary of the issues to emerge in the three previous chapters from the three main research projects. Double underlining has been used to highlight the over-riding concerns which emerge: concern for the nature of human expertise, concern for the nature of the management accounting task and concern for the social and technological context within which management accounting expert systems are developed. The first two, expertise and task, can be related directly to the work of Newell and Simon (1972) if expertise is assumed to be a specific example of information processing. Context is implied by Newell and Simon's argument that a task dictates information processing which dictates an appropriate context for the information processing in terms of programmes. The present findings take a broader view of context and thus extend Newell and Simon's theory.

Chapter 5 reported a protocol analysis of qualified accountants and revealed the possibility of two complementary but dichotomous models of expertise. One of the models can be related to expert systems development. It postulates a directed problem solving behaviour that is consistent with a problem space representation and can be expressed in production rule form. The name given to this model of human information processing within the context of this thesis is a rational model of expertise. The second model suggests that the human information processor searches for patterns in an uncertain world. The patterns are related back to existing models of the world and/or experience in order to reach judgements. This second model appears to be related to elements of behaviour which have been categorised by Weber (1968) as non-rational. This does not imply that such behaviour is in any way inferior to that which is rational. Within the context of the present thesis, it simply implies behaviour which is not consistent with the means-ends rationality of search within a problem space. The literature survey chapter suggested that expert behaviour which uses experience, common sense, analogies and principles cannot be coded in expert system terms. The non-rational model developed from the protocol study appears to be related to this type of expert behaviour and the existence of this type of behaviour suggests a difficulty in coding at least a part of the expertise of the management accountant.

Chapter 6 reported the results of a case study investigation of managerial problem solving and found:

- Human expertise is not an homogenous commodity. It is multi-faceted. The two model description of expertise developed in chapter 5 is not an entirely satisfactory view of management accounting expertise because placing knowledge in the context of day to day organisational problem solving introduces at least the element of actionability of knowledge. It is possible to classify management accounting knowledge into four types and in terms of a two by two matrix representing the dimensions of actionability and compiled/articulated knowledge.

- The incorrigible nature of some management accounting tasks implies that there is sometimes no rational foundation for the determination of the superiority of one solution over an alternative solution.
- Alternative forms of knowledge representation of management accounting tasks are available. Spreadsheet representation and strategic profiling are two examples of knowledge representation which appeared to be more acceptable to the management teams than expert system representation.
- The social context within which problems are solved influenced the ability to represent human management accounting expertise and the ability to gain acceptance for expert systems. In two of the case studies there were difficulties in finding a solid basis for knowledge representation: company B used the term hassle and company A provided a mass of company specific terminology which was initially opaque. In both cases, these situations were well understood within the social context of the company but proved difficult (in company A) or impossible (in company B) for outsiders to structure and operationalise.

Chapter 7 investigated the implications of building an expert system for a specific area of management accounting, standard costing. The major findings were:

- There were encouraging signs that the use of expert systems in education could be beneficial. A particular benefit is that developing expert systems provides fresh insights into areas of knowledge for lecturers. However, the benefits may vary according to the educational context within which the systems are implemented, from a student's point of view.

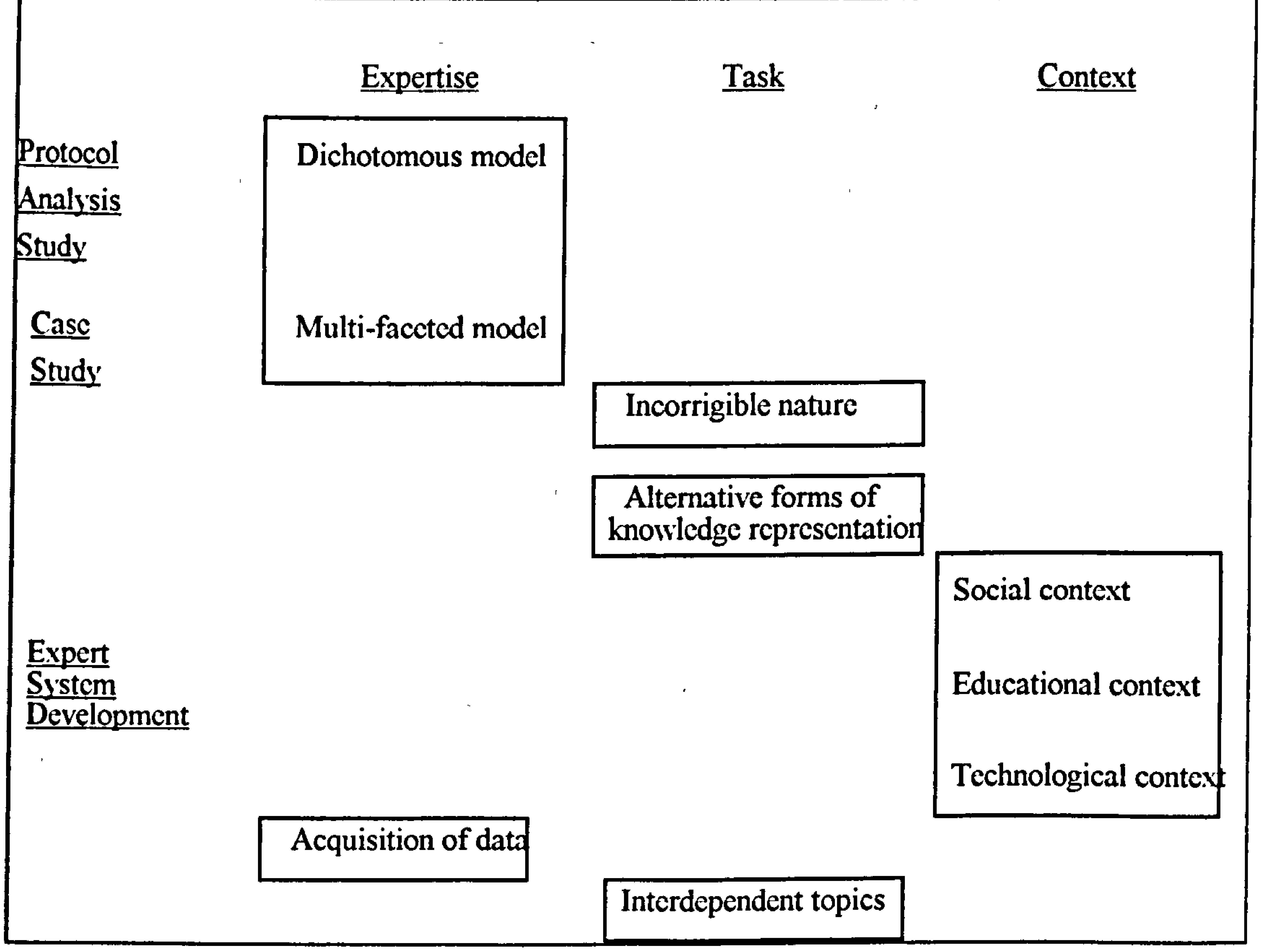
- Expert system development technologies provide rapid prototyping and a degree of flexibility. In some situations, these characteristics may make them suitable even where the task is inherently quantitative. However, there may be technological shortcomings. An examples is the adequacy of the explanation facilities provided by the expert system shell. The technological context of expert system development is therefore double edged.
- Acquisition of data in the context of the task was an essential and challenging aspect of problem solving in management accountancy for both the non-expert and the available expert system technology. The ease with which management accounting experts are able to deal with this aspect of problem solving appears to differentiate them from non-experts. Acquisition of data would therefore appear to be an important aspect of management accounting expertise.
- Management accounting tasks are related so that a particular task draws on a number of interdependent topic areas.

It can be seen that in all cases the critical factors of expert system development can be related to the research projects. The next section uses expertise, task and context in order to more fully discuss these findings.

8.3 Overview of Critical Factors

A grid showing the three research projects and the three concerns suggested by the previous section can be presented as shown in figure 8.1.

Figure 8.1 Critical Factors in Management Accounting Expert Systems



This analysis suggests that there are six critical factors for those interested in expert systems in management accounting. The six areas isolated in figure 8.1 are: models of expertise, the incorrigible nature of some management accounting tasks, alternative forms of representation of knowledge of the task, the social, educational and technological context, acquisition of data and the interdependence of topic areas.

The subsequent sections take each of these six areas in turn and revisit the available evidence from throughout the research studies. Acquisition of data is visited first, to be followed by the models of expertise. This follows the input-processing-output model and so is in accordance with a systems approach to expertise. The nature of the task is then explored and finally the context within which management accounting expert systems must operate is considered.

8.4 Acquisition of data

Acquisition is known to be important in human information processing (Libby, 1981) because it is interdependent with the processing of the data. If the expert acquires misleading data, then an incorrect evaluation is likely to result. This is similar to the Lecturer who decides to re-write a particular lecture because when it was delivered during a 9 o'clock session it provoked a dull and slow response from the students. Had the lecturer known that the students had spent the previous night at a birthday party which finished at 4 o'clock in the morning, he might have been impressed that any of the students attended the lecture, rather than concerned for the delivery of the lecture material. This hasn't happened to the author! It does reveal how incomplete data can be misleading and lead to an incorrect evaluation. Acquisition is also related to existing knowledge. Macintosh (1985) illustrates the point well in reporting a study of tonsillectomy diagnoses. A sample of children were shown to one doctor who selected a percentage for tonsillectomy operations. The children considered to be healthy were shown to a second doctor who again selected a percentage of the children as needing tonsillectomies. Doctors appeared to acquire data from their inspection of the children in such a way that their evaluations matched their prior models of tonsillectomy incidence in groups of children.

Acquisition is represented by the familiarity phase of the process model of human expertise devised by Bouwman et al (1987) and was therefore used to analyse the transcripts for the present study. Acquisition is therefore implicit in the model which informed the analysis of the research data and implicit in the two models of expertise that were drawn out of the data. The role of directed search in the rational model provides evidence to suggest that management accounting expert systems could be designed to acquire data from management accounting situations. Directed search would be necessary to expert system design because it is through an understanding of directed search that questions could be established which would feed the knowledge base with data with which the rule base would operate. The non rational model of expertise suggests that experts accumulate impressions. This presents rather more challenging demands of the expert system developer. It is not clear how the accumulation of impressions could be structured in an appropriate fashion in acquisition of data terms.

A second acquisition issue arising from the protocol analysis study is the extent to which experts acquire complete data for any one situation. It is clear from the protocol analysis study that experts are able to work with incomplete data. It is also clear from the transcripts that their demands for additional data are many but that they will still make judgements where there are outstanding demands. It is finally clear that they do not use all of the data which is made available to them; all experts exhibited cue redundancy by concentrating on only two out of the three years of data available to them. They were also more than happy to dismiss the academic's comments as "typical" rather than choosing to think through the implications of his statement.

The demands for additional data reflects a view raised by Wise and Kosey (1986,b) which was reviewed in the literature survey (section 2.5.1). Wise and Kosey found it necessary to develop an expert system which classified some applications as problematic, implying the need for further questioning. The present research findings suggest that this may not be necessary for human experts in management accountancy. By and large, the protocol analysis subjects formed their opinions in the face of incomplete data and therefore presumably did not find it necessary to conclude that the particular problem was problematic. However, it is intuitive that there will be some situations where management accountants would search for additional data before forming an opinion. With hindsight, this point is clear from the later stages of the transcript provided by S2. S2 concludes by stating that the funding issue would be partially resolved as a matter of policy and partially through additional information processing. He therefore failed in some ways to commit himself to a final conclusion.

The actors in the case studies made use of a variety of data and acquired the data in a variety of ways. For instance, company B used data collected by a market research exercise to help them come to the conclusion that they were under-pricing. The Financial Director of company C used a visit to Canada to formulate impressions about the Canadian opportunity. Data was partially quantitative and partially qualitative. This was also evident in company A where the financial model accounted for quantitative aspects whilst a checklist of questions accounted for the qualitative aspects of the transfer problem.

Appropriate mechanisms were necessary for the collection of data. In the case of the qualitative aspects of the transfer problem for company A, for instance, data was collected by asking managers to respond to questions according to a Likert scale. Similarly, a Likert scale was used for the scenario profiling exercise that was conducted with the Managing Director of company C. Case actors, in common with the protocol analysis subjects, were able to recognise that additional data was required. Part of the process of problem solving was to find ways of acquiring that data; determining that a market research exercise could add value to existing knowledge for the managers of company B, for instance.

The data acquisition issue raised by the expert system development study was the problem that data could be presented in a wide variety of ways depending on the context. This confirms the finding made by Myers (1988), which was reviewed in the literature survey (section 2.5.1), that possibly the most challenging part of the design process for expert systems in management accountancy is the design of data acquisition. It became clear that fitting data into existing frames was critical to success for the expert system itself and also for the students and the teachers who were observed as part of the development process. Remembering formulae and manipulating data within formulae was much less critical to success in problem-solving than the ability to acquire data from the problem situations in a way which matched or could be adapted to existing formulae. This illustrates the issue of the interdependence of acquisition and processing which began this section. Incomplete data was not a factor because examiners have not yet begun to set questions which demand of the students the ability to acquire data not available in the question before they proceed with their solutions.

From this analysis, data acquisition appears to be a significant skill of the management accountant. It is therefore surprising that data acquisition does not figure more prominently in the conventional wisdom of management accountancy. This could be significant. For instance, the roles of cue redundancy and the need to derive judgements in the light of incomplete information might explain the use of techniques by practitioners which are considered to be sub-optimal by the conventional wisdom. An example is product costing, where theory advocated one technique for some time but practice suggested, and continues to suggest, the use of an alternative and "theoretically" inferior technique. The "theoretically" superior technique required the split of costs into variable and fixed cost categories. If it could be shown that practitioners experience difficulties in inputting data into their financial systems in such a way that the categorisation of variable and fixed costs can be made then the explanation of practice becomes clear in a surprisingly simple way. This example derives from informal discussions between the author and a practitioner who is working through this and other ideas as part of a MPhil study and can only be speculative at this stage.

Additionally, current examination and educational practices often restrict the extent to which the data acquisition skills of using cue redundancy and working with incomplete information can be tested and developed. This seems to be because of the constraints imposed by the written word. Case studies overcome this to some extent where they present a variety of data and require the student to distinguish between significant and redundant elements of the case. The development of case study videos would seem to be a significant development in this respect because of the necessity to extract the necessary data from situations which are not dominated by the written word. Future developments in the use of information technology in education might perhaps follow the adventure game format in revealing data as a search through an uncertain world.

The significance of data acquisition is beginning to be reflected in criticisms of current management accounting practice. For instance, Bitner (1991, pg. 115) expresses the opinion:

"Another major shortcoming of the traditional AIS [Accounting Information System] system as input to management accounting is that it does not collect enough non-financial and external data .... "

This is easily said. The reality of data collection appears to be complex. The present research suggests that we need to understand much more clearly the nature of data acquisition in management accountancy before we can design effective systems to collect data. This impacts upon expert systems development as well as all other information processing, at both technological and human levels.

8.5 Models of Expert Behaviour

Expert behaviour is much researched, even if the research has not been conducted in the area of management accounting (Libby, 1981). The issues appear to be fairly well understood. Libby's (1981) review of accounting and human information processing systems can be used to provide a structure to the findings presented here. Libby divides the existing literature into three main areas:

- Regression, anova and multidimensional scaling.
- Probabilistic Judgement.
- Predecisional Behaviour.

These titles might not be particularly compelling but the contents of the respective chapters fit the data captured by the present research rather neatly.

The first area explored by Libby is broadly the area covered by multiple criteria decision making (Zeleny, 1982). In broad terms, a number of decision attributes are determined, measured in some way and the individual measurement values weighted to provide a final value which can be evaluated to provide a judgement. Existing research, which has been experimental in design, has explored the significance of the determination of attributes, approaches to measuring the attributes and the significance of scaling. A remarkably consistent picture emerges. Linear models can be shown to be accurate representations of human decision making. People seem to rely on a relatively small sub-set of the data which is available. The research has been important in suggesting decision aids which have been shown to outperform human decision makers partly because of the consistency guaranteed by computerised decision aids which cannot be matched by humans.

There was no evidence from any of the present studies to suggest that human decision makers systematically determine decision attributes, make measurements and apply weightings. However, there was compelling evidence to suggest that the computerisation of decision making could more effectively make use of multiple criteria decision making than expert system technologies. The solution provided for company A in the case study was a multiple criteria decision making solution. The debate addressed in that chapter and related to other works in the expert system literature is a debate about the respective values of a muliple criteria decision making or an expert system representation of the problem. The evidence provided suggests that multiple criteria decision making is both a simpler and at least an equally effective way of using existing technologies. Multiple Criteria Decision Making would thus seem from the present studies to be a suitable approach to the computerisation of decision making. There is little evidence to support its theoretical basis as a descriptive representation of management accounting expertise. Its contribution to management accounting may therefore be normative and the lack of literature applying multiple criteria decision making to management accounting may be an important oversight.

The second area explored by Libby raises two issues; the application of Bayes theorem, for which the present research makes no contribution, and a literature concerned with heuristics and biases. The three major heuristics reviewed are anchoring and adjustment, representativeness and availability.

Representativeness and availability heuristics were explicitly covered in the chapter covering the protocol analysis. Anchoring is concerned with the use by decision making individuals of an initial estimate or anchor against which adjustments are later made as additional information is received. This is similar to the protocol analysis subjects deciding that the organisation's financial health was sound early on in the interview and then reviewing this early estimate as new data was considered. There was therefore substantial evidence to support the interpretation that the protocol study subjects were using the heuristics suggested by Libby.

The use of these heuristics seems to be closely related to the qualitative conceptual modelling exercises adopted by experts, including the scripts and schema which were noted in the case study. Similarly, the frames which became significant to the development of the expert system explanations for variance calculations seem to be a part of the same phenomena. Qualitative conceptual models are apparently used to reduce the cognitive strains of dealing with extensive problem spaces. In many ways, these qualitative conceptual models could be interpreted as replacing the problem space as a method of resolving problems.

This body of ideas seems from the present studies to have value in providing a description of management accounting expertise. Qualitative conceptual modelling is consistent with the non-rational model of expertise which was used to explain the behaviour of the protocol analysis subjects. The essence of the qualitative conceptual model thus comes to be the accumulation of impressions in relation to scripts and schema in such a way that adjustment, representativeness and availability heuristics explain behaviour. In this respect, the non-rational model, Libby's heuristics and the script and schema explanations of expertise apparently provide competing syntax for semantic equivalence.

The final area of literature reviewed by Libby is described a "predecisional behaviour" but in fact concerns protocol analysis. Libby's major contribution in this area is in providing a critical evaluation of the protocol analysis literature and in reinforcing the point that regression, anova and multidimensional scaling, probabilistic judgement and predecisional behaviour are complementary rather than exclusive approaches to explaining human information processing. The predecisional behaviour literature supports the theoretical underpinning associated with the problem space and Newell and Simon (1972), which continues to be a major contribution to our understanding of expert behaviour and problem solving (Osherson and Smith, 1990, pp. 118).

Before moving into the final chapter, where the particular issues raised by this area of concern are covered in more detail, it is sensible to provide an initial assessment of the relevance of Newell and Simon (1972) to the research projects. The evidence from the protocol studies suggested that S1 provided examples to support a problem space interpretation of human information processing. However, all subjects displayed behaviour which can be interpreted as inconsistent with this and which has been described earlier in this section by the phrase qualitative cognitive modelling. Coupling the protocol study findings with the case study findings suggests that the qualitative cognitive modelling is more representative of expert behaviour than is the problem space. The lack of evidence for the problem space in the case study might imply that the problem space has no validity in describing the expertise of the management accountant, or that, perhaps, the case study method is an inappropriate way of teasing out the problem space. However, the case study suggested that there are different types of expertise and that *academic* expertise might accord with the rational model of expertise and thus might be capable of representation in problem space terms. Given the weakness in terms of generaliseability implied by the research strategies adopted for the studies, perhaps this is the most that can be stated at this stage. Expertise might need to be explained in both rational and non-rational terms, where the term rational implies consistency with Newell and Simon's (1972) theory of human information processing. Osherson and Smith (1990, pg.134) explain the point thus in discussing problem solving in general:

"The search metaphor for problem solving, as elaborated into formal models by Newell and Simon ... has clearly been extremely useful in understanding human problem solving. However neither the metaphor nor the models derived from it capture the full richness of the mental processes that underlie problem-solving skill."

As in the case of acquisition of data, there does not appear to be a body c management accounting research built upon theories of human information processing. This is unfortunate, because both Libby (1982) and Bouwman et al (1987) make clear the motivations for carrying out such research. These are the improvement of decision making through improving our knowledge of the strengths and weaknesses of human decision making, the training and education of accountants and the development of decision aids including expert system. These seem to be worthy aims. Given the lack of research in this area and the substantial literature relating these ideas to other areas of finance and accounting, it seems appropriate to repeat Libby's call for management accounting research in human information processing. The protocol analysis chapter suggests some specific lines of enquiry.

8.6 Alternative Forms of Knowledge Representation

In computing terms, knowledge can be represented in expert system terms but can also be represented in alternative artificial intelligence forms including neural networks, in third generation language terms (including COBOL, C, BASIC), in fourth generation language terms (including financial modelling packages and databases) and by means of word-processing, spreadsheets or graphics packages. Alternative manual representations include text, number, symbolic or graphic forms. Manual forms compete with computer forms of knowledge representation.

The objective of the protocol analysis study was to draw up the cognitive maps of qualified accountants as they engaged in a task of relevance to management accountancy. Given the propositions under investigation, the fundamental question posed by the protocol analysis study was concerned with the ability to represent the cognitive map of the human expert in problem space terms and thereby to develop expert system code. In this respect, a computer representation provides a model of human information processing which may or may not relate to the descriptive model of human information processing given by the cognitive map.

As discussed in the previous section, there are competing interpretations of the models which resulted from the protocol analysis study. It is only possible to state at this stage that a part of the expertise of management accountancy might be represented in expert system form. The competing, non-rational model of expertise might be represented in computer form in some other way than expert system form but this aspect of the study requires further investigation.

The case studies provided the inspiration for the present section. It was clear from the case studies that alternative ways of representing management accounting tasks existed and competed with each other. The non-adoption of expert systems by the companies is in part explained by the availability of alternative representations, including multiple criteria decision making. There was evidence that spreadsheet packages were used and were valuable as means by which management accounting problems could be represented and manipulated. This should provide no surprise, given the dominance of spreadsheets in the market for packages in general coupled with the relevance of spreadsheets to management accountancy (eg. Ballantine, 1991). The strategic profile uses a graphical representation. Financial and legal advisers provided reports in written form. It was clear that an expert system representation of knowledge was only one method of representation amongst many.

The development of the variance analysis expert system implied alternative knowledge representations and the alternative provided by spreadsheets was presented in the chapter. It was stated in the chapter that although the expert system provided advantages over alternative forms of representation for the prototype that was developed, further developments might go to a third generation language approach. The example that was given was the computer memory problem, which was important at the time the prototype was used but is becoming significantly less important as Personal Computers appear on the market with increased memory capacities. However, with hindsight, the use of a third generation language continues to make sense. One reason is that more substantial calculations for more difficult variance calculations could more naturally be represented in third generation language terms than in expert system terms.

The availability of alternative knowledge representations in the work of the management accountant, given partly by the combination of quantitative and qualitative data processed by the management accountant and partly by the need for the management accountant to communicate the results of judgements drawn, therefore appears to be an important factor. Expert systems must compete with alternative forms of knowledge representation for convenience from the end user's point of view. This might imply the need to reorientate the emphasis of expert system package development towards concern for the man-machine interface, as suggested by Barthet and Hanachi (1991), Berry and Hart (1990) and Berry and Hart (1991). Part of the interface problem concerns interfacing with other tasks which interact with the task under consideration. The importance of this aspect of expert system package design is related to the interaction between management accounting topics described in the next section.

8.7 Interdependency of Management Accounting Tasks

With hindsight, the protocol analysis study reveals that management accounting expertise addresses a variety of topic areas in the management area in general. This is only partially explored in appendix A and is not brought out in chapter 5. It does not appear to be a major aspect of the study. An example, taken at random, comes from S2:

protocol 74: "he [the management accountant] says that it is clear that all we have to do is to place all of the emphasis on making our courses relevant to society"

protocol 75: "what he's really implying is, we have to place our emphasis on making our courses available to those people who can afford them

S2's interpretation seems to illustrate the use of qualitative conceptual models based on S2's experience of the world. It may also reveal that the marketing strategy of segmentation is being introduced into the world of the management accountant. Similarly, S1 introduced marketing and strategic concepts to interpret the case study. It is difficult to argue for strong evidence of management accountants using knowledge of areas outside their expertise on this basis, but there is some evidence to suggest tentative links to other areas of management.

The evidence of links between management accountancy and financial accountancy are more clearly evident. All subjects applied financial accounting concepts, particularly the concept of consistency. They also thought through technical financial accounting matter, for instance a debate about revenue vs. capital expenditure was evident in all transcripts. Cost behaviour was the most obvious management accounting topic that was brought into consideration.

The clearest example of management accounting expertise needing to call upon topic areas in management in general is given by case organisation A, where a checklist of strategic, operations and marketing issues was a part of the solution adopted by the company. Company B and company C both presented problems which related management accountancy to marketing. The spreadsheet developed for company C used financial accounting relationships to develop a budgetary model. The case for the interdependency of topics seems to be clear, with the benefit of hindsight, in the case study.

The variance calculation expert system prompted this section and the details are provided in chapter 8. In broad terms, examples were provided in the development of the expert system for standard costing of knowledge bases for topics conventionally considered separately to standard costing but which were essential to resolving the particular problems confronted.

Although it is natural to compartmentalise individual knowledge bases for the purpose of text book writing or teaching, there is ample evidence that practitioners view management accounting problems holistically. This makes life difficult for expert system development because the judgements made appear to draw on such a broad area of interest. In many ways, this again illustrates Collins (1987) point about the classification of expert systems depending on ability to code the necessary range of knowledge necessary for the application. This point is most tellingly made in the development of the expert system because the objective of that particular project was to take a very narrow aspect of management accountancy. Still the problem of needing to consider other topic areas was present and limits the ability to develop the initial system to some extent. However, this problem seemed to be more acute in the case study setting where it was impossible to restrict the problem solving in the manner that was necessary for the protocol study or the expert system development study.

8.8 Task is inherently incorrigible

Evidence for inherent incorrigibility is provided by both the case studies and the protocol studies. The issue was raised initially because of the difficulties faced by company C in resolving the problem of competing choices for which no absolutely acceptable or absolutely unacceptable option presented itself. Hindsight is again necessary to see this facet in the protocol analysis studies. No subject suggested an absolute solution to the problem of reduced funding but all suggested in varying ways that cost reduction or changing the volume and/or mix of income would be necessary. For instance, S6 suggested three outcomes of a change in funding:

protocol 242: "were that to happen, and given that what we've said before, it's necessary to make a surplus in any circumstances, I would suggest various cost saving ideas would have to be investigated"

protocol 248: "lobbying all the various people such as the Arts Society; asking them to give grants to the University to see if they can come up with some extra money"

protocol 250: "or its going to have to increase the number of classes to a much higher level; the number of students in each class to a much higher level than it's doing at the moment; increase the number of students per each tutor"

It could be argued that this response was necessary because of the lack of information made available in the case study. However, it is difficult to see how management accounting information alone can resolve the questions raised by this conclusion. Additional issues would need to be assessed outside management accountancy itself so that the task can be said to be incorrigible in the sense that the use of management accounting information alone does not allow it to be resolved rationally. It is also tempting to suggest that, given the options described by S6, any reduction in funding brings unpalatable implications which would be unlikely to be acceptable to all groups within Higher Education; a cost saving in administration may be acceptable to academics, say, but not to administrators. In this respect, there is a social context within which incorrigibility operates.

The standard costing expert system development did not reveal this facet of management accounting. In many ways, it was unlikely to do so. Examiners show little inclination of setting examination questions in professional accounting examinations in management accountancy for which there is no absolute solution. However, it might be argued that some, or possibly most or even all, final year management examination questions in a School of Management or Business School have no absolute solutions. This might be an important difference between professional accounting studies and undergraduate or postgraduate studies.

So, it can only be said that some aspects of management accounting are incorrigible. It would seem for the purpose of discussing expert systems development to distinguish those systems which are incorrigible and therefore which may not be capable of resolution in rational terms. For instance, Thomas (1977) suggests that cost allocation and transfer pricing are incorrigible twins. Transfer pricing expert systems have been developed and were reviewed in the literature chapter (section 2.5.2). The literature survey chapter found the existing literature lacking. This is perhaps not surprising, given that it is unlikely that there is a rational basis for transfer pricing which stands up in practice, as most cogently explained by Vancil (1979, p.142):

"My third disappointment in this study is that I have been unable to say anything definitive, or even mildly useful, on the subject of transfer prices ... the issue remains a perennial puzzle for academics, while practitioners continue to cope. I wish the best of good fortune to the next researcher to tackle this problem."

It may be, to paraphrase Emmanuel et al (1990), in relation to transfer pricing, that there may be some problems that we will never be able to solve because they are not amenable to rational analysis. In this case, it would seem that incorrigible management accounting systems do not represent suitable applications for expert system development, given the desirability argued earlier for developing expert systems for topics where the knowledge base is articulated. An alternative interpretation of the importance of incorrigibility is that expert systems in areas such as transfer pricing cannot avoid including judgements made about matters which are inherently incorrigible. Such judgements may be important to understand and may be one way in which the process of developing expert systems is important in revealing underpinning assumptions inside organisations. It might be thought important that experts reveal the extent to which their judgements are incorrigible. Since disagreements between experts on matters which are incorrigible cannot be resolved rationally, this also questions the general acceptability of expert systems which incorporate judgements on incorrigible matters. This argues for further work that establishes a categorisation of management accounting topics according to the characteristic of incorrigibility.

8.9 Context

The protocol analysis was an investigation that was effectively taken out of context and so it is difficult to make definitive statements from that project about context. The more general point was raised by the previous section. The context within which management accountancy operates may be a broad management context since the protocol study subjects drew ideas not only from management accountancy but also from marketing, strategy and financial accountancy.

The case study chapter raised the issue of context for the first time in the thesis by describing the need for expert systems to be accepted by organisations. Expert systems must not only be technically competitive with other information processing tools but must also be acceptable to management if they are to be adopted. The feelings of the managers in company A were most revealing in this respect.

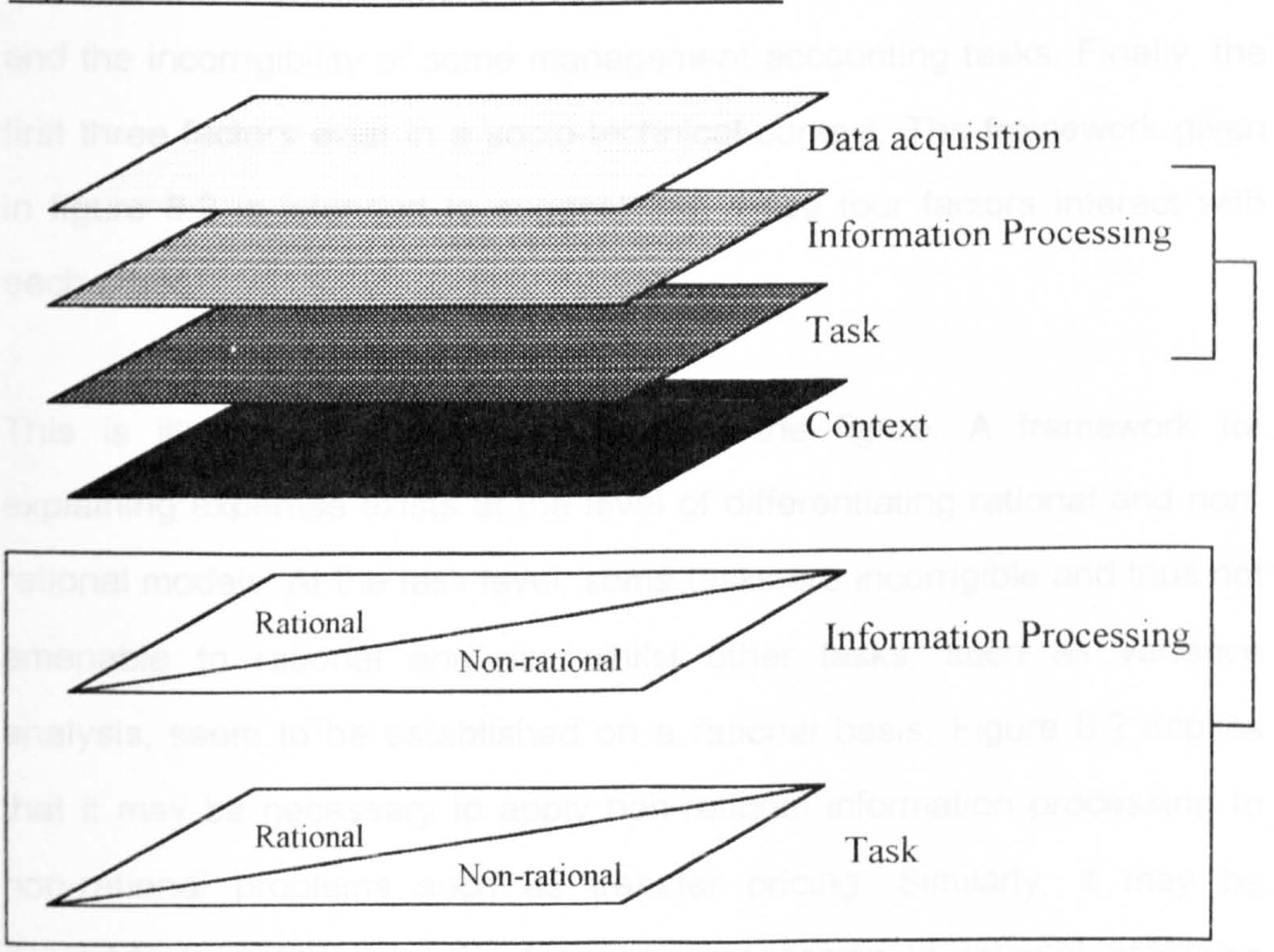
The standard costing expert system revealed the need for expert systems to be appropriately integrated into the curriculum by matching the learning cycles of learners. It also suggested that memory was a technical difficulty. In the intervening time, between the development of the prototype and now, the growth of memory capacity of personal computers may have addressed this problem but perhaps other technological limitations remain. Explanation facilities provides the most obvious example, as discussed in the chapter.

The issue of context reflects the need for expert systems to be developed with socio-technical optimality in mind. This is no more than the discovery made by the Tavistock Institute in the 1950s and reflected in, for instance, Trist and Bamforth (1951). So, in raising this issue, little is added to existing knowledge concerning the adoption of technology by management. However, given the lack of consideration of this issue by the existing literature on management accounting expert systems, the point would need to appear to be worth stressing. Stevenson's (1989) interpretation, discussed in the literature survey (section 2.6), which saw the adoption of expert systems in financial analysis as a sociological phenomenon appears to be a narrow aspect of this wider issue.

8.10 Framework

A framework for considering the six critical factors outlined in this chapter is provided by figure 8.2.

Figure 8.2 Framework based on the six factors



This framework suggests some pairing of the six critical factors to provide a four factor analysis which stresses inter-relationships. Data acquisition is given as the first issue and was discussed in section 8.4. Information Processing comes next and reflects sections 8.5 and 8.6; that there are alternative models of human information problem solving and alternative models of knowledge representation. Taken together, these combine human and technological information processing and force a debate on the necessity to split information processing sensibly between the human expert and the tool provided by technology. So, for instance, company A managers preferred to retain the element of human judgement in the final analysis of their problem, thus showing the importance of making choices in the division of responsibility between social and technological elements. The task is next presented, combining the issues of the interdependency of topics related to management accounting problems and the incorrigibility of some management accounting tasks. Finally, the first three factors exist in a socio-technical context. The framework given in figure 8.2 is intended to suggest that these four factors interact with each other.

This is illustrated by the lower half of the figure. A framework for explaining expertise exists at the level of differentiating rational and non-rational models. At the task level, some tasks are incorrigible and thus not amenable to rational analysis, whilst other tasks, such as variance analysis, seem to be established on a rational basis. Figure 8.2 implies that it may be necessary to apply non-rational information processing to non-rational problems such as transfer pricing. Similarly, it may be desirable to apply rational information processing to rational problems such as variance analysis. Chapter 7 suggested that analysing variance analysis according to problem space theory, itself a rational model of expertise, is valuable in extending our knowledge.

The value of the framework provided in figure 8.2 is in summarising this chapter and in providing a basis for the final chapter. The final chapter provides a conclusion by relating figure 8.2 to the propositions established earlier in the thesis.

CHAPTER 9

CONCLUSIONS

9.1 Introduction

This chapter brings together the material presented in chapters 1, 3 and 8. Chapters 1 and 3 defined the problem in terms of four propositions, the first of which was subdivided and related to propositions established by Newell and Simon's (1972) theory of the problem space. Chapter 8 provided an interpretation of the data captured throughout the research. The propositions are revisited one by one before a final conclusion is drawn.

9.2 Proposition 1

Proposition 1 was stated in the first chapter as follows:

> The knowledge base of management accountancy can be fully described in expert system terms.

Chapter 3 developed this initial statement in the light of Newell and Simon's (1972) theory of human information processing so that the following sub-propositions emerged:

Proposition 1a: The problem space representation is a reasonable form of representation for management accounting tasks, implying the relevance of objectives, states of knowledge and operators.

Proposition 1b: The cognitive map of the management accountant can be represented by a problem space for a particular management accounting task.

Proposition 1c: The structure of the task determines the structure of the problem space.

Proposition 1d: The structure of the problem space determines the possible programs (human or computer based) that can be used for problem solving and determines that an expert system is a suitable computer representation.

Proposition 1e: Problem solving takes place within the problem space as a search.

Each of these subpropositions will now be considered in turn.

9.2.1 Proposition 1a) The problem space representation is a reasonable form of representation for management accounting tasks, implying the relevance of objectives, states of knowledge and operators.

The state of knowledge of the expert at a particular state of time has been characterised by Bouwman (1987) as a set of knowledge elements. The knowledge elements encountered in the present study include knowledge of management accounting concepts and techniques, knowledge of financial accounting, knowledge of specific and general company characteristics and more general managerial knowledge such as that concerned with strategy or marketing. In this respect, the problem space representation is helpful in focusing attention on the types of knowledge which management accounting experts use.

A problem space representation presumes that the state of knowledge can be determined at each stage throughout decision making. This is difficult to evaluate partly because the evaluation depends on the model of expert behaviour which is considered and partly because there is little clarity in the evidence collected in the present studies about the relevance of objectives, states of knowledge and operators to management accountancy.

Difficulty is experienced in differentiating states of knowledge from initial knowledge and total knowledge, especially for the non-rational model of expertise. The expert seems to accumulate impressions which are related to the sum total of the expert's available knowledge. It is difficult to discern a step by step means-ends reasoning process. It is difficult to understand, even in the protocol analysis, why particular pieces of knowledge were referred to by subjects as the process of impression accumulation occurred. Rather than a structured problem space tree, it is possible to discern a network of related and unrelated ideas forming a patchwork of knowledge elements which at some stage result in the formulation of a conclusion.

The operators which are applied to move from one knowledge state to the next are also, in general, unclear. For the protocol and case studies, there does not seem to be the same kind of rule based operators which Newell and Simon found, or even the checklist based approach that Bouwman consistently found in his studies. At the most depressing level, there appears to be no evidence to reveal much about how the expert moves from one knowledge state to the next, even in the case of the reasoned behaviour revealed by S1 in the protocol studies. Only the standard costing expert system development made the problem space explicit. The operators that were used were concerned with algebraic manipulation.

The definition of problem is equally unclear. The protocol analysis study was anticipated to elicit a response related to product costing yet all subjects concentrated their comments on evaluating the financial health of the company. This can be interpreted as a response to the context of the case study, which provided financial statements which drew the majority of the attention of the subjects. The problem definition provided by each of the case study companies was not precise and could have been approached from a variety of points of view. The standard costing expert system alone represents a clearly stated problem; the calculation of variances from available data.

Newell and Simon had in mind concrete problems for which definitive problem solving strategies could be developed. The digits problem described in chapter 2 is one such, as is the examples of cryptarithmetic, logic and chess used by Newell and Simon. It seems from the present analysis that management accountancy as a whole differs from the tasks considered by Newell and Simon and calls for responses beyond the means-ends problem space search. The value of the problem space is in providing a novel way of investigating some management accounting tasks, where these tasks are clearly rational in basis and where the context demands rationality, as in the case of a teaching situation. It seems from both the protocol studies and the case studies that experts can avoid rationality where the task is inherently irrational or where alternative forms of knowledge representation exist, such as where a calculated value will provide a basis for judgement.

It could, of course, be argued that a calculative basis for reasoning is rational. It could also be argued that the non-rational model of expertise is a rational basis for determining action where tasks are inherently non-rational, or incorrigible. This is not, however, in question. The use of terms such as rational and non-rational models of expertise is not intended to imply absolute values concerning rational or irrational bases for action. The terms merely relate back to Newell and Simon's model of rationality and assess behaviour in relation to the problem space.

The current research suggests three types of rationality:

- Problem space rationality, as implied by the rational model of expertise developed in chapter 5, the need to articulate knowledge for the *academic* model of expertise developed in chapter 6 and the basis for the standard costing expert system described in chapter 7.
- Qualitative conceptual modelling rationality, as implied by the non-rational model of expertise developed in chapter 5 and the compiled forms of knowledge developed in chapter 6.
- Calculative rationality, as implied by multiple criteria decision making and spreadsheet analysis, developed in relation to chapter 6.

It also suggests that such rationality can be expressed in articulated or compiled form and that the way in which the rationality is used, in creating or merely indirectly influencing action, is important if expert systems are to be successfully implemented.

The framework provided by figure 8.2 places these alternative forms of rationality in the inter-relationship between information processing and task. Both information processing and task can be categorised according to the three types of rationality, the way they are expressed and their relationship to action. Calculative rationality is an alternative to problem space rationality and related to rationally based tasks in the studies, although this is a normative rather than a descriptive assessment of the evidence available in this thesis. It is clear from the case studies that calculative rationality was preferred to problem space rationality by the managers and accountants involved in the case studies.

In conclusion, it would seem that management accounting tasks can be represented in a variety of ways. The problem space is not a useful way of representing some kinds of knowledge and is only one way of representing certain others. The evidence from the present studies is a long way from giving full support for proposition 1a.

9.2.2 Proposition 1b: The cognitive map of the management accountant can be represented by a problem space for a particular management accounting task.

The discussion under section 9.2.1 established that only certain tasks can be represented in problem space format and even those tasks can be represented in other formats such as spreadsheet or multiple criteria decision making. There is no evidence to suggest that the entire cognitive map of a management accountant will be represented by a problem space although there does seem to be some value in forcing management accounting expertise into problem space format for teaching and learning purposes. The conclusion is that a problem space is capable of representing some aspects of the cognitive map of the management accountant but not all. It would appear that those tasks which might be represented in problem space terms will be processed by human decision makers in a variety of ways and that the problem space will not be a complete model of this problem solving behaviour.

9.2.3 Proposition 1c: The structure of the task determines the structure of the problem space.

There are now two elements to this proposition: firstly that a problem space may or may not be a valued knowledge representation and secondly that the nature of the task determines the nature of the knowledge representation. The first point has been discussed in the previous two sections and has been found wanting. For the second issue, Figure 8.2 made the suggestion that there are situations in which the task should determine the knowledge representation. However, section 9.2.1 suggested that this possessed normative rather than descriptive validity. For instance, it could be argued that standard costing variance analysis represents calculative rationality yet the standard costing expert system relied on problem space rationality. Similarly, it was argued that case A could have developed an expert system, and thus arrived at problem space rationality, and yet were satisfied with a multiple criteria/ spreadsheet solution. From this, it seems that not only does the nature of the task NOT determine the structure of the knowledge representation but that sometimes using an alternative form of representation throws new light on a task. Similarly, students might reveal their knowledge of a subject, or lack of knowledge, by being asked to reveal that knowledge in a novel form of representation. The use of essays to test students' understanding of problems which have traditionally been tested by means of calculations is an example from management accountancy. Similarly, this may provide a basis for understanding the value of Sangster and Wilson's (1991) use of expert systems in the teaching of standard statements of accounting practice. Students were asked to construct expert systems to represent the knowledge contained in the standard statements.

9.2.4 Proposition 1d: The structure of the problem space determines the possible programs (human or computer based) that can be used for problem solving and determines that an expert system is a suitable computer representation

There is no evidence from the present studies to support this proposition. Again, the general argument supports variety rather than a determined outcome. A variety of methods of programming appear to be available for management accountancy and are used. Expert systems are sometimes used, as shown by the literature survey and, when used, are alternatives to alternative forms of information processing. Figure 8.2 suggests that the determination of appropriate programs will be influenced by data acquisition, the task and the context, not the representation of the task alone.

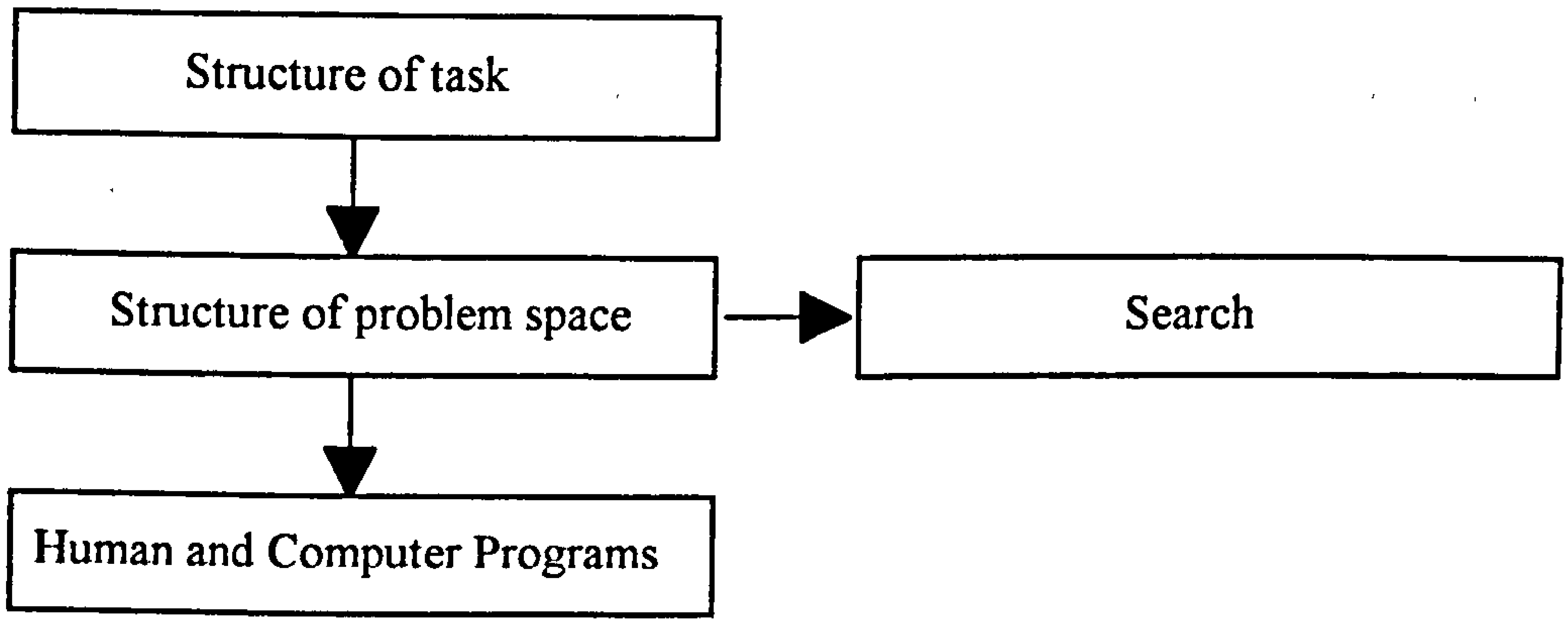
9.2.5 Proposition 1e: Problem solving takes place within the problem space as a search.

The problem space aspect of this proposition has been discussed. The second element, the importance of search, may be relevant but this relevance depends on the nature of data acquisition, the nature of the information processing and the nature of the task. Relevance is suggested even by qualitative conceptual modelling rationality because problem solving might be represented by search within a network of knowledge.

9.2.6 Assessment

The framework suggested by Newell and Simon, upon which proposition 1 is grounded in theory terms, can be illustrated by figure 9.1.

Figure 9.1 Diagrammatic Representation of the Problem Space theory



This contrasts starkly with the figure derived at the end of chapter 8 which summarised the findings of the present study. Newell and Simon's framework establishes a direct and deterministic relationship between task and information processing. The present thesis suggests the importance of data acquisition and context and shows the four features of management accounting expertise as interacting such that one feature does not directly determine the characteristics of another. Newell and Simon stress determination. The model developed by the present research stresses variety and choice.

9.3 Proposition 2

Proposition 2 stated:

The skill base of the management accountant can be fully described in ES terms.

The framework presented in figure 8.2 suggests a broad base of skills. The management accounting expert must have the skills to know how to acquire data and process information. Both of these processes may involve computers and /or human information processors. Both involve a variety of strategies. They must have a knowledge of a variety of tasks. They must function as socially and technologically skilled people.

In conclusion, there is no support for this proposition within the present studies.

9.4 Proposition 3

Proposition 3 stated:

Expert Systems can be beneficially developed as practical management accounting aids.

The evidence from both the protocol study and the case study provides a basis for assessing this proposition. Figure 8.2 implies that this proposition will be true where there is a good fit between expert system technology and management accounting problem solving on four dimensions. Taking these in turn provides a relatively gloomy picture. Expert systems provide only one of a number of ways of processing management accounting information and alternative methods were preferred in the case studies. Expert systems have limitations when the social context of human problem solving is brought into the equation. Taking the four elements together presents an even gloomier picture. It is not clear that expert systems provide any added value in dealing with non-rational tasks, where the costs of systems development to provide appropriate data acquisition and information processing facilities would be difficult to justify in terms of improving decision making quality.

9.5 Proposition 4

Proposition 4 stated that expert systems can be beneficially developed for teaching and learning.

The standard costing expert system provided some encouraging views on this proposition but also some contradictory evidence. The benefit of rapid prototyping and the ability of the expert system shell to offer the necessary facilities provides encouragement. Expert systems must be clearly effective in cost-benefit terms for both lecturers and students. This demands that expert systems be written with specific objectives in mind and must be fully integrated into the learning cycle of students.

A further encouragement was provided by the figure which appeared at the end of chapter 7 and which suggested the value of expert systems from the point of view of extending *academic* knowledge. This argument suggests that expert systems can become valuable research tools.

Figure 8.2 explains this relatively rosy outlook provided by this assessment. It was only in the educational setting that data acquisition and context could be controlled for a task that was relatively well understood. The problem of data acquisition was a major difficulty in the standard costing expert system development but could be controlled and had to be controlled. The problem of context was resolved for Derbyshire College, unknowingly at the time, because the educational context had been managed by tradition to allow the expert system to make a valuable contribution. It is anticipated that success in the use of the standard costing expert system at the University of Bath will critically depend on managing the total learning experience of students undertaking management accounting studies. Present plans envisage replacing lectures with appropriate distance learning material and expert systems. Lectures at present appear to involve a minimum but unhelpful interaction between students and lecturers as students try to come to terms with an initial exposure to material that they assimilate at different rates. Classes would be used to carry out those tasks which centrally depend upon human interaction; discussions, role play exercises and explaining those aspects of management accountancy which are repeatedly misunderstood. The key to success seems to be managing the context of the learning process and finding an appropriate learning context rather than achieving success in the development of the software. Further research in this area would appear to be appropriate.

9.6 Assessment

If the research set out to show the total value of the problem space to management accountancy and thus the pressing need for everyone to make greater efforts to write expert systems for management accountancy, then this chapter has painted a gloomy picture. However, the theory which has been developed as an alternative to the problem space theory perhaps does explain why so relatively few expert systems have been described in the literature.

Providing a theoretical basis for explaining the non-adoption of expert systems may complement the findings of Edwards and Connell (1989) that stress the potential value of the process of developing expert systems for extending knowledge. Edwards and Connell's findings were made against a background of a substantial literature. Even here there are still relatively few systems in practice.

Chapter 8 used four factors which together appear to provide a theory to explain the findings made in the three studies of management accounting expertise. Individually and together, each of these factors appears to be worthy of further research in relation to management accountancy in general.

The future of expert systems appears to be associated with improving and enlarging their available facilities and acceptability. Expert systems will compete with alternative forms of knowledge representation and so will need to be acceptable to human users. Even so, some tasks may not be entirely appropriate for expert system development because of their incorrigible nature, unless major breakthroughs in management accounting theory occur. At present their value would seem to be restricted to prototyping small management accounting tasks. In this they seem to have had a valuable part to play, as indicated by the literature describing the sufficient but relatively small number of systems which have been developed to date.

9.7 Postscript

The thesis began with a quotation to stress the universality of the underlying matters with which the thesis is concerned. It will end with two further quotations, this time taken from Tolstoy's War and Peace. The first is (p.507):

"What impressed Prince Andrei as the leading trait of Speransky's mentality was his absolute and unshakeable belief in the power and authority of reason. It was plain that it would never occur to him, as it did so naturally to Prince Andrei, that after all it is impossible to express the whole of one's thought; and that he had never known doubt .... And it was this very peculiarity of Speransky's mind that attracted Prince Andrei most."

To be seduced by the potential to resolve the difficult problems confronting human kind, including management accountants, by means of rationality, is only part of a natural human process. The seductive quality of expert systems may therefore be seen as a continuation of a long-standing obsession of the human race with rationality. There is every sign in recent times that the seduction of expert systems is passing but there are also signs that another seductive form will readily materialise. Perhaps next time it will be neural networks. Perhaps we do not yet know the name of the next solution to mankind's problems. Computers provide us with a basis for making this aspect of human nature relatively more easy to investigate because they allow simulations and experimentation which were impossible before computers were around. But it would be a mistake for researchers to imagine that resolving problems which have confronted mankind for centuries will be an easy exercise. It is perhaps in this regard that so much of the existing literature on expert systems is so disappointing; in pretending that management accounting expert systems were ever going to resolve the many broad and open ended accounting problems which confront everyday managers tackling often broad and open ended managerial problems.

The second quotation explains why even the best expert system solution to management accounting problems may only be partially successful (p.512):

"At this meeting Pierre was for the first time struck by the endless variety of the human mind, preventing any truth from ever presenting itself in the same way to any two persons."

Perhaps the theory of the problem space suggested by Newell and Simon was condemned to be found wanting simply because it dared to suggest a homogeneous view of human information processing. If so, then the value of the present thesis is in reasserting the great variability which confronts those who seek to provide a rational basis for managerial action.

Abdel-khalik, A.R., and Ajika, B.B., (1979), Empirical Research in Accounting: a methodological viewpoint, *Accounting Education Series, Volume 4*, American Accounting Association.

Abdolmohammadi, M.J., 1987, Decision Support and Expert Systems in Auditing: a review and research directions, *Accounting and Business Research*, Spring, 1-13. Reprinted in Vasarhelyi, M.A., 1989, *Artificial Intelligence in Accounting and Auditing*, New York: Markus Wienerpp, 75-100.

Abrahamson, M., (1983), *Social Research Methods*, Englewood Cliffs, NJ: Prentice Hall.

AICPA, (1985), *The Future Issues Committee - First Annual Report to the Board of Directors*, June.

Akers, M.D., Porter, G.L., Blocher, J., and Mister, W.G., (1986), Expert Systems for Management Accountants, *Management Accounting*, (USA), March, 30-34.

Aldridge, S., (1989), *The investigation and development of a transfer model to support the international manufacturing strategy of a major international electronics company*, Master of Business Administration thesis, University of Bath.

Alty, J.L., (1987), The limitations of rule-based expert systems, in J. Kriz, (editor), *Knowledge Based Expert Systems in Industry*, Chichester: Ellis Horwood, 17-22

Anderson, M.J., (1988), A Comparative Analysis of Information Search and Evaluation Behaviour of Professional and Non-professional Financial Analysts, *Accounting, Organizations and Society*, 13, (5), 431-446.

Anthony, R., Dearden, J., and Bedford, N., (1984), *Management Control Systems*, Illinois: Irwin.

Arnold, J., and Hope, T., (1983), *Accounting for Management Decisions*, London: Prentice Hall.

Astley W.G. and Van de Ven A.H., (1983), Central perspectives and debates in Organisational Theory, *Administrative Science Quarterly*, 28, 245-273.

Bailey, A.D. Jr., Hackenbrack, K., De, P. and Dillard, J., (1987), Artificial Intelligence, Cognitive Science, and Computational Modeling In Auditing Research: a research approach, *Journal of Information Systems*, Spring, 20-40. Reprinted in M.A. Vasarhelyi, (1987), *Artificial Intelligence in Accounting and Auditing*, New York: Markus Wiener, pp.3-32.

Ballantine, J., (1991), The spreadsheet revolution and its impact on the budgeting process, in B.C.Williams and B.J.Spaul, IT and Accounting: the impact of information technology, London: Chapman and Hall, 203-214.

Barr, A., and Feigenbaum, E.A., (1982), *The Handbook of Artificial Intelligence*, London: Pitman.

Barthet, M-F., and Hanachi, C., (1991), What kind of interface for expert systems?, *Expert Systems with Applications*, 2 (2/3), 195-200.

Batty, J., (1974), *Advanced Cost Accounting*, London, Macdonald and Evans.

Bauman, Z., (1978), *Hermeneutics and Social Science*, London: Hutchinson.

Beech, G., (editor), (1986), *Interactive Learning on the IBM-PC*, New York: Sigma Press.

Behr, A.L., (1988), Improving Teaching and Learning in Higher Education: an empirical study, *Studies in Higher Education*, 13, 189-200.

Berliner, D.C., (1987), Ways of thinking about students and classrooms by more or less experienced teachers, in J. Calderdale, (editor), *Exploring Teachers Thinking*, London: Cassell.

Berry, A.J., Capps, D., Cooper, P., Ferguson, T., Hopper, T., and Lowe, E.A., (1985), Management Control in an Area of the National Coal Board: Rationales of Accounting Practices in a Public Enterprise, *Accounting, Organizations and Society*, 3-28.

Berry, D., and Hart, A., (1990), *Expert Systems: human issues*, London: Chapman and Hall.

Berry, D., and Hart, A., (1991), User interface standards for expert systems: are they appropriate?, *Expert Systems with Applications*, 2 (4), 245-250.

Bidgoli, H., and Attaran, M., (1988), Improving the effectiveness of strategic decision making using an integrated decision support system, *Information and Software Technology*, 30 (5), 278-284.

Biggs, S.F., and Mock, T.J., (1983), Auditor Information Search in the Evaluation of Internal Controls and Audit Scope Decisions, *Journal of Accounting Research*, Spring, 234-255.

Biggs, S.F., (1984), Financial Analysts' Information Search in the Assessment of Corporate Earning Power, Accounting, Organizations and Society, 313-323.

Biggs, S.F., and Wild, J.J., (1985), An Investigation of Auditor Judgement in Analytical Review, The Accounting Review, October, 607-633.

Birch Paper Company, (1957), Copyright President and Fellows of Harvard College, revised 1964 and 1976. Written by W. Rotch and N.E. Harlan. Intercollegiate Case Clearing House Reference Number 9-158-001.

Black, W.J., (1986), *Intelligent Knowledge Based Systems - an introduction*, Wokingham: Van Nostrand Rheinhold.

Blanning, R.W., (1989), A Survey of Issues in Expert Systems for Management, in Silverman, B.G., (1989), *Expert Systems for Business*, Reading, Mass: Addison Wesley, pp. 24-39.

Blumer, H., (1969), *Symbolic interactionism*, Prentice Hall.

Bohanek, M., Bratko, I., and Raijkovic, V., (1983), *An Expert System for Decision Making*, in H.G. Sol, (editor), Processes and Tools for Decision Support Systems, Amsterdam: North Holland, pp. 235 -248.

Boley, H., (1990), Expert Systems shells: very high level languages for artificial intelligence, *Expert Systems*, 7 (1), 2-7.

Borthick, A.F., and Clark, R.L., (1987), Research on Computing in Accounting Education: opportunities and impediments, *Issues in Accounting Education*, Fall, 173-192.

Bouwman, M.J., (1978), *Financial Diagnosis: a Cognitive Model of the Processes Involved*, Phd Thesis, Graduate School of Industrial Administration, Carnegie-Mellon University.

Bouwman, M.J., (1982), The Use of Accounting Information: Expert Versus Novice Behavior, in Ungson and Braunstein, (editors), *Decision Making: An Interdisciplinary Inquiry*, Boston, Mass: Kent Publishing,134-167.

Bouwman, M.J., (1983), Human Diagnostic Reasoning by Computer; an Illustration from Financial Analysis, *Management Science*, June, 653-672.

Bouwman, M.J., (1984), Expert versus Novice Decision Making in Accounting: a Summary, Accounting, *Organizations and Society*, 325-327.

Bouwman, M.J., (1985), The Use of Protocol Analysis in Accounting, Accounting and Finance, May, 61-84.

Bouwman, M.J., (1987), How do Financial Analysts Make Decisions? A Process Model of the Investment Screening Decision, Accounting, Organizations and Society, 12(1), 1-29.

Bratko, I., (1986), PROLOG: Programming for Artificial Intelligence, Wokingham: Addison Wesley.

Brimson, J., and Fraser, R., (1991), The key features of ABC, Management Accounting (UK), January, 42-3.

Bromwich, M., (1990), The case for strategic management accounting: the role of accounting information for strategy in competitive markets, Accounting, Organizations and Society, 27-46.

Bromwich, M., (1992), Strategic Management Accounting, in C.Drury, (editor), Management Accounting Handbook, Oxford: Butterworth Heinemann.

Brown, C.E., and Phillips, M.E., (1990), Expert Systems for Management Accountants, Management Accounting, (USA), January, 18-23.

Bumbaka, F., (1988), Intelligent Computer Assisted Instruction: a theoretical framework, International Journal of Man Machine Studies, 29, 227-255.

Burchell, S., Clubb, C., Hopwood, A., Hughes, J., and Naphiet, J., (1980), The Roles of Accounting in Organizations and Society, Accounting, Organizations and Society, 5-27.

Casey, C.J., (1980), Variation in Accounting Information Load: the Effect on Loan Officers' Prediction of Bankcruptcy, The Accounting Review, January, 36-49.

Checkland, P.B., (1981), Systems Thinking, Systems Practice, Chichester: New York.

Checkland, P.B., (1983), OR and the systems movement: mappings and conflicts, Journal of the Operational Research Society, 34(8), 661-75.

Checkland, P.B., (1985), From optimising to learning: a development of systems thinking for the 1990's, Journal of the Operational Research Society, 36, 757-67.

Checkland, P.B., (1989), Soft Systems Methodology, in J.Rosenhead, (editor), Rational Analysis for a Problematic World, Chichester: John Wiley, 71-100.

Choo, F., (1989), Cognitive Scripts in Auditing and Accounting Behaviour, Accounting, Organizations and Society, 14 (5/6), 481-493.

Chua, W.F., (1986), Theoretical Constructions of and by the real, Accounting, Organizations and Society, 11(6), 583-598.

CIMA, (1991), European managers discuss financial control, Management Accounting, 69 (6), 3.

Clancey, W.J., (1988), The Role of Qualitative Models in Instruction, in J.Self, (editor), Intelligent Computer Aided Instruction, London: Chapman and Hall, 49-68.

Clark, D.N., and Finlay, P.N., (1991), Chartwell books - a case study in mathematical modelling, Journal of Operational Research Society.

Cleverly, G., (1971), Managers and Magic, London: Longman.

Coats, P.K., (1988), Why Expert Systems Fail, Financial Management, Autumn, 77-86.

Coleman, M.J., "Teacher-orientated software," in K.A. Duncan, and D.I. Harris, Eds., (1985), Computers in Education, Proceedings of the IFIP fourth world conference on computers in education, July 29 - August 2 (New York: North Holland,), pg. 154.

Collins, H.M., (1984), Researching spoonbending: Concepts and Practice of Participatory Fieldwork, in C.Bell and H.Roberts, Social Researching: Politics, Problems, Practice, London: Routledge and Kegan Paul, 54-69.

Collins, H.M., (1987), Expert systems, artificial intelligence and the behavioural co-ordinates of skill, in B. Bloomfield (ed) The Question of Artificial Intelligence, philosophical and sociological perspectives, London, Croom Helm.

Colville, I., (1981), Reconstructing "Behavioural Accouniting", Accounting, Organizations and Society, 119-132.

Connell, N.A.D., (1987), Expert Systems in accountancy: a review of some recent applications, Accounting and Business Research, 17 (67), 221-233.

Cooper, D.J., and Hopper, T.M., (1990), Critical Accounts: reorientating accounting research, Basingstoke: Macmillan.

Cooper, R., (1988/9), The Rise of Activity Based Costing, Parts 1-4, Journal of Cost Management, Summer, Fall, Winter, Spring.

Cooper, R., and Kaplan, R., (1988), Measure Costs Right: Make the Right Decisions, Harvard Business Review, September/ October.

Corcoran, A.W., 1978, Costs: accounting, analysis and control, Santa Barbara, Calif, Wiley.

Cowdry, S., Hayward-Surry, P., Johnson, G., Owen, R., and Rushton, D., (1990), Contact 24: a problem in pricing, BSc Business Administration thesis, University of Bath.

Crowningshield, G.R. and Gorman, K.A., 1979, Cost Accounting: principles and managerial applications (4th edition), Boston, Houghton and Mifflin.

Demetrius, D.G., (1986), Expert Systems and Board Level Decisions, in L.F. Pau, (editor), Artificial Intelligence in Economics and Management, Amsterdam: Elsevier, pg. 233-240.

Demski, J.S., (1988), Positive Accounting Theory: a review, Accounting, Organizations and Society, 13(6), 623-629.

Denzin, N.K., (1970), The Research Act, Chicago: Aldine.

Denzin, N.K., (1978), Sociological Methods: a sourcebook, McGraw Hill.

Dilts, D.M., and Turowski, D.G., (1989), Strategic Investment Justification of Advanced Manufacturing Technology Using a Knowledge-Based System, Proceedings of the 3rd International Conference on Expert Systems and Leading Edge in Production and Operations Management, 193-206.

Dixon, R., Hood, K., Priestnall, S., (1988), Expert Systems in Context, London: Chartered Institute of Management Accountants.

Doney, L.D., (1987), Using Expert Systems for Job Cost Estimates, Management Accounting, (US), December, 63-64.

Doney, L.D., (1988), Expert Systems: New Technology for Job Cost Estimating, Corporate Accounting, 6 (2), 66-71.

Dopuch, N., Birnberg, J.G. and Demski, J.S., 1982, _Cost accounting (3rd edition)_, New York, Harcourt Brace Jovanovich.

Doukidis, G.I., and Paul, R.J., (1990), A Survey of the Application of Artificial Intelligence Techniques with the OR Society, _Journal of the Operational Society_, 41 (5), 363-375

Dorr, P., M. Eining, and J.E. Groff, "Developing an accounting expert system decision aid for classroom use," _Issues in Accounting Education_ (Spring 1988), pp. 27-41.

Dreyfus, H.L., and Dreyfus, S.E., (with Athanasiou, T.),(1986), _Mind over Machine: the power of Human Intuition and Experience in the Era of the Computer_, New York: Free Press.

Drury, J.C., (1988), _Management and Cost Accounting_, (2nd. edition), London: Chapman and Hall.

Drury, J.C., (1990), Lost Relevance: A Note on the Contribution of Management Accounting Education, _British Accounting Review_, 22(2), 123-135.

Drury, J.C., (1992), _Management and Cost Accounting_, (3rd edition), Londong: Chapman and Hall.

du Boulay, B., and A. Sloman, "Bread today, jam tomorrow: the impact of AI on education," In J.H. Collins, N. Estes and D. Walker, Eds., _The Fifth International Conference of Education and Technology, Edinburgh University, March 1988, Vol 1_ (Edinburgh: CEP Consultants, 1988), pp. 82-85.

Duchastel, P. and J. Imbeau, (1988), "Intelligent computer assisted instruction (ICAI): flexible learning through better student-computer interaction", _Journal of Information Technology_, **3,** pp. 102 - 105.

Duda, R.O., Gaschnig, J.G., and Hart, P.E., (1979), Model Design in the PROSPECTOR Consultant System for Mineral Exploration, in Mitchie, D., (editor), _Expert Systems in the Micro-Electronic Age_, Edinburgh: Edinburgh University Press, 153-167.

Dworetzky, J.P., (1991), _Psychology_, (Fourth edition), St Paul: West Publishing.

Earle, T.R., (1985), "Instructional design and course implementation," in K.A. Duncan and D.I. Harris, Eds., _Computers in Education, proceedings of the IFIP fourth world conference on computers in education, July 29 - August 2_, New York: North Holland, pp. 129-134.

Easterby-Smith, M., Thorpe, R., and Lowe, A., (1991), Management Research: an introduction, London: Sage.

Eccles, R.G., (1985), The Transfer Pricing Problem: a theory for practice. Massachusetts: Lexington.

Eden, C., (1988a), Cognitive Mapping as a Visionary Tool: strategy embedded in issue management, Alfred-Houle Seminar, Faculte des Sciences de l'Administration, Universite Lavel, Quebec, March.

Eden, C., (1988b), Strategic Decision Support through Computer-based Analysis and Presentation of Cognitive Maps, Alfred-Houle Seminar, Faculte des Sciences de l'Administration, Universite Lavel, Quebec, March.

Eden, C., (1989), Using Cognitive Mapping for Strategic Options Development and Analysis (SODA), in J. Rosenhead, (editor), Rational Analysis for a Problematic World: problem structuring methods for complexity, uncertainty and conflict, Chichester: John Wiley.

Edwards, A. and Connell, N.A.D., (1989), Expert Systems in Accounting, Hemel Hempstead: Prentice Hall International, in association with The Institute of Chartered Accountants in England and Wales.

Einhorn, H.J., and Hogarth, R.M., (1981), Behavioural Decision Theory: Processes of Judgement and Choice, Journal of Accounting Research, 19(1), 1-31.

Einhorn, H.J., Kleinmuntz, D., and Kleinmuntz, B., (1979), Linear Regression and process tracing models of judgement, Psychology Review, 86, 465-485.

Emmanuel, C., Otley, D., and Merchant, K., (1990), Accounting for Management Control, (2nd edition), London: Chapman and Hall.

Emmanuel, C., and Otley, D., (1985), Accounting for Management Control, Wokingham: Van Nostrand Rheinhold.

Ericsson, K.A., and Simon, H.A., (1984), Protocol Analysis, Cambridge, Mass: MIT Press.

Ernst, C.J., (editor), (1988), Management Expert Systems, Wokingham: Addison-Wesley.

Ezzamel, M., Hoskin, K., and Macve, R., (1990), Managing it all by numbers: a review of Johnson and Kaplan's "Relevance Lost", Accounting and Business Research, 20(78), 153-166.

Feigenbaum, E., (1985), Quoted in P. Harmon and D. King, Expert Systems: artificial intelligence in business, New York: John Wiley, pg. 5.

Ferguson, P., (1988), The Contribution of Cognitive Psychology to the Design of Accounting Information Systems, British Accounting Review, 20 (1), 5-20.

Finlay, P.N., and King, M., (1989), Experiences in Developing an Expert System for MBA Admissions, Journal of The Operational Research Society, 40 (7), 625-635.

Fischer, R.J., (1972), My 60 Memorable Games, London: Faber and Faber.

Freundlich, Y., (1990), Transfer Pricing:integrating expert systems in MIS Environments, IEEE Expert, February, 54-62.

Frost, R.A., (1986), Introduction to knowledge base systems, London: Collins.

Garson, G.D. Academic Microcomputing: a resource guide (London: Sage Publications, 1987).

Ghiaseddin, N., Matta, K., and Diptendu, S., (1990), The Design of an Expert System for Inventory Control, Expert Systems with Applications, 1, 359-366.

Gioia, D.A., (1986), Symbols, scripts and sensemaking: creating meaning in the organisational experience, in H.P.Sims and D.A.Gioia, The Thinking Organisation: dynamics of organisational social cognition, San Francisco, Jossey Bass.

Glaser, D.G., and Strauss, A.L., (1967), The Discovery of Grounded Theory: strategies for qualitative research, New York: Aldine.

Glautier, M.W.E. and Underdown, B., 1988, Cost Accounting, London, Pitman.

Govindarajan, V., (1980), The Objectives of Financial Statements: an Empirical Study of the Use of Cash Flow and Earnings by Security Analysts, Accounting, Organizations and Society, 383-392.

Grigoriou, M.M. and Willey, P.C.T., (1987) Multiple-criteria Method for Selecting an Expert System Shell, in Proceedings of Third International Expert

Systems Conference, London 2-4 June 1987, Oxford: Learned Information, pp.277-289.

Gummesson, E., (1991), Qualitative Methods in Management Research, London: Sage.

Hammermesh, R.G., (1986), Making Strategy Work, New York: John Wiley.

Hammond, P., (1987), Logic-based tools for building expert and knowledge-based systems: successes and failures in transferring the technology, in J. Kriz, Ed., Knowledge-based Expert Systems in Industry, Chichester, Ellis Horwood, pp. 69-90.

Hansen, J., and Messier, W.F., (1986), Preliminary Investigation of EDP-XPERT, Auditing: a Journal of Practice and Theory, Fall, 109-123.

Haralambos, M., and Holborn, M., (1990), Sociology: themes and perspectives, (3rd edition), London: Collins.

Harmon, P. and King, D., (1985), Expert Systems: artificial intelligence in business, New York: John Wiley.

Harmon, P., Maus, R. and Morrisey, W., (1988), Expert Systems: tools and applications, New York: John Wiley.

Hartley, R.V., 1983, Cost and managerial accounting, Boston, Mass, Allyn and Bacon.

Hayes, R.H., and Abernathy, W.J., (1980), Managing our way to Economic Decline, Harvard Business Review, July-August, 67-77.

Hayes, R.H., and Garvin, D.A., (1982), Managing is if Tomorrow Mattered, Harvard Business Review, May-June, 71-80.

Hayes-Roth, F., (1988), Knowledge-based Expert Systems: the State of the Art, in C.J. Ernst, (editor), Management Expert Systems, Wokingham: Addison Wesley, pp. 3-18.

Hayes-Roth, F., Waterman, D.A., and Lenat, D.B., (1983), (editors), Building Expert Systems, Reading, MA: Addison Wesley.

Herbsman, Z., and Wall, R.A., (1987), An Expert System for Estimating Construction Cost, Proceedings of the Fourth International Symposium on Robotics and AI in Building Construction, Isreal, 208-221.

Hewitt, C., (1985), The Challenge of Open Systems, BYTE, 10 (4), 231-242.

Hill, T., (1983), *Production Operations Management*, London: Prentice Hall.

Hollander, A., (1987), *A Rule-Based Approach to Variance Analysis*, Phd Dissertation, University of Tennessee.

Hopwood, A.G., (1976), *Accountancy and Human Behaviour*, Prentice Hall.

Hopwood, A.G., (1978), Towards an Organisational Perspective for the Study of Accounting and Information Systems, Accounting, Organizations and Society, 3-13.

Hopwood, A.G., (1979), Editorial, Accounting, Organizations and Society, 145-147.

Hopwood, A.G., (1983), On Trying to Study Accounting in the Contexts in which it Operates, Accounting, Organizations and Society, 287-305.

Horngren, C.T., (1974), *Accounting for Management Control: an introduction*, 3rd edition, Englewood Cliffs N.J., Prentice Hall.

Horngren, C.T., (1982), *Cost accounting: a managerial emphasis (5th. edition)*, Englewood Cliffs, Prentice Hall.

Horngren, C.T., (1984), *Introduction to Management Accounting (6th edition)*, Englewood Cliffs, Prentice Hall.

Horngren, C.T. and Foster, G., (1987), *Cost accounting: a managerial emphasis (6th edition)*, Englewood Cliffs N.J., Prentice Hall.

Hosseini, J., Baharaeen, S., and Zheng, X., (1988), Design of a Knowledge Based System for Inventory Control, an OPS5 Implementation, *Artificial Intelligence in Engineering*, 3 (1), 39-43.

Huff, A.S., (1990), Mapping Strategic Thought, in A.S. Huff, (editor), *Mapping Strategic Thought*, Chichester, John Wiley, 53-70.

Humphreys, P., (1989), Intelligence in Decision Support - a process model, in Doukidis, G.I., Land, F., and Miller, G., (editors), *Knowledge-based Management Support Systems*, Chichester: Ellis Horwood, pg. 22-51.

Hwang, H-L., Emrich, M.L., and Morris, J., (1987), Using AI in the Preparation of Budget Submissions, *Proceedings of the 2nd. International Symposium on Methodologies for Intelligent Systems*, North Carolina: Elsevier.

Inman, M.L., (1988), *Cost Accounting*, London, Heinmann.

Innes, J. and Mitchell, F., (1991), *Activity Based Cost Management*, London: Chartered Institute of Management Accountants.

Iverson, S.C., and Jorgensen, J.E., (1986), Manufacturing Systems Delphi Study, *IIE Transactions*, June, 158-165.

Jacob, V.S., Gaultney, L.D., Salvendy, G., (1986), Strategies and biases in human decision making and their implications for expert systems, *Behaviour and Information Technology*, 5(2), 119-140.

Johnson, G., and Scholes, K., (1988), *Exploring Corporate Strategy*, London: Prentice Hall.

Johnson, H.J., and Kaplan, R.S., (1987), *Relevance Lost: the Rise and Fall of Management Accounting.* Boston: Harvard Business School.

Johnson, P.E., (1984), The Expert Mind: A New Challenge for the Information Scientist, in M.A. Bemelmans (ed), *Beyond Productivity: Information Systems Development for Organizational Effectiveness*, North Holland: Elsevier Science, 367-386.

Johnson, P.E., Jamal, K., and Berryman, R.G., (1989), Audit Judgement Research, *Accounting, Organizations and Society*, 14(1/2), 83-99.

Johnson, P.E., Severance, D., and Feltovich, P., (1979), Design of Decision Support Systems in Medicine: Rationale and Principles from Analysis of Physicians Expertise, in B.Shriver, T.Walker and B.Sprague, (eds), *Proceedings of the Twelfth Hawaii International Conference on System Sciences: Selected Papers in Medical Information Processing.*

Jones, S., (1987), Choosing Action Research: a rationale, in I.L.Mangham, (editor), *Organisational Analysis and Development*, Chichester: Wiley.

Kahnemann, D., and Tversky, A., (1972), A Subjective Probability: A Judgement of Representativeness, *Cognitive Psychology*, 3, 430-454.

Kaplan, R.S., (1986), Must CIM be Justified on Faith Alone, *Harvard Business Review*, March-April, 87-95.

Kaplan, R.S., (1986), The Role for Empirical Research in Management Accounting, *Accounting, Organizations and Society*, 11(4/5), 429-452.

Kaplan, R.S., (1982), Advanced Management Accounting, Englewood Cliffs, Prentice Hall.

Kaplan, R.S., and Atkinson, A.A., (1989), Advanced Management Accounting, (2nd, edition), Englewood Cliffs: Prentice Hall.

Kaye, G.R., (1987), Conceptual Design of an Accounting Skills Workshop, in G.R. Kaye, (editor), Proceedings of Computers in Accounting Education Workshop, London: Chartered Institute of Management Accountants, pp 63-88

Keen, P.G.W., and Scott-Morton, M.S., (1978), Decision Support Systems: an organisational perspective, Adison-Wesley.

Killough, L.N. and Leininger, W.E., (1977), Cost accounting for managerial decision making, Encino, California, Dickenson.

Kim, J., and Courtney, J.F., (1988), A Survey of Knowledge Acquisition Techniques and Their Relevance to Managerial Problem Domains, Decision Support Systems, 4, 269-284

King, M., (1988), A framework for teaching OR techniques, Journal of Operational Research Society, 39(12), 1087-1093.

King, M., (1989), Mathematical modelling in part-time MBA programmes, Management Education and Development, 20 (4), 303-312.

King, M., "Experiments with experts developing simple expert systems," Omega: International Journal of Management Science **17** (1989), pp. 123-134.

King, M., and McAulay, L., (1989), Information Technology and the accountant: a case study, Behaviour and Information Technology, 8 (2), 109-123.

King, M., and McAulay, L., (1991), A Standard Costing Knowlege Base: building and using an expert system in management accountancy, Issues in Accounting Education, 6 (1), 97-111.

King, M., McAulay, L., and Cragg, P.B., (1991), 'Experiences in applying a general modelling methodology', Omega: international journal of management science, 19(6), 567-575.

King, M., and Phythian, G.J., (1992), Validating an Expert Support System for Tender Enquiry Evaluation: a case study, Journal of the Operational Research Society, 43 (3), 203-214.

Kirsch, R.J., Strouble, D.D., Johnson, W.A., and Aungst, S.G., (1991), Transfer: An Expert System Approach to Transfer Pricing, Expert Systems with Applications, 3, 481-487.

Kjellen, B., and Soderman, S., Praktikfallsmetodik, Malmo: SIAR/Liber.

Klersky, G.F., and Mock, T.J., (1989), Verbal Protocol Research in Auditing, Accounting, Organizations and Society, 14(1/2), 133-151.

Kollaritsch, F.P., (1979), Cost systems for Planning, Decisions and Controls: concepts and techniques, Columbia, Ohio, Grid.

Kotler, P., (1984), Marketing Management: analysis, planning and control, London: Prentice Hall.

Larcker, D.F., and Lessig, P., (1983), An Examination of the Linear and Retrospective Process Tracing Approaches to Judgement Modelling, The Accounting Review, January, 58-77.

Laughlin, R.C., and Lowe, E.A., (1990), A Critical Analysis of Accounting Thought: Prognosis and Prospects for Understanding and Changing Accounting Systems Design, in D.J Cooper and T.M.Hopper, (eds), Critical Accounts: reorientating accounting research, Basingstoke: Macmillan, pp. 15-43.

Layne, W.A. and Rickwood, C., 1984, Cost accounting and control, London, Macmillan.

Lee, J.K., and Kang, B.S., (1988), Intelligent Production Planning System Using the Post-Model Analysis Approach, in Turban, E., and Watkins, P.R., (editors), Applied Expert Systems, North Holland: Elsevier, pp. 87-106.

Lee, D., and Newby, H., (1983), The Problem of Sociology, London: Hutchinson.

Leininger, W.E. and Killough, L.N., 1984, Cost accounting: concepts and techniques for management, St Paul, Mn., West.

Libby, R., (1981), Accounting and Human Information Processing, theory and applications, Englewood Cliffs, NJ, Prentice Hall.

Lidtke, D.K., "Expert systems for computer based training," in J.H. Collins, N. Estes and D. Walker, Eds., The Fifth International Conference of Education and Technology, Edinburgh University, March 1988, Vol 2 (Edinburgh: CEP Consultants, 1988), pp. 22-25.

Liebowitz, D.S., 1990, The Maturing Process of Expert Systems (Editorial), Expert Systems with Applications, 1(1), 1.

Lilien, G., and Kijewski, V., (1987), How an expert system evaluates budgeting for marketing, Marketing News, 21 (5), pg. 22

Lin, T.W., (1986), Expert Systems and Management Accounting Research, Management Accounting: News and Views, 4 (1), Spring, 11-13. Republished in Vasarhelyi, M.A., (1989), Artificial Intelligence in Accounting and Auditing, New York: Markus Wiener, pp.69-73. Also republished in Wilson, R.M.S., and Chua, W.F., (1988), Managerial Accounting: method and meaning, London: Van Nostrand Reinhold, pp.484-488.

Lindblom, C.E., (1968), The Policy-Making Process, New York: Prentice Hall.

Lord, R.G., and Foti, R.J., (1986), Schema Theories, Information Processing and Organizational Behaviour, in H.P. Sims and D.A Gioia, (editors), The Thinking Organization; dynamics of organizational social cognition, San Francisco: Jossey Bass.

Louderback, J.G. and Dominiak, G.F., (1978), Managerial Accounting, (2nd edition), Belmont California, Wadsworth.

Louderback, J.G. and Hirsch, M.L., (1982), Cost accounting: accumulation, analysis and use (1st. edition), Boston Mass, Kent.

Macintosh, N.B., (1985), The Social Software of Accounting and Information Systems, Chichester: John Wiley.

Magee, R.P., (1986), Advanced Managerial Accounting, New York; London, Harper and Row.

Martin, C.J., and Clarke, B.A., (1990), Executive Information Systems: recent developments and research imperatives, British Journal of Management, 1 (1), 27-34.

Matz, A, and Usry, M.F., 1976, Cost accounting: planning and control, (6th edition), Cincinatti, South Western.

McAulay, L., and Tomkins, C.R., (1992), A Review of the Contemporary Transfer Pricing Literature with Recommendations for Future Research, British Journal of Management, 3, 101-122, McCarthy, W.E., (1989), On the Future of Knowledge-Based Accounting Systems, in M.A. Vasarhelyi, (editor), Artificial Intelligence in Accounting and Auditing, New York: Markus Wiener, pp.33-66.

McCarthy, J., 1984, We Need Better Standards for AI Research, The AI Magazine, Fall, 7-8.

McDermott, J., (1984), Background, Theory and Implementation of Expert Systems, Paper presented at the CPMS Seminar on Expert Systems, December.

McMahon, R.G.P., (1990), A Bibliography of Expert Systems in Accounting, Finance and Management, The Flinders University of South Australia: Accounting and Finance Research Paper 90/3.

McMahon, R.G.P., (1990), Financial Decision Support in Smaller Growth Enterprises: the prospects for expert systems, The Flinders University of South Australia Accounting and Finance Research Paper 90/1.

Messier, W.F.Jr. and Hansen, J.V., (1989), Expert Systems in Auditing: the state of the art, in M.A. Vasarhelyi, (editor), Artificial Intelligence in Accounting and Auditing, New York: Markus Wiener, pp.127-145.

Messier, W.F., and Hansen, J.V., (1983), Expert Systems in Auditing: A framework and review, Proceedings of the University of Oklahoma Behavioral Research Committee.

Messier, W.E., and Hansen, J.V., (1984), Expert Systems in Accounting and Auditing: a framework and review, in S. Moriarty and E. Joyce, (editors), Decision Making and Accounting: current research, University of Oklahoma, pp.182-202.

Michaelson, R.H., Mitchie, D. and Boulanger, A., (1985), The Technology of Expert Systems, BYTE, April, 303-312.

Miller, R.A., Pople, H.E., and Meyers, J.D., INTERNIST-1, (1982), an Experimental Computer-Based Dignostic Consultant for General Internal Medicine, New England Journal of Medicine, 468-476.

Mockler, R.J., (1989), Knowledge based Systems for Management Decisions, Englewood Cliffs, NJ., Prentice Hall.

Montgomery, A.T., (1979), Managerial Accounting Information: an introduction to its content and usefulness, Reading, Mass, Addison Wesley.

Moore, C.L., Jaedicke, R.K. and Anderson, L.K., (1984), Managerial Accounting, (6th edition), Cincinatti, South Western.

Morgan, G., and Smircich, L., (1980), The Case for Qualitative Research, Academy of Management Review, 491-500.

Morse, W.J., (1978), Cost accounting - processing, evaluating and using cost data, Reading, Mass, Addison Wesley.

Morse, W.J., Davis, J.R. and Hartgraves, A.L., (1984), Management Accounting, Reading Mass, Addison Wesley.

Muller, R., (1988) Foreward in C.J. Ernst, (editor), Management Expert Systems, Wokingham: Addison Wesley, pg. v-vii.

Murdoch, H., (1990), Choosing a Problem - when is artificial intelligence appropriate for the retail industry, Expert Systems, 7 (1), 42-49.

Murphy, B., (1985), Management Accounting, Sevenoaks, Hodder adn Stoughton.

Myers, S.C., (1988), Notes on an Expert System for Capital Budgeting, Financial Management, Autumn, 23-31.

Nelson, A.T. and Miller, P.B.W., (1977), Modern Management Accounting, Santa Monica, Goodyear.

Newell, (1981), Reasoning, problem solving and decision processes: the problem space as a fundamental category, in R. Nickerson (ed), Attention and Performance, Vol.8, Hillsdale N.J., Erlbaum.

Newell, A., Shaw, J., and Simon, H., (1958), Elements of a Theory of Human Problem Solving, Psychology Review, 3, 151-166.

Newell, A., and Simon, H., (1972), Human Problem Solving, Englewood Cliffs, N.J.: Prentice Hall.

Nisbett, R.E., and Wilson, T.D., (1977), Telling More than we can Know: Verbal Reports on Mental Processes, Psychological Review, 231-259.

Norgaard, C.T., (1985), Management Accounting, Englewood Cliffs N.J., Prentice Hall.

Northcott, D., (1991), Rationality and Decision Making in Capital Budgeting, British Accounting Review, 23(3), 219-233.

O'Lave, M., Lavrac, N., and Cestnik, B., (1988), Application of Expert Systems to the Evaluation of Managerial Performance in Public Enterprises of Developing Countries, OMEGA: International Journal of Management Science, 16 (4), 353-362.

O'Leary, D.E., (1989), The Use of Artificial Intelligence in Accounting, in Silverman, B.G., (1989), Expert Systems for Business, Reading, Mass: Addison Wesley, pp. 83-98.

O'Leary, D.E. and Lin, W.T., (1989), An Expert System for Cash Flow Analysis, in M.A. Vasarhelyi, (editor), Artificial Intelligence in Accounting and Auditing, New York: Markus Wiener, pp.307-314.

O'Neill, M., and Morris, A., (1989), Expert Systems in the United Kingdom: an evaluation of development methodologies, Expert Systems, 6 (2), 90-98.

O'Shea, T., and Self, J., (1983), Learning and Teaching with Computers: Artificial Intelligence in Education, London: Harvest Press.

Osherson, D.N., and Smith, E.E., (editors), (1990), Thinking: an invitation to cognitive science, Cambridge, Mass., The MIT Press.

Otley, D.T., (1984), Management Accounting and Organizational Theory: A Review of their inter-relationship, in R.W.Scapens, D.T.Otley and R.Lister, Management Accounting, Organizational Theory and Capital Budgeting: Three Surveys, London: Macmillan.

Owler, L.W.J. and Brown, J.L., (1978), Wheldon's Cost Accounting and Costing Methods (14th. edition), Estover, Macdonald and Evans.

Partridge, D., (1987), The scope and limitation of first generation expert systems, Future Generation Computer Systems, 3 (1), 1-10.

Payne, J.W., Braunstein, M.L., and Carroll, J.S., (1978), Exploring Pre-decisional Behaviour: An Alternative Approach to Decision Research, Organizational Behaviour and Human Performance, 22, 17-44.

Payne S.J., (1988), Methods and mental models in theories of cognitive skill in J. Self, (ed), Artificial Intelligence and Human Learning: intelligent computer-aided instruction, London, Chapman and Hall.

Pizzey, A., (1987), Principles of Cost Accounting: a managerial perspective (5th edition), London, Cassell.

Pollitzer, E. and Jenkins, (1985), "Expert knowledge, expert systems and commercial interests, " _Omega: International Journal of Management Science_ **13** , pp 407-418.

Porter, M.E., (1980), _Competitive Strategy_, New York: The Free Press.

Porter, M.E., (1985), _Competitive Advantage_, New York: The Free Press.

Quere, M., (1985), "Expert systems: towards CAI of the future?" in K.A. Duncan, and D.I. Harris, Eds., _Computers in Education, proceedings of the IFIP fourth world conference on computers in education, July 29 - August 2_, New York: North Holland, pp. 159-163.

Ramsden, P., (1987), "Improving teaching and learning in higher education: the case for a relational perspective," _Studies in Higher Education_ **12**, pp. 275-286.

Reitman, W., (1985), Artificial Intelligence Meets Decision Support: A.I-Based Decision Support Systems, _Unpublished presentation_, Palladian Software.

Ricchiute, D.N., (1984), An Empirical Assessment of the Impact of Alternative Task Presentation Modes on Decision-Making Research in Auditing, _Journal of Accounting Research_, Spring, 341-350.

Rich, E., (1983), _Artificial Intelligence_, New York: McGraw Hill.

Rixhon, P., (1986), Intelligent Knowledge-Based Systems: a tool for manufacturing planning and scheduling, in Pau, L.F., (editor), _Artificial Intelligence in Economics and Management_, North Holland: Elsevier, pp 283-288.

Roberts, J., and Scapens, R.W., (1985), Accounting Systems and Systems of Accountability - Understanding Accounting Systems in their Organizational Contexts, _Accounting, Organizations and Society_, 443-456.

Roslender, R., (1990), Sociology and Management Accounting Research, _British Accounting Review_, 22(4), 351-372.

Ryan, R.J. and S.M. Simpson, (1988), "Computer aided instruction for ab initio teaching in accounting," _British Accounting Review_ **20**, pp. 111 - 130.

Sangster, A., and Wilson, R.A., (1991), Knowledge-Based Learning Within the Accounting Curriculum, _British Accounting Review_, 23(3), 243-261

Scapens, R.W., (1984), Management Accounting-a survey paper, in _Management Accounting, Organizational Behaviour and Capital Budgeting,_ London: Macmillan/ESRC.

Scapens, R.W., (1990), Researching Management Accounting Practice: The role of Case Study Methods, _British Accounting Review_, 22(3), 259-281.

Scapens, R.W., (1991), _Management Accounting: a review of recent developments_, (2nd edition), Basingstoke: Macmillan.

Schanke, J.K. and Churchill, N.C., (1982), Variance analysis: a management orientated approach, in A. Rappaport (ed), _Information for Decision Making - readings in cost and managerial accounting, (3rd edition)_, Englewood Cliffs, Prentice Hall.

Schattke, R.W. and Jensen, H.G., (1981), _Managerial Accounting, concepts and uses_, Boston [Mass]; London, Allyn and Bacon.

Schmidt, P., (1985), Teaching mathematical story problems, in K.A. Duncan and D.I. Harris, Eds., *Computers in* _Education, proceedings of the IFIP fourth world conference on computers in education, July 29 - August 2_, New York: North Holland, pp. 389-392.

Schmiedicke, R.E. and Nagy, C.F., (1983), _Principles of Cost_

Shaoul, J.E., and Smith, P.J., (1988), Expert Systems or Proficient Systems? The Calculation and Diagnosis of Standard Cost Variances, In Collins, J.H., Estes, N., and Walker, D., (editors), _The Fifth International Conference of Education and Technology, Edinburgh University_, March, Volume 2, Edinburgh: CEP Consultants, 17-21.

Shaw, M.E. and Costanzo, P.R., _Theories of Social Psychology_, New York: McGraw Hill.

Shields, M.D., (1980), Effects of Information Supply and Demand on Judgement Accuracy: Evidence from Corporate Managers, _The Accounting Review_, April, 284-303.

Shim, J.K., and Rice, J.S., (1988), Expert Systems Applications to Managerial Accounting, _Journal of Systems Management_, 41 (6), 6-13.

Shpilberg, D. and Graham, L.E., 1986, Developing ExperTAX: An Expert System for Corporate Tax Accrual and Planning, _Auditing: A Journal of Practice and Theory_, Fall, 75-94.

Simon, H.A., (1947), *Administrative Behaviour*, New York: Macmillan.

Simon, H.A., (1958), A Behavioural Model of Rational Choice, *Quarterly Journal of Economics*, 69, 99-118.

Simon, H.A, (1960), *The New Science of Management*, Harper and Row.

Simon, H.A., (1976), *Administrative Behaviour*, New York: Macmillan.

Simon, H.A., (1981), *The Sciences of the Artificial*, (2nd edition), Cambridge, Mass., The MIT Press.

Simon, H.A., (1982), *Models of Bounded Rationality*, Cambrige, Mass.: MIT Press, 2 Volumes.

Simon, H.A., (1986), Rationality in Psychology and Economics, *Journal of Business*, 59(4:2), S209-, reprinted in R.M. Hogarth and M.W. Reder, (editors), (1987), Rational Choice: the contrast between economics and psychology, Chicago: The University of Chicago Press.

Simpson, L., 1979, *Management accounting: techniques for non financial managers*, London, Business Books.

Sizer, J., (1989), *An Insight into Management Accounting*, London: Penguin.

Sleeman, D., and Brown, J.S., (1982), *Intelligent Tutoring Systems*, London: Academic Press.

Smith, G., (1990), Executive Decision Support Systems, Business Goal Seeking, Expert Planning Systems, *First International Conference*, Brighton, 27-29 June, Conference Publication number 322.

Smith, H.W., (1975) *Strategies of Social Research: the methodological imagination*, London: Prentice Hall.

Solomons, D., (1972), Flexible budgets and the analysis of overhead variances, in H.R. Anton and P.A. Firmin (eds), *Contemporary issues in Cost Accounting: a discipline in transition, (2nd edition)*, Boston, Houghton and Miflin.

Steinbart, P.J., and Gal, G., (1989), The Role of Expert Systems in Accounting Research, in Vasarhelyi, M.A., *Artificial Intelligence in Accounting and Auditing*, New York: Markus Wiener, pp.315-340.

Stevenson, H., (1989), Expert Systems in the UK Financial Services Sector: A Symbolic Analysis of the Hype, in Doukidis, G.I., Land, F., and Miller, G., (editors), Knowledge-based management support systems, Chichester: Ellis Horwood, 276-303.

Stock, D., and and Watson, C.J., (1984), Human Judgement Accuracy, Multidimensional Graphics and Humans Versus Models, Journal of Accounting Research, Spring, 192-206.

Sugaya, H., "A prolog frame system for knowledge-based design and diagnosis," in J. Kriz, Ed., Knowledge-based Expert Systems in Industry (Chichester: Ellis Horwood, 1987), pp. 117-129.

Sullivan, C.H., and Yates, C.E., (1988), Reasoning by Analogy - A Tool for Business Planning, Sloan Management Review, Spring, 55-60.

Szent-Gyorgyi, A., (1972), Dionysians and Apollonians, Science, 176, pg.966.

Takkenberg, C.A.Th., (1983), CAP: A Decision Support System for the Planning of Production Levels, in Sol, H.G., (Editor), Processes and Tools for Decision Support, Amsterdam: North Holland, pp 249-259.

Thacker, R.J. and Ellis, L., 1981, Management accounting: concepts and applications, Reston Virginia, Reston.

Thomas, A.L., (1980), A Behavioural Analysis of Joint Cost Allocations and Transfer Pricing, Stipes Publishing.

Thornton, N., 1978, Management Accounting, London, Heinmann.

Thorpe, J.C., Marr, A., and Slack, R.S., (1989), Using an Expert System to Monitor an Automatic Stock Control System, Journal of the Operational Control Society, 40 (11), 945-952.

Titard, P.L., 1983, Managerial Accounting: an introduction, Chicago; London, The Dryden Press.

Tolstoy, L., trans. Edmonds, R., (1960), The Cossacks, Happy Ever After, The Death of Ivan Ilyich, Harmondsworth: Penguin.

Tolstoy, L.N., (1869), trans. Edmonds, R., (1957), War and Peace, Harmondsworth: Penguin.

Tomkins, C.R., (1986), Commentary on R.S.Kaplan: the role for empirical research in management accounting, Accounting, Organizations and Society, 11(4/5), 453-456.

Tomkins, C.R., (1991), Corporate Resource Allocation: integrating finance and stratey, Oxford: Basil Blackwell.

Tomkins, C., and Groves, R., (1983), The Everyday Accountant and Researching his Reality, Accounting, Organizations and Sociey, 8(4), 361-374.

Tonn, B., Kunz, D., Hosack, G., (1988), An Application of Knowledge-Based Systems to Navy Budget Analysis, Interfaces, 18 (6), 114-122.

Trist, E.L., and Bamforth, K.W., (1951), Some social and psychological consequences of the longwall method of coal-getting, Human Relations, 4, 3-38.

Tubb, A.J., (1979), Cost Accounting, Sevenoaks, Hodder and Stoughton.

Turner, B.A., (1981), Quality and Quantity, Elsevier Scientific Publishing, Amsterdam, 15, 225-247.

Turner, B.A., (1983), The Use of Grounded Theory for the Qualitative Analysis of Organisational Behaviour, Journal of Management Studies, 20(3), 333-48.

Tversky, A., and Kahneman, D., (1973), Availability: A Heuristic for Judging Frequency and Probability, Cognitive Psychology, 5, 207-232.

Vasarhelyi, M.A., (1989), Expert Systems in Accounting and Auditing, in M.A. Vasarhelyi, (editor), Artificial Intelligence in Accounting and Auditing, New York: Markus Wiener, pp xiii - xxiv.

Vedder, R.G., (1989), PC-based expert systems shells: some desirable and some less desirable characteristics, Expert Systems **6**, pp. 28-42.

Wald, J., (1978), Biggs Cost Accounts (10th edition), Plymouth, Macdonald and Evans.

Walsh, D., (1972), Functionalism and systems theory, in P.Filmer, M.Phillipson, D.Silverman and D.Walsh, (editors), New Directions in Sociological Theory, London: Collier Macmillan.

Walters, J. and Nielsen, N. R., (1988), Crafting knowledge based systems: expert systems made realistic, New York, John Wiley.

Waterman, D.A., and Newell, A., (1976), Pas II: An Interactive Task-Free Version of an Automatic Protocol Analysis System, IEEE Transactions on Computers, 402-413.

Webb, G.I., (1988), A knowledge-based approach to computer-aided learning," International Journal of Man-Machine studies, **29**, pp. 257-285.

Weber, M., (1961), General Economic Theory, New York: Collier.

Weber, M., (1968), Economy and Society: an outline of interpretive sociology, (editor G.Roth and C.Wittich), New York: Bedminster Press.

Wenger, E., (1987), Artificial Intelligence and Tutoring Systems: computational and cognitive approaches to the communication od knowledge, C.A: Morgan Kauffman.

Whalen, T., and Schott, B., (1983), Representing and Manipulating Forecasting Problems and Techniques, Proceedings of the International Conference on Systems, Man and Cybernetics, Bombay, India, New York:IEEE Press, Vol 1, 127-131.

Whitley, R.D., (1988), The Possibility and Utility of Positive Accounting Theory, Accounting, Organizations and Society, 13(6), 631-645.

Williams, P.F., (1989), The Logic of Positive Accounting Research, Accounting, Organizations and Society, 14(5/6), 455-468.

Wilson, R.M.S. and Chua, W.F., (1988), Managerial Accounting: method and meaning, London: Van Nostrand Rheinhold.

Wilson, R.M.S. and Chua, W.F., (1993), Managerial Accounting: method and meaning, (2nd. edition), London: Van Nostrand Rheinhold.

Wise, B.P., and Kosy, D.W., (1986,a), Model-Based Evaluation of Long-Range Resource Allocation Plans, in Pau, L.F., (editor), Artificial Intelligence in Economics and Management, North Holland: Elsevier, pp 93-102.

Wise, B.P., and Kosy, D.W., (1986,b), Overview of Rome: a reason-orientated modeling environment, in Pau, L.F., (editor), Artificial Intelligence in Economics and Management, North Holland: Elsevier, pp 21-29.

Wolfgram, D.D., T.J. Dear and C.S. Galbraith, Expert Systems for the Technical Professional (Chichester: Wiley, 1987).

Wright, G. and P. Ayton, (1987), "Eliciting and modelling expert knowledge," Decision Support Systems, **3,** pp. 13-26.

Zeleny, (1982), *Multiple Criteria Decision Making*, New York, McGraw Hill

Ziman, J.M., 1968, *Public Knowledge: An Essay Concerning the Social Dimension of Science*, Cambridge: University Press.

Appendix A

Preface

Introduction

The structure of the appendix is as follows. This preface introduces the data analysis that was carried out, provides a table of contents for the material contained in the full appendix and presents tables of analysis. The full appendix is not presented here because of its length and can be made available via L.McAulay, University of Bath, Claverton Down, Bath BA2 7AY. The section of the appendix presented here is the material for S1 and is shaded in the table contents. The preface is followed by the data analysis itself and the original data for each of the six subjects.

The order of the presentation within the main body of the appendix is as follows, for each Subject:

- Episode Analysis. This includes expert system (ES) rules where appropriate. The analysis provides an interpretation at the episode level but develops issues at the protocol level where necessary. It explains the interpretation which gave rise to the cognitive map for each subject and explores some of the alternative interpretations of the data that are possible.
- Summary of Episode analysis, by issue raised and referenced to the episode analysis by page number.
- Cognitive Map. This is developed at the episode level and is referenced to episodes by number.
- Episode Summary, referenced to protocol analysis by page number.
- Protocol analysis. This follows Bouwman's work as closely as possible.
- Original transcript.

Introduction to Episode Analysis

Objectives:

- Interpretation of episodes to make the interpretation explicit. The primary aim was to develop reasoning chains which might provide a problem space representation of the knowledge revealed by the subjects.
- The development of a cognitive map for each of the subjects.
- Derivation of rules from the reasoning chains represented within the cognitive map for each of the subjects.

Process:

The protocols were interpreted in reverse order in order to build reasoning chains from a knowledge of outcomes.

This was found to be more effective than attempting to interpret the protocols in order. This process was arrived at by trial and error since there does not seem to be any guidance in the existing literature.

Some ES rules were developed as part of this analysis, where this was felt to be sensible. They are presented in pseudo code, using conventions which are consistent with VP Expert.

Introduction to the Summary of Episode Analysis

A grounded theory approach to the Episode Analysis raises a number of issues in two broad areas: the process by which the subjects appear to reason and the content associated with that reasoning process. The objective of the present research fits better with an investigation in process rather than content. The Summary of Episode Analysis therefore provides a summary in process terms. The issues which emerge are:

Familiarisation
Scanning
Evaluation - logical outcome of previous reasoning
- early foreclosure
Rule formation
Cue Redundancy
Comfort factor, accumulation of impressions
Conceptual modelling - experientially based
- theoretically based, supported by case study data
- theoretically based, unsupported by case study data
Pattern seeking
Theme
Template
Manipulation of incomplete information
Manipulation of inconsistencies
Manipulation of inaccuracies
Consistency of judgement

These issues arise from the analysis which is presented as table A.3 on page (v) of this appendix.

The issues form the basis for chapter 5.

Introduction to Cognitive Map.

A cognitive map for each of the subjects is presented, except in the case of S4. The reasons for excluding S4 are given in his Episode Analysis.

Introduction to Episode Summary

An Episode Summary, referenced to the Protocol Analysis by page, is provided. This gives an interface between the Protocol Analysis and the Cognitive Map for each subject.

Introduction to Protocol analysis.

The full analysis and coding are provided. An analysis of protocols which allows a comparison to be made with Bouwman et al (1987) is tabulated at tables A5 and A6 on page (viii). The characteristics of the Subjects and the Interviews which formed the basis for the protocol analysis is given in tables A1 and A2 on page (iv).

Original transcript.

The original transcript is provided so that the process of analysing protocols is fully transparent.

Table of Contents for the full version of the appendix

Table A.1 Characteristics of Subjects

Ref	Name	Accounting Qualification	Educational qualifications	Age range	Years of experience	Experience	Sex
S1	CC	ACMA	Phd	35-45	10	Academic	Male
S2	TS	ACA	Graduate	35-45	15	Self employed, small business sector	Male
S3	PC	ACA	Non-graduate	35-45	20	Financial Director, Retailing	Male
S4	RM	FCCA	Masters degree	45-55	25	University Secretary	Male
S5	PV	CIPFA	Graduate	35-45	10	Professional Institute	Male
S6	CS	ACA	Non-graduate	25-35	10	Manufacturing	Male

Table A.2 Characteristics of Interviews

Tape	Subject Ref	Number of interviewers	Case Study studied prior to session?	Session time, minutes	Words used by Subjects
1	S1	One	Yes	21	4600
2	S2	Two	No	68	5400
3	S3	Two	Yes	41	5900
4	S4	Two	No	72	8500
5	S5	One	Yes	50	5900
6	S6	One	Yes	40	4600

Table A.3 Analysis of Episode Analyses and Summary of Episode Analyses: specific references to issues raised in Summary of Episode Analyses

Issue	S1	S2	S3	S4	S5	S6
Familiarisation	✓	✓	✓	✓	✓	✗
Scanning	✗	✓	✗	✓	✗	✓
Evaluation: logical outcome of reasoning	✓	✓	✓	✓	✓	✓
Evaluation: early foreclosure	✓	✗	✓	✗	✓	✗
Rule Formation	✓	✓	✓	✓	✓	✓
Cue Redundancy	✓	✓	✗	✗	✗	✓
Accumulation of impressions, comfort	✓	✓	✓	✓	✓	✓
Modelling: experience based	✓	✓	✓	✓	✓	✓
Modelling, theoretical, case study based	✓	✓	✓	✓	✓	✓
Modelling, theoretical, general	✓	✗	✗	✓	✗	✗
Pattern seeking	✗	✓	✗	✓	✓	✗
Theme	✓	✓	✓	✓	✓	✓
Template	✓	✗	✗	✓	✗	✗
Incomplete and uncertain data	✓	✓	✓	✗	✗	✗
Inconsistency	✗	✗	✗	✓	✗	✗
Inaccuracy	✓	✗	✗	✓	✗	✓
Consensus of judgement	✗	✓	✓	✓	✓	✓

Table A.4 Analysis of Protocol Coding: numbers of protocols recorded for each code, by Subject

Code	S1	S2	S3	S4	S5	S6
Reading and Evaluation codes						
R	11	14	16	28	10	22
PAR	2	2	4	1		4
TREND	6	6	10	8	10	4
COMP	18	25	4	14	20	19
C	5	9	4	2	7	5
CI	8	3		16	2	8
Reasoning codes						
SUM	16	8	37	9	12	11
INF	28	21	50	19	38	34
EXPL	13	11	46	18	33	10
HYP	19	8	11	5	3	6
CONF		1	2	1	1	1
AS	30	27	119	187	77	80
Q	19	28	33	4	28	12
Goal codes						
SG	11	13	13		4	3
FG	13	5		1	3	
GR						
GI						
Memory access codes						
SF	1	1	7			
RET	14	2	10	6	8	10
Comment codes						
COM	5	4	24	163	44	21
MC	4	3	29	14	20	8
Interaction with Interviewer(s)				6		12
Total	223	191	419	502	320	270

Table A.4a Analysis of Protocol Coding: Code Descriptions (extracted from Bouwman et al (1987, pg.9), Exhibit 3

Code	**Description**
Reading and Evaluation codes	
R	Read information item
PAR	Paraphrase
TREND	Compute trend
COMP	Compute
C	Compare two items
CI	Compare with internal norm
Resoning codes	
SUM	Summarise evaluations
INF	Infer
EXPL	Explain
HYP	Formulate problem hypothesis
CONF	Confirm problem hypothesis
AS	State an assumption
Q	Formulate a question
Goal codes	
SG	State goal
FG	State (potential) future goal
GR	Select a specific report
GI	Select a specific item
Memory access codes	
SF	Stress a specific observation
RET	Retrieve information from memory
Comment codes	
COM	Comment re task content
MC	Comment re problem solving process

Table A.5 Activity code frequencies: comparison with Bouwman et al (1987, pg.11); total frequencies and frequencies per Subject

Activity	Bouwman frequency	McAulay frequency	Bouwman frequency per Subject	McAulay frequency per Subject
Examination/ reading	2060	327	172	54
Reasoning	1177	1116	98	186
Formulating goals	499	66	42	11
Memory retrieval	209	59	17	10
Commenting	929	339	77	56
Interaction with Interviewer	92	18	8	3
Total	4966	1925	414	320

Table A.6 Activity code frequencies: comparison with Bouwman et al (1987, pg.11); relative frequencies

	Mean		Median		Range	
Activity	Bouwman	McAulay	Bouwman	McAulay	Bouwman	McAulay
Examination/ reading	42%	17%	43%	18%	18-63%	9-31%
Reasoning	24%	58%	23%	56%	16-42%	48-71%
Formulating goals	10%	3%	10%	3%	4-16%	1-11%
Memory retrieval	4%	3%	4%	4%	1-8%	1-7%
Commenting	19%	18%	10%	12%	1-48%	4-35%
Interaction with Interviewer	2%	1%	2%	-	1-5%	0-4%

S1 Episode Analysis

Episode 48 is the conclusion and seems to provide an evaluation of the problem of a changed funding structure in terms of a prioritised response. The reasoning chain summary shows that episode 48 largely follows on from themes established earlier but some contradictory thinking is evident in the logic surrounding cost reduction. S1 has already established that cost reduction will be difficult given the evidence of previous cost reductions but even so recommends further cost reduction if necessary.

Episode 47 presents two ideas: Tabh's position in the market and a review of the cost position. There does not seem to be any directly logical way in which episode 47 is taken further; it offers something more in the way of the accumulation of impressions rather than a consistent cause-effect reasoning chain with episode 48. This accumulation of impressions might contribute to the comfort factor; impressions accumulate until the expert feels sufficiently comfortable with the data presented to provide an evaluation.

Episode 48 holds up cost reduction as a second order priority, if no new sources of funds are discovered, whilst episode 47 merely talks of reviewing "fairly radically my cost position"; protocol 211 states that "I might do one or two exercises to look at the behaviour of my costs", which can be linked back to the split between variable and fixed costs explored at protocol 13. Episode 47 becomes a wish list of information requirements and it is perhaps surprising that episode 48 can follow such an admission of the need for greater information. This does at least reveal the expert's ability to be decisive even when confronted by incomplete information. S1 reflects personal experience in at least two places: at protocol 207, the diagnosis of a possible strategic response may reflect S1's personal interest in strategy, known to the interviewers through previous discussions, and, more explicitly, the call for MORI research (protocol 215) which S1 acknowledges as derived from personal experience. All in all, a rich tapestry of ideas with no obvious links to the data provided in the case study, with evidence that ideas are driven by impression and personal experience.

Other interpretations abound. For instance, Protocol 220 reveals that S1 has in mind a bidding system which might operate within the Higher Education sector. Funding and cost behaviour might be affected by any new bidding system. Episode 47 is therefore an exploration based on conjecture and templates, real or imagined, and might represent S1 considering alternative interpretations of the situation before making the decisive summing up. This suggests a pattern of logical cause-effect reasoning supplemented by searches for alternative templates which might affect the analysis. S1 might therefore be merely working through alternative scenarios in a possibly systematic way rather than accumulating impressions and relating the case study to experience. These two interpretations may not be mutually exclusive.

Either or both of these interpretations are problematic from an ES point of view. The coding of experience or the handling of impressions requires much further research if it is to be understood in the context of clear production rules. S1 provides little guidance as to where templates might originate. Both experience and the development of alternative templates cause problems in terms of developing complete ES knowledge bases; how would the Knowledge Engineer know that the knowledge base is complete?

Episode 46 contains one inference drawn from previous reasoning based on the case study data; that cost control has been good and that cost reduction will therefore be difficult. This links in the contradictory fashion discussed earlier with episode 48. Having drawn the inference that cost reduction would be difficult, it is interesting that S1 should continue to consider cost reduction an appropriate approach. Perhaps the following informal knowledge base encapsulates the thinking in rule form:

```
Find:     consider_solution

Rule:     if cost_control = good
          then cost_reduction = difficult

Rule:     if cost reduction = difficult
          then solution = not_available

Rule:     if cost_reduction = difficult
          then cost_reduction strategy = not_impossible

Rule:     if solution = not_available and
          if cost_reduction strategy = not_impossible
          then consider_solution = attempt_cost_reduction
```

Given a clear chain of reasoning, it is clearly not impossible to develop an ES using protocol analysis of management accounting situations, which is encouraging. However, there is a problem of completeness; we do not have values from the protocol analysis study for cost_reduction = average or cost_reduction = bad. It is difficult to see how case study material could be presented to overcome this problem.

Nor is this problem evident in Newell and Simon for a reason that may be significant and which shows the value of thinking in problem space terms. Newell and Simon produced production rules which generated the problem space; in Prolog terms, the declarative programming was sufficient for the problem space to be investigated in much the same way as the digits problem of the early stages of the present research. The rules developed from S1 are of a substantially different nature; they ARE WITHIN the problem space itself. Newell and Simon generated production rules representing the principles from which the problem space is generated (articulated knowledge within the articulated/ compiled paradigm developed from Wenger): ES production rules are not general principles but are the compiled rules within which the expert is operating. Principles may or may not exist within the knowledge base operated by S1; we can only be clear that S1 does not articulate any such principles. Newell and Simon were able to demonstrate completeness for their production rules because they could show that reasoning was undertaken within the problem space generated by their production rules. In much the same way that for the digits problem it is possible to show that the solution exists within the problem space and by working with students it is possible to show that the problem space strategy is one strategy persued by humans. It is probably impossible to demonstrate completeness for the problem space described by production rules of the kind generated from S1.

So, we have two types of production rule:

1. Newell and Simon type production rules articulate the priniciples from which the problem space can be generated when required. A solution is given by search within the problem space in ways developed through the AI literature, for instance see Rich.

Simple example from mathematics: The principle of multiplication is repeated addition. Using repeated addition, multiplication tables can be generated.

2. ES type production rules containing compiled rules which are part of the problem space itself.

Simple example from mathematics: Tables showing the results of multiplication which can be consulted to provide solutions.

Episode 45 provides two possibilities: that new sources of income may be available (protocol 192) and that existing surpluses may be increased (remainder of episode).

The new sources of income comes from no-where in terms of reasoning, to emerge at episode 48 as the prime contender for resolving Tabh's financial problems. It would be difficult to write an ES rule for this; S1's interpretation works on the availability of new sources of income as a compiled fact, hedged at episode 48 with maybes, necessitating such a possibility to be available as a fact within the ES knowledge base, since it is not driven by data from the case study. S1 is further able to work with the uncertainties surrounding this "fact" in deriving the prioritised response at episode 48. How the uncertainties work and how S1 seized upon the possibility of the "fact" are hidden by the compiled nature of the knowledge being used, a situation made more difficult by the lack of clues in previous episodes. Perhaps S1 is applying experience.

Episode 44 is enigmatic. Protocols 188 and 190 are close to non-statements but are of prime importance if links to subsequent episodes are to be drawn. A constructive interpretation of these protocols has been included in the reasoning chain summary; that these points link to episodes 45 and 47. However, there is at least one other interpretation; that S1 is again testing to find alternative templates prior to firming up the ideas that come in the subsequent episodes. The modelling exercise that occurs at protocols 184-186 provides some support for the template testing interpretation. Whatever the interpretation, S1 is working from assumptions about future courses of action which cannot be substantiated from the case study data. Are the assumptions the result of S1's experience or imagination? It is not possible to say from the available evidence. A final interpretation is that episode 44 is a social interlude; S1 is talking whilst gathering his thoughts for the less ambiguous episode 48. Possibly, episode 44 could be ignored entirely.

Episode 43 is the logical evaluation based on the first stage in the case study exercise, prior to the Interviewer focusing attention on the implications of a change in the proportion of central funding. S1 concludes that the financial health of Tabh is sound but outlines three critical factors: funding, cost control and product mix. There are possible links to the enigmatic episode 44 and strong links to episode 46, where cost control is inferred to be problematic but, at episode 48, necessary if all else fails.

Episodes 40-43 provide a chain of reasoning about the academic's comments. A simple rule provides the flavour of this sequence:

Find: interpretation

```
Rule:
    if academic's_views = do_not_use_quant_measures and
    if finance = not_considered
    then interpretation = academic_is_not_facing_reality
```

Thus, the academic's views are rejected and forgotten. This shows the expert passing judgement on a situation and using that judgement to close down the problem space; the issues inherent in the academic's comments are simply ignored. This might be a kind of cue redundancy; the wealth of implications in the academic's statement is neglected.

A problem is evident in the discontinuity which characterises the chain of reasoning. Episode 40 is a modelling exercise based on the assumption that Universities teach and research; a totally plausible assumption presumably supported by direct experience. Episode 41 infers from episode 40 that costs should be split between teaching and research; a logical inference in the circumstances. Episode 42 then jumps to the case study data to draw the conclusion that the academic is not facing reality. This has only an indirect link to episodes 41 and 42. Episodes 40 and 41 share a common subject matter with episode 42 but no strongly reasoned cause and effect chain.

Episode 39 leads logically to episode 47 and two rules emerge:

Find: imperative_action

Rule: if more_information_on_demand = needed
then imperative_action = review_market_position

Rule: if ave_cost_per_student <> relevant_cost
then imperative_action = review_cost_position

These border on the platitudinous.

Episode 38 explains the information requirements and the underlying modelling assumptions which give rise to episode 39, particularly the rule which establishes that costs should be reviewed. This sort of reasoning, based on experience, appears to be an example of Collins "nexus"; the set of knowledge which bridges the codable knowledge and the welter of knowledge used by the expert often in a tacit fashion. The challenge for the Knowledge Engineer is to set up sensible questions to fire the rules given for episode 39. For instance, the following rule and questions would appear to work in conjunction with one of the episode 39 rule and to be consistent with S1's reasoning:

Rule: if course_cost = different_between_courses and
if more_information = available
then ave_cost_per_student <> relevant_cost

Question: "Is the course cost:
CHOICES: different_between_courses,
same_as_between courses

Question: "Is more_information:
CHOICES: available, not available

S1 appears to derive answers to both of these questions before moving to episode 39. However, it is a moot point as to whether a user of an ES developed from this transcript would not be equally placed to answer questions drawn directly from episode 39; ie. to ignore the reasoning inherent in episode 38. This point is problematic and in line with Collins "nexus" concept because the fundamental reasoning is supported by S1's ability to move on when confronted with incomplete information (as expressed in protocol 157) and with a model building exercise not built on the case study data but on personal experience. How much of this experience would need to be coded for the ES to function in practical settings, where a range of possible situations would be confronted, this is the nub of the point behind Collin's "nexus" concept.

Episode 37 leads to much the same comments as were made for episode 38, but this time for the issue of the market place. Again, S1 appears to reason based on incomplete information (protocols 155 and 156) and a model (protocol 154) whose assumption it is difficult to confirm from the closed world of the case study. To ape S1, it is again necessary to bring into the knowledge base external factors which broaden the range of knowledge which could be associated with Collin's nexus.

Episode 36 is the reasoning behind episode 37; it confirms that episode 37 is based on incomplete information and modelling assumptions. Protocol 145 is particularly interesting because S1 appears to draw later inferences based on this, even though the data in protocol 145 is not correctly drawn from the case study. This shows the ability of S1 to reach decisive evaluations and to express opinions authoritatively when utilising noisy data.

Episode 35 is the starting point for the causal reasoning chain 35-36-37-39-47-48 which now seems to be complete:

Formulate Propositions	____	Information Processing, including Incomplete information Incorrect information Modelling assumptions	____	Evaluate	____	Future Goal is to review market and cost position

In other words, exploring the marketing and costing issues leads to the consistent statement that more information is necessary. The weakness of the chain is the link to episode 48, as discussed earlier. The problem for an ES is to manipulate incomplete and incorrect information in such a way as to show judgement in knowing when to conclude that additional information is required; elsewhere Subjects manipulate incomplete and incorrect information and reach decisive evaluations despite the quality of the information.

Episode 34 is either a branch of reasoning which appears to go nowhere directly, or is part of the reasoning which contributes to the evaluation at episode 39, that the Management Accountant's cost per student is irrelevant. The latter interpretation is the more interesting from an ES perspective.

The point of linkage is sustainable in that episode 34 concludes that most costs are fixed in the short term but that other considerations are important in the long term. The influence of the recent works of Kaplan might be inferred here; that all costs are variable in the long term. The linkage is not sustainable if episode 34 is merely taken at face value since the direct argument is not repeated in the summing up process at episode 48. It is possible that episode 34 is part of a process of accumulating impressions to support a comfort factor which culminate at episode 48, rather than a link in a direct line of reasoning.

Episode 34 is interesting in presenting a standard academic argument. Most of the episode presents a modelling exercise based on marginal costing and Activity Based Costing. Given that the modelling exercise provides contradictory signals, perhaps it is not surprising that S1 can go no further than the evaluation at protocol 140; that some courses might be justifies. Equally, it is not surprising that the contradictory signals seem to place episode 34 secondary to the modelling exercise at episode 38; that course costs differ. Is it significant that the modelling exercise at episode 38 appears later to take precedence over the contradictory modelling of episode 34?

Episodes 29 to 33 are part of the reasoning chain leading to episode 34. This chain produces the rule:

```
Rule:     if time_span = long_term and
          if activity_change = major
          then variable_cost > academic_costs
```

This would seem to be a perfectly normal ES rule. It provides one minor challenge: establishing the criteria by which long_term and major would be established. This would presumably be a case of fine-tuning the ES through direct questioning of S1.

At episode 31, S1 applies the High-Low method to the data provided in the case study and arrives at a cost per student explicitly ignoring the effects of inflation. The cost per student is not used by S1 as a precise measurement but judgement is used to convert the calculation into a range value. S1 subsequently shows an ability to work with extraordinarily imprecise data, based on this cost per student calculation; protocols 130 and 131 suggest that S1 is happy to use £3000 to £8000 as a measurement of the relevant cost per student. Protocols 127 and 128 suggest that S1 is applying a rough intuitive feel in the situation rather than the kind of clear-cut cause-effect reasoning that would be associated with an ES. This example appears to show an expert going somewhat beyond ES ideas of fuzzy reasoning.

A "hard" interpretation of the problem outlined in the previous paragraph is, however, available. Using £3000 to £8000 as a range, a mean value and possibly a standard deviation might be established in order to assess the probability that the revenue of £4000 per student would be adequate. This interpretation could be operationalised in ES terms with a combination of procedural programming (establish mean and standard deviation) and declarative programming (establish rules for accept/reject for different levels of confidence that £4000 will exceed the relevant cost). However, S1 also appears to be influenced by the long-term fixed cost argument presented at protocol 133. We cannot know with any degree of certainty from the transcript whether S1 is evaluating the situation on the basis of the overall weight of evidence (possibly accumulating impressions before forming a judgement) or whether the cost behaviour modelling exercise at episode 29 is dominating S1's reasoning or whether the High-Low calculation at protocol 33 is taking precedence.

Here and at episodes 34 and 38 S1 is modelling in different ways:

a) based on experience, without the support of data from the case study (for instance, at episode 38 where the assumption is that Engineering courses are expensive);
b) based on argument or techniques which are included in text books, supported by case study data (for instance, the use of the High-Low method at episode 31);
c) based on argument which is recognisably available in text books, unsupported by case study data (for instance, episode 30 combines the Marginal Costing argument, that relevant cost is the variable cost which changes with activity in the short term, and Kaplan's argument that all costs are variable in the long term).

It would appear that of these three, (b) would be the most natural form of modelling to replicate in ES form whilst (a) is the most difficult. This latter point is more fully explored elsewhere.

Episode 28 sets up the chains of reasoning 29-30-33 and 31-32-33 by proposing that the Management Accountant's argument is dubious, based on a familiarisation exercise addressing the Management Accountant's figures at episode 27. This proposition is resolved by episode 34 by means of two interacting and paralled lines of reasoning which have the shape:

```
COMP ---- INF ---- SUM
AS   ---- INF ---- SUM
```

This analysis suggests that the reasoning process is partially data driven and partially built on assumptions. The assumptions appear to be driven by experience which ties this analysis back to the previous explanation of the alternative types of modelling approaches being pursued by S1. The analysis also suggests a problem for ES development. An ES would appear to not only take in data via ES questioning, in this case from the case study data, but also needs to embody the experience of the expert. This latter point is the problem in terms of Collins' nexus. For this particular situation, either of the two paralled lines of reasoning leads to the necessary conclusion and so it could be argued that for this situation an ES could be built, subject to the notes for episode 31.

Episode 26 concludes a chain of reasoning which leads to the conclusion that efficiency is very good and that costs are under control. This seems to lead unambiguously to episode 46 and seems to provide a mainstream of reasoning which is codable in ES rule terms and which leads to the ultimate evaluation. It is difficult to code the protocols at episode 26 as any other than SUM, possibly suggesting a hierarchy of evaluations where the SUM protocols from one level of analysis are taken to the next level of analysis. There may also be support for Bouwman's assertion that experts use calculations to create symbolic reasoning which is used in subsequent episodes.

Episode 25 leads to episode 26. It is interesting in that S1 uses a combination of approaches to Information Processing: assumptions, computations and requests for additional information. Despite the requests for additional information, S1 still succeeds in drawing an inference; that Pensions are not significant to the issues being explored. This is a further example of the expert's ability to work with incomplete information. The item of Pensions is raised in the first place because it is a material item (protocol 84) and yet is ultimately interpreted as insignificant because it is presumed to be an extraordinary item (protocol 88). This suggests the manipulation of models within a framework of financial accounting concepts and also the ability to balance contradictory messages; an interpretation in rule form would be:

```
Rule:     if cost_item > given_value and
          if cost_item_trend = inconsistent
          then cost = significant
```

```
Rule:     if cost_item = extraordinary
          then cost = not_significant
OR

Rule:     if cost_item = extraordinary
          then cost = can_be_ignored
```

The process of reasoning is interesting but not transparent. One interpretation might be that the first rule triggered an investigation by S1. The result of the investigation is represented by the second rule. How this process worked is not entirely clear, even if this interpretation is accepted.

The chain through to the final conclusion is now a little clearer and can be summarised as follows:

some costs are significant but can be ignored ---- inference that costs are under control ---- cost reduction may still be necessary even though costs are under control

This chain would seem to be codable in rule form despite the problems already discussed.

Episodes 23 and 24 establish firstly that Administration and Central Costs are significant and then that they are under control. The basis for episode 24 is calculations made prior to the protocol interview session. Clearly, videoing these sessions would provide a degree of verifiability which taping alone cannot supply.

Episode 23 generates the rule:

```
Rule:     if cost_increase > given_percentage and
          if cost_increase_percentage > given_rank_order
          then cost = significant
```

Further clarification of given_percentage and given_rank_order could presumably be provided through further questioning and fine-tuning of the knowledge base.

Episode 24 generates the rule:

```
Rule:     if cost_increase = scarcely_increased
          then cost_control = good
```

Episode 22 makes sense in relation to episode 18. A logical interpretation might be:

```
Rule:     if cost_type = capital_expenditure
          then cost_control = not_an_issue
          BECAUSE "Capital expenditure is an investment
          concern and is therefore subject to investment
          control rather than cost control considerations."
```

Episode 22 links to episode 26 in a similar way to episode 25. Episode 21 signals that equipment and furniture is an issue of investment control which is presumed to be outside the scope of the present exercise. It is a conclusion which does not appear to lead anywhere. It might be an example of the skill of drawing boundaries around the task confronting the expert. This may be another form of cue redundancy.

Episode 20 appears to be a random observation. It is drawn from the data but does not appear to lead anywhere.

Episode 19 is a logical building block in the reasoning chain 18 - 19 - 21, which now has the characteristic:

R,COMP,Q,ASS
3
INF
3
SUM

This suggests a conclusion drawn by an inferencing process built on a range of approaches to the data: calculations, searching for wider implications, or alternative templates, through a questioning process and modelling, this time presumably based on experience because it is difficult to see where else protocol 69 might be coming from. The chain itself appears to develop in a logical, cause and effect manner.

The interest of episode 18 is that it shows S1 using a variety of approaches to familiarisation/ exploration/ data capture. Of these, reading and calculating appear to be most amenable to ES manipulation in this case. Seeking the wider implications through a questioning process provides another aspect of Collins' nexus, raised earlier.

Episode 17 appears to be taking stock, rather than contributing to the development of ideas. It seems to reinforce that episode 15 is directly linked to episode 26.

Episode 16 provides the rationale for the goal of exploring the main items of cost; the investigation of the proposition that costs are under control. It also explains the choice of the major items; those which vary by the greatest amount. This determination of materiality might link to the management accounting theory surrounding the investigation of variances; the variances in this case being variances as between one year's results and the preceding year's results. The investigation rule applied by S1 seems to be to investigate all variances over a certain percentage. Episode 16 therefore appears to be meta-reasoning, or, alternatively, the social process of explaining the reasoning which is being undertaken.

Episodes 14 and 15 represent a reasoning chain with the following characteristics:

COMP

3

INF

3

SUM

This time the familiarisation/exploration phase is marked by calculation alone. A rule emerges:

```
Rule:     if cost_per_student = fallen
          then cost_control = good
```

This appears to be both data driven and relatively straightforward in ES terms. It does not even ask a lot of the ES used to establish that cost_per_student has indeed fallen. S1's choice of cost per student as a basis for the calculation is interesting and we do not know how other approaches to establishing that cost control is good would have been handled. Equally, we do not know from the protocol transcript how S1 would have reacted if cost_per_student had increased. There are therefore problems of completeness of S1's knowledge base revealed by the protocol analysis interview. The permutations might be many, for instance:

```
    cost_per_student = small_increase (e.g. > 5%)
    cost_per_student = less_than_inflation
    cost_per_student = modest increase
    total_cost = decrease
```

and so on. Presumably a direct interviewing technique would be necessary to pursue this issue.

Episode 13 is the starting point for the group of episodes 13 to 26. This appears to be a familiarisation process but there is some ambiguity between the roles of familiarisation and exploration. A variety of approaches to familiarisation/exploration are adopted. Protocol 49 reveals an internal norm for an acceptable productivity improvement. This is both impressive and confusing, given that to our knowledge S1 has no basis in research, textual material or experience for the statement. The motivation for this protocol is not obvious.

The challenge to ES design is again that of alternatives; what would S1 suggested for differing sets of results? How many case studies would need to be devised before sufficient data could be collected for a general ES to be built. Having established that ES rules can be developed where clear causal reasoning chains can be built, there does not appear to be much reason for reducing the protocol analyses for the remaining subjects to rule form to the degree of rigour applied to the analysis of S1's transcript.

Episode 12 provides a theme which does not re-emerge until the chain given by episodes 35 - 47; relating cost and revenue issues to each other. The idea appears to emerge first in episode 10, where it seems to take the form of C-V-P analysis. It is not easy to see the part played by this particular theme. It borders on the platitudinous. The chain given by episodes 35 - 47 is only ambiguously linked to the final verdict. Whilst the management accounting issues present in the case study clearly involve C-V-P analysis and it is therefore possible to understand why the theme is present in S1's transcript, it does not actually appear to go anywhere. Similarly, the cost behaviour analysis and rejection of the Management Acccountant's expansionery strategy is only tenuous (episode 27 - 34 link ambiguously to episode 39).

Episode 11 is the starting point for the main line of argument which culminates at episode 46. Understanding episode 11 provides a problem. Episode 10, which triggers one track of reasoning at episode 11, is simply not articulated in terms that can be related back to prior chains of reasoning; the ideas appear to be compiled in S1's mind. The explanation for this might be that S1 carried out considerable work prior to the taped session and it will be important to contrast S1's analysis with the subjects who did not prepare in advance. There may be value in not giving subjects the case study material in advance of the protocol analysis interview.

Episode 11 triggers two lines of argument:

Cost Control: Costs well controlled ---- Only reduce cost if no other options available

Choice of activities: No reliable data ---- Seek additional data

Episodes 7 to 9 appear to be logical and largely case study data driven. It would be useful if they could be interpreted as clearly linking to episodes 10 to 12. As it is, this interpretation is not unambiguous and the most that can be said is that they are largely a matter of S1 going through a process of familiarisation. Episodes 7 to 9 may be a process of attempting to gain one's bearings.

Episodes 1 to 6 appear to be important in providing the missing link to episode 48. The chain combines case study data driven reasoning with a search for missing information (episode 5).

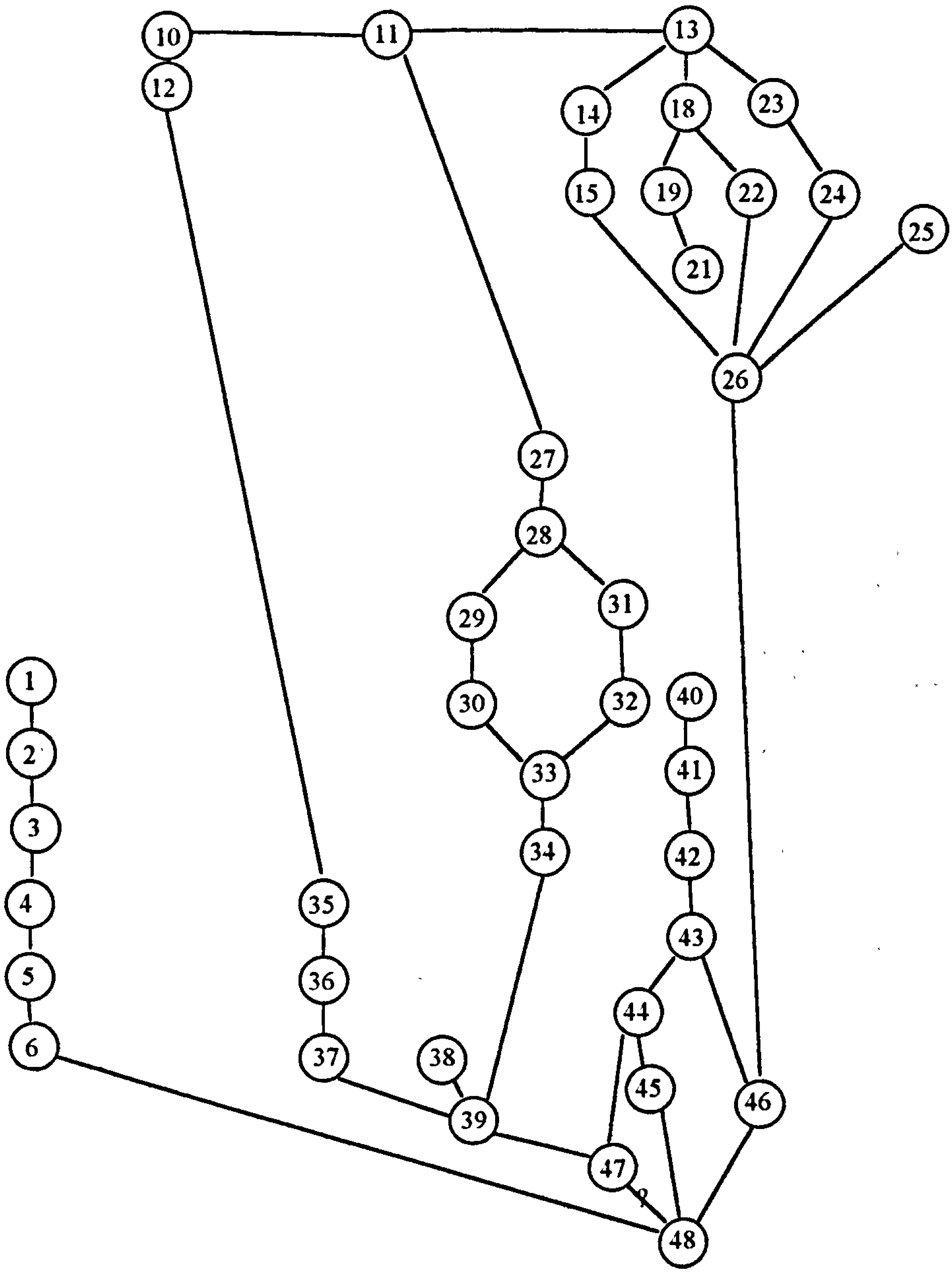
In terms of general problem solving strategy, an analysis of S1 suggests the form:

FAMILIARISATION
FORM PROPOSITIONS
RESOLVE PROPOSITIONS
EXPRESS OPINION

In general, from an ES perspective, there appears to be sufficient evidence in this interpretation of S1's transcript that ES rules can be determined to resolve the propositions, with the exceptions of coding the experience used in S1's reasoning and the problems of incompleteness of the knowledge base, given the existence of alternative rules for which no evidence is present. A further problem might be that S1 sometimes used a variety of strategies at the familiarisation stage. This would be particularly difficult in the case of the strategy of casting about for the wider implications; in S1 expressed as the search for additional information or asking questions about the broader context.

S1 Summary of Episode Analysis

S1 Cognitive Map



Episode Summary

S1 Protocol analysis

FAMILIARISATION

Episode 1 State that goal is familiarisation

1	SG	get the figures sorted out in a way which is meaningful

Episode 2 State that goal is to match related items

2	SG	take out related income with related costs

Episode 3 Familiarisation with Research items

3	R	take out research income
4	R	match against research expenditure
5	C	that reveals a surplus
6	TREND	that has increased
7	COMP	by a factor of five
8	CI	which is fairly small

Episode 4 Familiarisation with Residential items

9	R	match up the residential expenses
10	R	against residential income
11	CI	since that appears to be a slightly separate activity to the main core issues coming here
12	TREND	residential surpluses have gone down
13	C	by a little bit
14	COMP	rather more than halved
15	C	still running a surplus in 1989
16	CI	it didn't seem to be a major problem then
17	CI	it seemed reasonable

Episode 5 Familiarisation with Other Services items

18	Q	we could do with more information to group other services income and match against other services expenditure

Episode 6 Reason and Summarise Findings:
- scope to increase residential surplus
- research, residential and other services "healthy"

19	EXPL	the results of pulling out those three separate activities is that one could draw some fairly minor conclusions

20	INF	there is perhaps a little bit more scope to increase the residential surplus
21	INF	those three activities appear to be doing quite healthily

<u>Episode 7 State that goal is to consider main income</u>

22	SG	the main usefulness of that exercise is that we can look at all the other sources of income which seem to be rather more main stream
23	SG	and match that against the costs associated with them
24	SG	and in that way get a little bit more of an idea of what is going on with these figures

<u>Episode 8 Familiarisation with main income</u>

25	C	other [main] income has increased from £22,600,000 to £30,000,000 between 1987 and 1989
26	TREND	other income per student has also increased from about £6,000 to just over £7,000
27	COMP	that is about 20%

<u>Episode 9 Familiarisation with total income</u>

28	INF	the total income available has gone up in line with that income, plus the surplus from those three other activities which we've looked at

<u>Episode 10 Reasoning and summarising findings</u>

29	EXPL	the point from that is that, if other income per student is rising by 20% over two years
30	FG	when we look at either cost control
31	FG	or an allocation of resources
32	FG	we're clearly going to have to take into account that rising level of income

<u>Episode 11 Formulate propositions</u>

33	HYP	We seem to have two types of issues:
34	HYP	one is [an] issue of efficiency, perhaps cost control,
35	HYP	the other issue appears to be one of choice of activities, which is more to do with allocation;

Episode 12 State that goal will be to consider both revenue and costs in choice of activities discussions

36	FG	if we're going to be concerned with choice of activities, then clearly the discussion needs to reflect both the revenue and cost
37	EXPL	it appears to be rather foolish just to say that costs have increased without any reference to rising surpluses, in particular the rising income per head

INTERPRETS THE UNIVERSITY DIRECTOR'S COMMENTS

Episode 13 Familiarisation with expenditure

38	R	if we start off by looking at the cost side
39	SG	to get a better understanding of that
40	COMP	having taken out the core costs, the main stream costs per student in 1987 were about £6,900
41	COMP	and they fell down to £6,500 in 1988
42	COMP	and have just gone up slightly back to about £7,000 in 1987
43	TREND	they have risen only by 1.8% over the last two years
44	R	bearing in mind that the majority of those costs are academic staffing costs
45	HYP	would appear to indicate that extremely tight cost control
46	EXPL	bearing in mind salary increases running more or less within inflation
47	HYP	that implies quite considerable productivity increases over the last two years
48	COMP	I guess somewhere around 8% per year
49	CI	which in a service organisation
	CI	appears to be indicative of a good level of cost control

Episode 14 Familiarisation with academic staffing cost

50	R	the main item of cost is the academic staffing cost per student
51	CI	it seems to be pretty big
52	COMP	that's actually fallen by about 1.5%
53	COMP	the amount paid for academic staff per student has gone down over the past couple of years from £3,300
54	COMP	to £3,260
55	TREND	a slight fall

Episode 15 Reason and summarise findings

56	INF	it would appear that the costs have been quite well controlled
57	EXPL	in that the largest costs have been controlled particularly well
58	EXPL	with rising productivity

Episode 16 State that goal is to analyse most significant items of expenditure

59	SG	we could go on to do a cost analysis if we wanted to take that argument a little bit further to look at the main items of costs. One way of doing that is to actually analyse cost increases between 1987 and 1989 and to see where the biggest component of cost increases have come from, even though the overall costs seem to have been kept down

Episode 17 Familiarisation with academic staffing

60	RET	the main element here, as has been discussed, is academic staffing
61	RET	which accounts for 35% of the cost increase
62	RET	that has been well controlled

Episode 18 Familiarisation with equipment and furniture

63	R	the next major element is the equipment and furniture costs
64	COMP	which accounts for about 33% of the increase
65	TREND	if we look more closely at that, there has been an increase
66	COMP	even over the last year of 1.7 million
67	CI	but that doesn't necessarily reflect an issue of cost control
68	Q	without having more information
69	ASS	the speed of increase of those costs would seem to indicate that they have been based on total capital costs rather than on an implied depreciation on those items
70	Q	I would want to look more closely at those policies

Episode 19 Reason and summarise findings

71	INF	that does not necessarily imply that cost control is weak, if it's a capital item and if that rise in equipment and furniture can be justified in terms of the University's future investment funding

Episode 20 Familiarisation with Computer Baord grant, related to equipment and furniture

72	C	I've noticed that the rise of 1.5 million last year also might tally with the increase in the Computer Board's grant
73	AS	and it is possible that that might include the computer budget
74	AS	it looks quite likely that it does
75	Q	I would like a breakdown of what that equipment is
76	AS	it is even possible that there could be offsetting grants reducing that

Episode 21 Reason and evaluate

- equipment and furniture investment may need to be controlled

77	SUM	the conclusion from that is we might possibly want to control the investment there

Episode 22 Reason and summarise findings

78	INF	but it looks like it's not a major issue of cost control

Episode 23 Familiarise with Admin. and Central costs

79	R	we then come down, in terms of issues that have been increasing our costs, down to the next most important item of admin. and central services
80	COMP	which in the last couple of years account for 14% of the increase

Episode 24 Reason and summarise findings

81	INF	in the last year it looks like these have been controlled particularly well

82	INF	it may be that someone has been cutting back admin. and central overheads
83	EXPL	in 1988-1989, they have been scarcely increased at all

<u>Episode 25 Familiarise with Pension costs</u>

84	R	the other major element of cost increase on these figures seems to be pensions,
85	COMP	which accounts for about 19% of the cost increase in the last year 1988/89.
86	AS	one would guess that has got to do with redundancy payments, or some such policy,
87	AS	it seems unlikely that that really reflects an increase in costs that can really be matched against income this year.
88	AS	it looks like there has been a one off extraordinary cost associated with a decision to retire people,
89	AS	and possibly once and for all costs.
90	Q	on the issue of pensions it would be interesting to know more about the policies that are being used in showing those costs.
91	INF	it doesn't really appear to reflect any issue of efficiency of costs getting out of control.
92	EXPL	it is probably a one off, redundancy scheme I suspect.

<u>Episode 26 Reason and evaluate</u>
<u>- efficiency is very good, as measured by improvements in productivity and costs under control</u>

93	SUM	the costs that are associated with the more mainstream income of supporting students would appear to be well under control.
94	SUM	although we could, if we really wanted to go into fine detail, pinpoint one or two areas we could look at just slightly.
95	SUM	the question of efficiency appears to be very good;
96	SUM	implied by an increase in productivity, on the one hand,
97	SUM	and costs under control, on the other.

INTERPRETS THE MANAGEMENT ACCOUNTANT'S COMMENTS

Episode 27 Familiarisation with Management Accountant's comment

98	SG	moving on to the issues of choice of activity
99	PAR	we now come to the management accountant's discussions of relevant costs
100	R	which he claims are £3,263 per student
101	COMP	which is based on the direct staffing costs, only, divided by the number of students

Episode 28 Formulate proposition

102	HYP	this argument would seem to be slightly dubious
103	INF	he's clearly implying that that is the one element of variable costs with all other costs fixed costs
104	HYP	that's slightly debatable in some ways

Episode 29 Explore cost behaviour of academic staffing

105	HYP	even as to whether the direct academic costs are relatively fixed
106	AS	it could be quite difficult for those to move with short-term fluctuations
107	AS	if we were talking about a small increase in student numbers, that we might well be able to accommodate that within the existing academic staffing
108	AS	at some point, if we're looking to a larger increase in activity and we're perhaps looking to the longer term, we would expect academic staffing costings to go up in line with student numbers we would expect that at some point they are going to become a variable cost
109	AS	if there was a short term and fairly minor increase in costs, I could imagine those cost elements being kept fixed if we really wanted to, with increased productivity, as I suggested earlier
110	FG	we could put some figures on it
111	AS	I'm having to make an assumption about the rates of pay increases rising with inflation
112	RET	and that led me to estimate an increase in productivity [of] something like 8% per year
113	FG	I could pin this down a bit more carefully
114	AS	if we were dealing with just small numbers of extra courses that we were being

		offered, it is possible that we might be able to respond to that, without even direct academic staffing costs increasing; that would imply that they are relatively fixed

Episode 30 Reason and summarise findings

115	INF	the Management accountant's argument, which is implying that they are variable, is a slightly dangerous argument
116	INF	it depends on whether we're taking a short term view of small fluctuations
117	INF	or whether we're looking to the long term cost behaviour and perhaps we are considering quite major changes in our level of activities and in the type of activities that we are putting on
118	INF	it's a slightly random judgement that the relevant variable cost is given by the staffing costs only

Episode 31 Explore cost behaviour from the available data

119	SG	it's perhaps of some interest to look at the way that costs behave as we've increased the number of students
120	MC	this is admittedly only going to be a very crude exercise
121	COMP	if we focus on the costs that have been matched against the core activity, teaching students, those costs increased by £3.39 million over the last couple of years
122	COMP	against a rise in students from 3,797 to 4,216
123	COMP	the change in costs has worked out at £8,100 per student
124	MC	I think that's a fairly crude argument
125	HYP	that would suggest that a cost of £8,100 in the last couple of years per student is something like the variable cost
126	COM	I have to be quite careful about that because some of this cost increase is going to reflect inflation over the period
127	MC	I've tended to imply here that the cost increase is entirely on the basis of the increase in the number of students
128	MC	I would end up at a very rough intuitive feel

Episode 32 Reason and summarise findings

129	FG	I perhaps could do some further calculations there
130	INF	if we were talking about major changes in activities, if we were talking abut the longer term, I would have guessed that the longer term is considerably higher than the £3,000 [£3263] implied by the management accountant
131	INF	and somewhere between that and £8,000; it's obviously going to be rather less than £8,000, once I take out inflation

Episode 33 Reason and evaluate:
- additional students are not beneficial at £4000 per student, if the long term view is taken coupled with a major change in activity

132	PAR	the Management Accountant is arguing that we have an opportunity here to sell new courses at £4,000 per student.
133	RET	I would expect that if we were talking about a major change in activity, and if we're taking the longer term, I would actually expect the relevant cost to actually be above that £4,000 figure.
134	SUM	therefore, for a major change in activity, I would not accept his argument here, that it is actually beneficial.

Episode 34 Reason and evaluate:
- some courses might be beneficial at £4000 per student, assuming a one-off decision with minor implications for activity

135	INF	there are two possible lines of argument
136	INF	the first line of argument is that we are really talking only about a fairly small increase in numbers for a particular course; a one off opportunity that is a little bit out of our main stream; someone has come up with an opportunity to do one or two courses and we just have to decide whether it's worth doing
137	INF	although the variable costs are well above £4,000 per student if we looked at cost behaviour over some time, if I was looking at the short term, it's possible that, a lot of these costs would in fact be relatively fixed
138	INF	from that point of view, you could argue that it's not just a question of the academic staffing costs here

139	INF	I think you could argue that you probably could get away with the assumption of a lot of those costs being fixed
140	SUM	I think it would therefore justify some courses
141	RET	it would be dangerous to apply that argument to the long term
142	RET	from a longer term point of view, the costs that are likely to vary are going to be well above that £4,000

Episode 35 Formulate proposition

143	COM	from a longer term point of view, and if we're talking about major changes in activities, I think the argument that the Management accountant is putting forward points out a different area of debate that I think is very important
144	HYP	that area of debate really is saying that, if we go for `relevant courses', then we could increase the number of students in the University in total

Episode 36 Explore marketing considerations

145	RET or COMP	income per student from central funding is more like £8,000 per student [£7400 per student based on prior calculations, using a consistent basis. There is no basis for £8,000 per student. Is S1 recalling £8,000 from memory, ie. the cost per student previously calculated? Or rounding off £7,400 to £8,000?]
146	AS	the argument here about which sort of courses we place ought really to take into account what is going on in the market place for students
147	AS	if we reckon that our income is really somewhere in the order of £8,000 then the important thing is to switch our activities to courses that students generally are applying for in large numbers, because business studies or engineering has suddenly become very popular
148	INF	that argument really has as much to do with the income effect as it does with these costs that the management accountant has put forward
149	Q	in terms of the cost side of that debate, we really need to know more about the market here

150	Q	we've got no information to clarify the argument put forward by the Management accountant as to whether the courses relevant to society are in demand or not
151	AS	I would be very interested in information on that side, because, if they are in demand, my conventional funding might well be able to increase e.g. I might be able to bid for students
152	INF	it might be possible to bid for students well above the £4,000 cost per student
153	EXPL	because it looks to me like the income per student on conventional courses is well above that figure

Episode 37 Reason and summarise findings

154	AS	we really have a market place issue here
155	Q	we want to know more about where the demand for students is
156	Q	as yet we don't have any information on whether the government is prepared to pay more for certain types of student than others and I would certainly like to know that before making decisions on which course were attractive

Episode 38 Explore student costing implications

157	Q	secondly, I would like to know more about the cost structure as between different subject courses
158	AS	for example costs on engineering courses are considerably higher than those on managerial studies courses and so on; I would expect that that is the case
159	AS	I could imagine them being as much as twice as high

Episode 39 Reason and evaluate
- more information on market demand is required
- the Management Accountant's cost per student is irrelevant because it does not relate to course cost per student

160	RET	from those two points, we've first of all discussed efficiency and the cost side
161	RET	which appears to be well under control
162	RET	we've then moved on to an issue of choice of activities and we need more information from the market on market demand
163	SUM	in terms of trying to understand cost behaviour as between different courses, I don't really feel that either of the

		figures presented by the management accountant are particularly relevant to that debate

INTERPRETS THE ACADEMICS COMMENTS

Episode 40 Explore Academic's comments

164	SG	finally, we really need to move on to the academic's point of view
165	SG	as well as deciding on issues of efficiency and issues of allocation, we need to look at what the University's goals are
166	AS	the University has more than one objective
167	AS	one of the objectives is to do with student teaching
168	AS	there are objectives to do with research
169	EXPL	because the justification, presumably, of relatively low student-teacher ratios, as compared with polytechnics, must be based on the role of the University in terms of research, in terms of advancing knowledge

Episode 41 Explore implications of research objective

170	INF	just to look at the student income effect in isolation appears to be only part of the argument.
171	Q	one would be wanting clarification of what emphasis was going on research, what emphasis was going on teaching.
172	AS	we have to be aware of the fact that within the staffing costs, possibly as much as half of those costs are really supposed to be associated with research activities,
173	COM	it's a little bit difficult to break that down
174	INF	and a little bit dangerous to imply that all of those are costs that are matched against teaching activities only.

Episode 42 Reason and summarise findings

175	INF	the academic is ignoring the financial side of the argument
176	INF	and also the marketing side of the argument;
177	EXPL	by simply saying that we should not use measures at all,

Episode 43 Reason and evaluate:
- academic's goals could be met if the University takes account of financial and marketing implications; it is not sufficient for the academic to "bury his head in the sand"

178	SUM	there would appear to be scope for meeting the academics goals, and indeed some of the broader, perhaps slightly less tangible goals of the University in terms of their research efforts
179	SUM	if they are a well funded University, if they both keep their costs under control, as they appear to be doing, and also allocate those resources towards an appropriate mix of courses, then this could bring in funds which would benefit some of those goals of increase in knowledge
180	Q	if we had further information that would enable us to allocate activities sensibly
181	EXPL	the academic is rather putting his head in the sand if he doesn't even consider what the costs are, what the possible revenues are from the different activities, and then make any choices in terms of how much money to put into research and so on; at least on the basis of some understanding of where the costs are, where the relevant incomes are and so on

Question

One final point; how would you react to a restructuring where the central funding became 40% of the total income?

Answer

Episode 44 Explore critical factors

182	SF	it hinges on the way in which the government bodies are cutting this back.
183	Q	I would like more information on what their perception is of what's going to happen on the incomes side
184	AS	it would seem quite likely that you might get a reduction in automatic funding for universities, complemented by other sources of funds supplied by the government
185	AS	so it's possible that the government may be saying, "well, we're now going to help the students to provide income for the universities themselves, through loans or whatever"

186	AS	in which case, it may be that I have to face up to a new split of students, some of whom are funded centrally and some of whom are funding themselves, for example.
187	Q	I'd quite like to know what are the possible sources of income that would offset that decline in central funding
188	HYP	I would hope to be responding to those opportunities for other income in a way that kept up my total income
189	Q	if the new sources of income are coming in a way that generates a different cost structure, to what's happening at the moment, then I would want to know a bit more about any way in which my costs are going to change
190	HYP	if they altered the balance between new income arrangements and the way my costs are going to behave, then I've got to respond to the match between the two, rather than just willy nilly try to keep up my central funding

<u>Episode 45 Explore other sources of income</u>

191	COM	there are two other responses to that
192	HYP	it's possible that I may have to start looking for completely different sources of income
193	AS	if the government is trying to cut back
194	HYP	then it may be that I want to look a little bit more at opportunities outside for bringing in other grants
195	HYP	one possibility might be to try and gain an increase in the income on research grants and contracts
196	RET	we are running a surplus on that in terms of our income versus our costs. In fact, a fairly minor one, but
197	RET	it has increased by 400% over the last couple of years
198	HYP	I don't see a lot of scope in the residential side, but it's possible that, if we're now moving to a system of students being more self-sufficient, that I might have to make those services earn a little bit more income
199	Q	and perhaps I might be interested in knowing a bit more about other sources of income
200	RET	we've seen an increase from virtually zero to half a million in the last couple of years alone
201	Q	I'd be interested to know whether or not there are any possibilities in raising funds in that direction

Episode 46 Reason and summarise findings

202	HYP	we might have to look at even tighter cost control.
203	INF	that's going to be difficult, given the control that we've already exercised,
204	HYP	we might try to squeeze just a little bit harder, a little bit more blood out of the stone.

Episode 47 Explore implications of the introduction of a bidding system for students

205	AS	if we are now able to bid for funds
206	FG	that could force me to review fairly radically both my position in the market and my cost position
207	HYP	if I felt that we were in a strong position to bid for certain types of students in the future, possibly at premium prices, or that I felt that I was competitive against those students, then I think that I'm into the game of trying to address the more strategic decision of which part of the market I'm going to steer myself towards
208	AS	in the past, with central funding, it's a fairly straight forward offer of income in return for teaching
209	AS	but it's possible that under the new arrangement there may be quite radical opportunities for bidding at low cost for higher volumes of students
210	FG	which is an issue that might be worth addressing
211	FG	I might do one or two exercises to look at the behaviour of my costs
212	FG	I would be wanting to look at where we were strong; what sort of things we were good at in the University
213	COM	that gets back to the Management accountant's point earlier about whether we ought to look at the balance of our courses
214	Q	I'd be wanting to know where demand was strong
215	FG	the University could consider even carrying out a market research exercise perhaps using an organisation such a MORI
216	EXPL	who I have used before,
217	Q	who would look at the demands of students applying for universities, to get a clearer idea as to where the courses that they are going to ask for in the future

218	FG	and trying to match that against the areas that the University appears to be good at

<u>Episode 48 Reason and evaluate:</u>
<u>Response would be to:</u>
<u>- find out sources of new funds</u>
<u>- consider cost reduction</u>
<u>- increase existing surplus creating activities</u>

219	SUM	I'd be looking very closely at where the new funds were coming
220	SUM	looking for responses I'd need to make to that
221	SUM	and seeing whether there were opportunities there
222	SUM	if we ended up with a conclusion that there was still some belt tightening to be done, we might have to look at a little bit tighter cost control in some areas
223	SUM	and look very hard at pushing up the income from some of these other activities

Table 1
Analysis used by S1

	1989 £'000	1988 £'000	1987 £'000
Main income			
Central funding	21091	18712	16985
Academic fees	5012	4439	3698
Endowments	590	213	146
Computer board	2264	1523	1198
Other general income	1059	684	595
	30016	25571	22622
Surpluses			
Residences & catering	128	67	280
Research	523	411	112
Other services	479	149	-13
	1130	627	379
Expenditure			
Academic staff	13756	12913	12567
Academic administration	3032	2867	2856
General academic exp.	539	501	485
Maintenance of premises	4288	4179	4309
Central services	1933	1837	1472
Student & staff fac.	665	641	639
Pensions	1029	333	638
Equipment & furniture	4143	2417	3028
Miscellaneous	94	104	95
	29479	25792	26089
Surplus/(Deficit)	1667	406	(3088)
No. students	4216	3948	3797
Expenditure per student	6992	6533	6871
Direct academic staff cost, per student	3263	3271	3310
Increase in expenditure, 1987-1989, £'000	3390		

TAPE 1

The first action is to try and get the figures sorted out in a way which is meaningful. One way of doing that seems to be to take out three aspects of related income with related costs {associated that seems to be the main issue of student costs}. The first one is to take out research income and match against that research expenditure. Taking out that reveals a surplus that has increased by a factor of five which is fairly small. Second, it seems to be worth making up the residential expenses against residential income, since that appears to be a slightly separate activity to the main core issues coming here. Residential surpluses have in fact gone down by a little bit, have rather more than halved but it was still running a surplus in 1989. It didn't seem to be a major problem then; it seemed reasonable. We could do with more information to group other services income and match against that other services expenditure.

So, the results of pulling out those three separate activities is that one could draw some fairly minor conclusions in the sense that there is perhaps a little bit more scope to increase the residential surplus. By and large those three activities from the information we've got appeared to be doing quite healthily. However, we're talking fairly small beer and the main usefulness of that exercise is that we can hopefully then look at all the other sources of income which seem to be rather more main stream and match that against the costs associated with them and in that way get a little bit more of an idea of what is going on with these figures.

Looking at that, it appears that other income has increased from £22,600 to £30,000 between 1987 and 1989. Other income per student has also increased from about 6,000 to just over 7,000 and that is about 20%. Similarly the total income available has gone up in line with that income, plus the surplus from those three other activities which we've looked at. The point from that is that if other income per student is rising by 20% over two years, then when we look at either cost control or an allocation of resources we're clearly going to have to take into account that rising level of income.

Can I step back a little bit and look at the discussion? We seem to have two types of issues, one is issue of efficiency, perhaps cost control, and the other issue appears to be one of choice of activities, which is more to do with allocation. If we're going to be concerned with choice of activities, then clearly the discussion needs to reflect both the revenue and cost, so it appears to be rather foolish in the discussion just to say that costs have increased without any reference to rising surpluses, in particular the rising income per head.

But if we start off by looking at the cost side, to get a better understanding of that, having taken out the core costs, the main stream costs per student, and that those in 1987 were about 6,900 and they fell down to 6,500 in 1988 and have just gone up slightly back to about 7,000 in 1987 so they have risen only by 1.8% over the last two years, which, bearing in mind that the majority of those costs are academic staffing costs, would appear to indicate that extremely tight cost control on that side and, bearing in mind the likelihood of academic staff costs, of salary increases running presumably more or less within inflation, that actually implies quite considerable productivity increases over the last two years. I guess somewhere around 8% or something like that per year which in a service organisation appears to be indicative of a good level of cost control on the cost side. The main item of cost is the academic staffing cost per student and if we look more closely at that particular item it seems to be pretty big. That's actually fallen by about 1.5%. The amount we're paying for academic staff per student has gone down over the past couple of years from £3,300 to £3,260, a slight fall. Looking at the costing side, it would appear that the costs have been quite well controlled in that the key element in costs, the largest element in costs, has been controlled particularly well, with rising productivity.

We could go on to do a cost analysis if we wanted to take that argument a little bit further to look at the main items of costs. One way of doing that is to actually analyse cost increases between 1987 and 1989 and to see where the biggest component of cost increases have come from, even though the overall costs seem to have been kept down. The main element here, as has been discussed, is academic staffing, which accounts for 35% of the cost increase. Obviously, that has been well controlled. The next major element that accounts for the increase in cost over the period, that might be of concern to the University Director, is the equipment and furniture costs, which accounts for about 33% of the increase. So, if we look more closely at that, there has been an increase even over the last year of 1.7 million. But that doesn't necessarily reflect an issue of cost control without having more information. In the first place, the speed of increase of those costs would seem to indicate that they have been based on total capital costs rather than on an implied depreciation on those items. So I would want to look more closely at those policies. And at any rate, that does not necessarily imply, if it's a capital item, that cost control is weak, if that rise in equipment and furniture can be justified in terms of the University's future investment funding. The other thing I've noticed here is that the rise of 1.5 million last year also might tally with the increase in the Computer Board's grant and it is possible that that might include the computer budget. In fact, it looks quite likely that it does. So I would like a breakdown of what that equipment is. It is even possible that there could be offsetting grants reducing that.

The conclusion from that, without further information, is we might possibly want to control the investment there, but it looks like it's not a major issue of cost control. We then come down, in terms of issues that have been increasing our costs, down to the next most important item of admin. and central services, which in the last couple of years account for 14% of the increase. But, in fact, in the last year it, looks like these have been controlled particularly well. It may be that someone has been cutting back admin. and central overheads. And, in fact, in 1988-1989, they have been scarcely increased at all.

So, finally, the other major element of cost increase on these figures seems to be pensions, which accounts for about 19% of the cost increase in the last year 1988/89. One would guess that has got to do with redundancy payments, or some such policy, but it seems unlikely that that really reflects an increase in costs that can really be matched against income this year. It looks like there has been a one off extraordinary cost associated with a decision to retire people and possibly once and for all costs. So, on the issue of pensions it would be interesting to know more about the policies that are being used in showing those costs. But, it doesn't really appear to reflect any issue of efficiency of costs getting out of control. That, probably one off, redundancy scheme I suspect.

So, getting away from that, if we've looked at the costs that are associated with the more mainstream income of supporting students, it would appear that they are well under control in the main areas that the University Director might be concerned about. Although we could, if we really wanted to go into fine detail, pinpoint one or two areas we could look at just slightly; look a bit more closely at cost control if he was interested in that area.

So, moving on now from the question of efficiency, which appears to be very good; implied in increase in productivity, on the one hand, and costs under control, on the other.

Moving on to the issues of choice of activity, we now come to the management accountant's discussions of relevant costs, which he claims are £3,263 per student, which is based on the direct staffing costs, only, divided by the number of students. This argument would seem to be slightly dubious, in that he's clearly implying that that is the one element of variable costs, with all other costs, which we have under the expenditure category in his view, fixed costs. That's slightly debatable in some ways, even as to whether the direct academic costs are relatively fixed, since it could be quite difficult for those to move with short-term fluctuations.

Question

On what basis do you say that?

Answer

I could imagine that, if we were talking about a small increase in student numbers, that we might well be able to accommodate that within the existing academic staffing. At some point, if we're looking to a larger increase in activity and we're perhaps looking to the longer term, at some point we would expect academic staffing costings to go up in line with student numbers. So, in other words, we would expect that at some point they are going to become a variable cost. Certainly, if there was a short term and fairly minor increase in costs, I could imagine those cost elements being kept fixed if we really wanted to.

Question

What evidence do you have to support this?

Answer

Well, with increased productivity, as I suggested earlier, we could put some figures on it. But I was suggesting that probably I'm having to make an assumption about the rates of pay increases rising with inflation and that led me to estimate an increase in productivity something like 8% per year. I could pin this down a bit more carefully if you wanted me to. But in which case, if we were dealing with just small numbers of extra courses that we were being offered, it is possible that we might be able to respond to that, without even direct academic staffing costs increasing. Certainly without them increasing on a pro rata basis, as is implied by the argument that they are all variable.

Question

And if you use lecturing isn't it just as cheap to teach 200 as 100?

Answer

Well, that would imply that they are relatively fixed. But I think that, rather, that the Management accountant's argument, which is implying that they are variable, well, I mean, even that is a slightly dangerous argument, because it depends on whether we're taking a short term view of small fluctuations or whether we're looking to the long term cost behaviour. And perhaps we are considering quite major changes in our level of activities and in the type of activities that we are putting on. So, my feeling is that it's a slightly random judgement that the relevant variable cost, which is really what we are talking about here, is given by the staffing costs only.

I think it's perhaps of some interest to look at the way that costs behave as we've increased the number of students. This is, obviously, admittedly only going to be a very crude exercise. But you might make the argument that if we focus on the costs that have been matched against the core activity, teaching students, those costs increased by £3.39 million over the last couple of years against a rise in students from 3,797 to 4,216. So that, you might say that the change in costs has worked out at £8,100 per student. So I think that's a fairly crude argument. But that would suggest that a cost of £8,100 in the last couple of years per student is something like the variable cost.

I have to be quite careful about that because, quite clearly, some of this cost increase is going to reflect inflation over the period, whereas I've tended to imply here that the cost increase is entirely on the basis of the increase in the number of students. But, even so, I would end up at a very rough intuitive feel. I perhaps could do some further calculations there, that the cost is the variable cost. If we were talking about major changes in activities, if we were talking abut the longer term, I would have guessed that the longer term is considerably higher than the £3,000 implied by the management accountant and somewhere between that and £8,000. It's obviously going to be rather less than £8,000, once I take out inflation.

Now, he is arguing that we have an opportunity here to sell new courses at £4,000 per student and I would expect that if we were talking about a major change in activity, and if we're talking the longer term, I would actually expect the relevant cost to actually be above that £4,000 figure. And, therefore, for a major change in activity, I would not accept his argument here, that it is actually beneficial.

I think that there are two possible lines of argument that would take a slightly different direction here. The first line of argument is that we are really talking only about a fairly small increase in numbers for a particular course; a one off opportunity that is a little bit out of our main stream, not necessarily a long term opportunity, and we're not necessarily thinking in terms of long term changes of activities. Someone has come up with an opportunity to do one or two courses and we just have to decide whether it's worth doing. Now, although I feel that the variable costs are well above £4,000 per student if we looked at cost behaviour over some time, then, if I was looking at the short term, it's possible that, in fact even direct academic staffing costs, a lot of these costs would in fact be relatively fixed. And I think that you might find, from that point of view, you could argue that it's not just a question of the academic staffing costs here. But I think you could argue that you probably could get away with the assumption of a lot of those costs being fixed. I think it would therefore justify some courses.

However, I think it would be dangerous to apply that argument to the long term because, as I've said, I think that, from a longer term point of view, the costs that are likely to vary are going to be well above that £4,000.

I think that from a longer term point of view, and if we're talking about major changes in activities, I think the argument that the Management accountant is putting forward, when he talks about relevant courses; all we have to do is place all our emphasis on making our courses relevant to society, I think that points out a different area of debate that I think is very important. And that area of debate really is saying that, if we go for `relevant courses', quote, that we could increase the number of students in the University in total. Now, bearing in mind that the income per student; I'm talking at the moment about the income that we're making for each student from various sources; central funding, and so on, the income per student is more like £8,000 per student. So the argument here about which sort of courses we place ought really to take into account what is going on in the market place for students. If we reckon that our income is really somewhere in the order of £8,000, and I'm talking now in terms of conventional students, then there might be an argument that, really, the important thing is to switch our activities to courses that students generally are applying for in large numbers, because business studies or engineering has suddenly become very popular. But that argument really has as much to do with the income effect; as the fact that these courses might be popular, has as much to do with the income effect as it does with these costs that the management accountant has put forward.

In fact, in terms of the cost side of that debate, we really need to know more about the market here. We've got no information to clarify the argument put forward by the Management accountant as to whether the courses relevant to society are in demand or not. And I would be very interested in information on that side, because, if they are in demand, my conventional funding might well be able to increase; e.g. I might be able to bid for students. And, there we would be talking, presumably, I would have thought, it might be possible to bid for students well above the £4,000 cost per student, because it looks to me like the income per student on conventional courses is well above that figure. And so I think we really have a market place issue here. We want to know more about where the demand for students is. As yet we don't have any information on whether the government is prepared to pay more for certain types of student than others and I would certainly like to know that before making decisions on which course were attractive. And secondly, I would like to know more about the cost structure as between different subject courses. Whether for example my costs on engineering courses are considerably higher than those on managerial studies courses and so on. And I would expect that that is the case; I could imagine them being as much as twice as high.

So, in conclusion, from those two points, we've first of all discussed efficiency and the cost side, which appears to be well under control, but we've then moved on to an issue of choice of activities and we're really saying we need more information from the market on market demand. And, really, in terms of trying to understand cost behaviour as between different courses, I don't really feel that either of the figures presented by the management accountant are particularly relevant to that debate.

Finally, we really need to move on to the academic's point of view. Because, at the end of the day, as well as deciding on issues of efficiency and issues of allocation in some sensible way, particularly as we get to the issue of allocation, we need to look at what the University's goals are; what it's all about, what it is trying to do. Clearly, the University has more than one objective. One of the objectives is to do with student teaching. There are objectives to do with research because the justification, presumably, of relatively low student-teacher ratios, the justification of that, as compared with polytechnics, must be based on the role of the University in terms of research, in terms of advancing knowledge. And, therefore, just to look at the student income effect, the student costs and matched income in isolation, appears to be only part of the argument. So, really, one would be wanting clarification of what emphasis was going on research, what emphasis was going on teaching. And we have to be aware of the fact that within the staffing costs, possibly as much as half of those costs are really supposed to be associated with research activities, and therefore it's a little bit difficult to break that down and a little bit dangerous to imply that all of those are costs that are matched against teaching activities only.

However, I feel that the academic is ignoring the financial side of the argument and also the marketing side of the argument by simply saying that we should not use measures at all, that there would appear to be scope for meeting the academics goals, and indeed some of the broader, perhaps slightly less tangible goals of the University in terms of their research efforts, in terms of their desire to further knowledge and so on. That, if they are a well funded University, if they both keep their costs under control, as they appear to be doing, and also allocate those resources towards an appropriate mix of courses, then this could bring in funds which would benefit some of those goals of increase in knowledge. So, I think, if we had further information that would enable us to allocate activities sensibly, I think that the academic is rather putting his head in the sand if he doesn't even consider what the costs are, what the possible revenues are from the different activities, and then make any choices in terms of how much money to put into research and so on; at least on the basis of some understanding of where the costs are, where the relevant incomes are and so on.

Question

One final point; how would you react to a restructuring where the central funding became 40% of the total income?

Answer

I think it really rather hinges on the way in which, presumably, the government bodies are cutting this back. And I would really like more information on what their perception is of what's going to happen on the incomes side here. It would seem to me quite likely that you might get a reduction in, if you like, automatic funding for universities, complemented by other sources of funds supplied by the government. So it's possible that the government may be saying, "well, we're now going to help the students to provide income for the universities themselves, through loans or whatever". In which case, it may be that I have to face up to a split, not so much a sudden one of reduction in income, but it's possible that I may have to be adapting my activities to a new split of students, some of whom are funded centrally and some of whom are funding themselves, for example. So, in the first place, I'd quite like to know what are the possible sources of income that would offset that decline in central funding.

If the income is coming in another way, I would hope to be responding to those opportunities for other income in a way that in the first place kept up my total income. Obviously, if the new sources of income are coming in a different way, in a way that generates a different cost structure, to what's happening at the moment, then, obviously, I would want to know a bit more about any way in which my costs are going to change, given the new type of funding arrangement. Because, if they altered the balance between new income arrangements and the way my costs are going to behave, then I've got to respond to the match between the two, rather than just willy nilly try to keep up my central funding.

There are two other responses to that. It's possible, without knowing more, that, even allowing for that, that I may have to start looking for completely different sources of income. That, if the government is trying to cut back, and if other sources of income, perhaps from the students themselves, backed up with loans, if there's a danger that that won't keep up the level of income, then it may be that I want to look a little bit more at opportunities outside for bringing in other grants. One possibility might be to try and gain an increase in the income that I'm making, for example, on research grants and contracts. We are running a surplus on that in terms of our income versus our costs. In fact, a fairly minor one, but it has increased by 400% over the last couple of years. I might well be looking at that as a little bit of an opportunity to try and offset that funding decline. I don't see a lot of scope in the residential side, but it's possible that, if we're now moving to a system of students being more self-sufficient, it's possible that it could be conceded that I might have to make those services earn a little bit more income. And perhaps I might be interested in knowing a bit more about other sources of income. We don't really know about the classification of other services rendered and things. But it's possible there; we've seen an increase from virtually zero, the surplus, up again, to half a million in the last couple of years alone. I'd be interested to know whether or not there are any possibilities in raising funds in that direction.

I think, if it implied or it was likely to lead, even allowing for those opportunities, to a net reduction in cost; being cynical, if the government was chopping back more than it was going to give us back in other directions, we might have to look at even tighter cost control. That's going to be difficult, given the control that we've already exercised, that we might try to squeeze just a little bit harder, a little bit more blood out of the stone to offset that slightly.

I think that the other big issue, but I'm speculating a little bit, is, if with the new system, we are now able to bid for funds, I obviously don't quite know exactly the way in which any bid system might work, that could force me to review fairly radically both my position in the market and my cost position. Because, if, for example, I felt that we were in a strong position to bid for certain types of students in the future, possibly at premium prices, or that I felt that I was competitive, against those students, then I think that I'm into the game of trying to address the more strategic decision of which part of the market I'm going to steer myself towards. In the past, with central funding, it's a fairly straight forward offer of income in return for teaching, but it's possible that under the new arrangement there may be quite radical opportunities for bidding at low cost for higher volumes of students, which is an issue that might be worth addressing if I felt that the University was appropriate for high volume courses. And I might do one or two exercises to look at the behaviour of my costs. But at the same time, I would be wanting to look at where we were strong; what sort of things we were good at in the University. That gets back to the Management accountants point earlier about whether we ought to look at the balance of our courses. And I'd be wanting to know where demand was strong; where we were perceived to be strong. The University could consider even carrying out a market research exercise, perhaps using an organisation such a MORI, who I have used before, who would look at the demands of students applying for universities, to get a clearer idea as to where the courses that they are going to ask for in the future and trying to match that against the areas that the University appears to be good at.

In summary, how would I handle the change in structure? I'd be looking very closely at where the new funds were coming, indirectly. Looking for responses I'd need to make to that, and seeing whether there were opportunities there. On the other hand, if we ended up with a conclusion that there was still some belt tightening to be done, we might have to look at a little bit tighter cost control in some areas and look very hard at pushing up the income from some of these other activities.

Appendix B

Preface

Appendix B presents brief case study reports to support the material presented in chapter 6. In all cases more significant reports form the basis for the material presented here. The appendix therefore provides notes on the background to the case organizations and the to the studies.

Contents

Company A

Basic Features

Sector: High Technology

Status: Division of a multinational

Owner: US Parent Company

Size: 1989 Turnover £100 million
Employees 900

Location: South-west

Market: Highly competitive, centred on Europe

Nature of relationship with company

The author supervised an MBA student project with the company. There were four visits to the company by the author:

1 Introductory visit to meet company-based supervisor;
2 Meeting organized by student, including introduction to the company and its operations;
3 Student presentation to company, followed by discussion;
4 Follow-up meeting to discuss project success with the company-based supervisor.

The full project is Aldridge (1989). For the remainder of the case study write-up, Aldridge is referred to as "the researcher". This project is copyright Aldridge and the company has insisted on full confidentiality. These case study notes are therefore drawn up from personal notes taken over the period of the project. Confidentiality has been fully respected.

The researcher worked for three months, full-time, on the project.

Nature of company problem

The problem concerned the transfer of product manufacture from one group company to another. Company A requested the development of a computerised decision aid which would be used to evaluate future transfers.

The company developed products at a number of sites world-wide. Each site took on full responsibility for the products developed under its charge. In some cases, it was advantageous from the Group point of view for the product to be manufactured at another site. Where a product responsibility lay with one site but the manufacturing was entrusted to a second site, the product was said to have been "transferred" to the second site. Full responsibility remained with the first site and it was customary for the first site to receive the product profits.

Company A had strong motivations to transfer products to its site but had no clear idea as to how it should construct proposals to allow this to happen. Each time in the past that company A had decided to investigate a transfer, a proposal had been produced but little consistency in proposal writing was evident. The company wished to correct this and so the nature of the problem posed by company A was to develop a systematic way of appraising transfers in order that coherent proposals could be drawn up. The division felt that if it proved to be possible to systematize the process of transfer proposal justification then other Group companies would become very interested, with benefits of prestige for company A.

Company A appeared to have three main reasons for wishing to transfer products:

1 Resource implications. Company A could fill up surplus capacity with transferred products. Although company A would not benefit in profit terms, it could make a case for continued survival in based on manufacturing to a significant level of capacity. On the other hand, if company A filled its manufacturing capacity with transfer products alone, it would forego profitable opportunities arising from manufacture of its own products. The resource issue was therefore one of balancing resource commitments.

2 World-wide profits. By transferring products, say, from the United States, freight and duty costs could be avoided, thus substantially improving world-wide profits for the Group as a whole. The division was surprisingly highly motivated to increase world-wide profits, as opposed to divisional profits, perhaps as a consequence of the strategic direction for which the parent was famous.

3 Local content. European markets were sensitive to the proportion of the product which was made in Europe. Marketing perceived that products made, for instance, in the United States would be at a disadvantage to products made in Europe. Transferring products therefore brought direct marketing advantages.

Solutions investigated

Three solutions were investigated:

1 A management accounting solution which derived a solution to the problem based on a payback period model;

2 A checklist solution which provides a number of questions to which managers must respond in order to evaluate the qualitative aspects of the transfer.

3 An expert system solution, adopting the shell VP Expert because of its availability and ease of learning.

Solution adopted

Both the spreadsheet and the checklist solutions were developed by the researcher and accepted by the company.

The participants at the Presentation meeting stated that these provided a sound basis for future development. The spreadsheet and checklist were stated to add nothing to the existing knowledge base of the company but were valuable in structuring that existing knowledge. A decision had been taken using the spreadsheet and checklist by the time of the final visit. The company representative expressed satisfaction at the way in which the decision proceeded.

The participants at the Presentation meeting discussed the establishment of "strategic profiling" using a graphical output of the spreadsheet and checklist procedures. The overall system would operate as follows:

1 a knowledge engineer expresses the factors of importance to a decision in the form of a series of questions;

2 responses to the questions are collected in numerical form using, for instance, Likert scales, so that a range of questions can be combined to provide a single numerical value. The theory underpinning this is provided by Multiple Criteria Decision Making (eg. Zeleny, 1982);

3 composite values for ranges of questions are presented in graphical format so that a profile emerges.

The profiles can form the basis of discussions between managers from which decisions would result. The participants at the Presentation were keen to adopt this solution and were particularly attracted by the combination of problem structuring and flexibility which was allowed by combining spreadsheet/checklist and discussion.

Problems encountered

The researcher encountered a number of problems in setting about this project, mostly of a consultancy nature. Full details and a description of how these problems were resolved is provided in King et al (1991).

In discussing these problems, it became apparent that the nature of the knowledge provided by managers on site was the central issue. The knowledge structures that were revealed during interviewing seemed to be very similar to the problem space in that a tree-like description appeared to be most appropriate. However, the managers used company specific knowledge which was difficult to interpret and did not make the links between their statements totally transparent. It was as though the responses to questions were compiled in their minds.

Given a problem space representation of knowledge, discussions took place with the researcher to encourage the production of an expert system. However, the researcher, who had previously been an experienced programmer, expressed strong dislike of the if ... then structures available in the expert system shell suggested as a possible route to such a system. The researcher was happy to work with Lotus 1-2-3 but very unhappy to work with Third Generation structures such as if ... then statements. The problem of the researcher's attitude to such programming influenced the final choice of a solution.

The use of an expert system was discussed at the Presentation meeting. The participants were generally against the use of an expert system. The term "expert system" was seen to be emotive and to give the resolution of the transfer problem a legitimacy it did not deserve. The general feeling was that the problem needed to be addressed in a flexible, if structured manner. The author discussed the possibility of applying sensitivity analysis, as permitted by, for instance, VP Expert, but this was not well received. It was suggested that Senior Managers would "believe" the outcome of an expert system consultation simply because such a system would be called an expert system and would be computer based.

Company B

Basic Features

Sector: Direct Marketing

Status: Division of UK Company

Owner: UK Parent Company

Size: 1990 Turnover £1.1 million
Employees 20

Location: South West

Market: There is a dominant market leader. The customer base of company B includes major national and multinational companies

Nature of relationship with company

The author supervised an undergraduate project with the company. There were three visits to the company:
1 Initial visit to meet Managing Director and to gain some familiarity with Company B's operations;
2 A mid-sessional meeting at which a presentation was made to the company;
3 A final meeting at which a second presentation was made to the company.

A full project is written up as Cowdry et al (1990). The report is neither copyright nor confidentiality protected. The project was pursued over six months as a single module in final year studies. Confidentiality has been maintained for consistency reasons only, since the report is freely available.

Nature of company problem

The company requested a review of its selling price policy. The company operated on a competitive contract bidding basis, quoting for a contract on the basis of the provision of a range of services from answering the telephone to dispatching postal material in response to clients' customers' particular needs.

Solutions investigated

The problem was tackled in two ways; as a market research problem and as a product costing problem. Market research involved sending questionnaires to clients following a limited number of semi-structured interviews with clients to determine the important variables. Product costing followed Checkland (1981) and Finlay and King (1986) in terms of methodology and evolved into an activity based costing exercise. The product costing procedure developed through activity based costing was modelled using a spreadsheet package.

Discussions were held with the managers of company B at the final meeting to gain an understanding of their reaction to the use of expert systems. There was some enthusiasm for the general idea, particularly amongst the representatives from the Head Office. The main advantage was perceived to be that expertise could be provided to support relatively small divisions such as company B in a way which is cost effective whilst maintaining company policy and procedures.

Solution adopted

Both approaches to the problem pointed to the same conclusion; that company B had been underpricing its product. A small number of contracts had been subsidising the major number of contracts. In particular, one contract which was typified by hoax calls was extremely profitable because the resource demands envisaged in the contract agreement were rarely needed.

The company adopted the spreadsheet package to assist in the calculation of prices in the future. It was agreed that market research would be used again but on a need-to-know, rather than on a regular basis.

Problems encountered

One of the major difficulties in providing a solution to the selling price problem was ignored in the final solution. This concerns the qualitative issues which the company collectively referred to using the term "hassle". From the companies point of view, pricing reflected two factors: a set of relatively simple procedures which provided a benchmark price, coupled with an assessment of "hassle" which would subjectively provide a premium rating for the contract bid. There was strong consensus about "hassle" but no way of measuring it in systematic terms and therefore no way of incorporating it into the analysis.

Hassle did not follow any kind of discernable pattern. However, given that the company changed to a more rigorous cost base in its selling price decision making, it is possible that objective assessments of cost-based prices might provide data from which hassle could be evaluated on a consistent basis. No opportunity has presented itself to pursue this line of enquiry.

Company C

Basic Features

Sector: Timber import and wholesale

Status: Private Limited Company

Owner: Family owned

Size: 1990 Turnover 12 million
Employees 18

Location: Wales

Market: Customer base includes national D-I-Y chains

Nature of relationship with company

The author provided a management accounting consultancy in return for a fee under the DTI Business Growth and Training initiative. The fee has been used to finance the research described in this thesis and amounted to approximately £6,000, of which the University of Bath extracted its customary contribution towards overheads.

The author's interest in problem solving and the use of computers was openly discussed with the company and its officials so as not to compromise the ethical implications of research. The company openly entered into and supported the initiatives described here. Full confidentiality has been maintained.

Nature of company problem

The particular problem described here concerned the options faced by the Managing Director when confronted by a funding problem. Funding had become a limiting factor to the company's continued expansion and increasingly assumed crisis proportions as the problem was explored.

Alternatives considered were:
1 sale of the business to a Canadian Company which was involved in a joint venture with company C at the time of the funding crisis;
2 sale of the business to a cash rich Irish Company which had ambitions to diversify into the timber industry;
3 expansion through retained profits over a number of years whilst retaining the existing funding arrangements, which relied on a combination of guaranteed overdraft and

factoring. The overdraft was guaranteed on the Managing Director's property, part of which was used as a home for his family;

4 winding up the business, with the Managing Director accepting one of several opportunities to take up Marketing Director positions with competitors, at salaries in the range £70,000 to £100,000.

Solutions investigated

A number of structured and unstructured ways of resolving the problem were investigated.

Alternatives 1 and 2 presented the necessity to value the company. Company valuation is a specialist expertise and the company sought external advice from one of the major accounting partnerships. The final valuation arrived at a figure of £600,000 based on a P/E ratio calculation. The adviser used past profits and a P/E based on the industry sector. The P/E used was 8. A reduction of 25% was made because company C was not listed on the Stock Exchange. The Irish company insisted that the valuation depend on future profits in the coming three year period and that a P/E ratio of 6 be used.

The Managing Director also took legal advice on the proposed sale of his business to the Canadian and Irish companies. Amongst the advice he received were the following statements:

1 accept only proposals which include an up-front payment for the business as it stands;

2 do not enter into agreements with a 50:50 share of ownership;

3 only enter into agreements which provide independence for the foreseeable future;

Alternative 3 involved financial forecasting to establish the feasibility of a retained profits funding policy. A spreadsheet model was developed for this purpose. Unfortunately, the Managing Director effectively ignored this option by demanding that funding be made immediately available; this was entirely consistent with his impulsive management style. However, the spreadsheet model was extensively and enthusiastically used in preparing forecasts to use in negotiations with the Canadian and Irish companies. The spreadsheet model provided a relatively user-friendly approach to forecasting figures for which the Managing Director had been paying consultants (one of the big six accounting partnerships) £1000 per forecast run. Its value was not difficult to justify, therefore.

Alternative 4 was not seriously considered by the Managing Director because he had a strong desire to retain his personal autonomy.

All alternatives were screened using the strategic profile method described for company A. In fact, company A's strategic statement was used as a basis for the questions that were asked of the Managing Director in forming an evaluation of the four options. Unfortunately, the Managing Director simply reinforced his existing choice by rating his preferred option most highly in regard to the questions asked. However, the Managing Director did state that he found the exercise helpful and it is possible that structured approaches to decision making may be valuable to managers as a means to rationalising decisions once impressions have been formed.

The strategic profiling session involved the author in a series of meetings with the Managing Director which stressed the long-term basis of the business. One aspect of this was concerned with discussing the objectives of the business. The Managing Director made a number of statements about the nature of his business, some of them contradictory. For instance:

1 'guaranteeing future employment for personnel is secondary to ensuring the future of the business';

2 'the business is the people associated with its running'

The Managing Director appeared to find it challenging and beneficial to explore such inconsistencies as a management development process. Other issues to emerge included operational and financial issues. For instance:

1 'the critical factor in this business is supply. I can sell everything I can source.'

2 'supply depends critically on the ability to buy on a cash basis because no-one is interested in extending credit in this business.'

It was clear from the way in which systems operated that the Managing Director epitomised Hopwood's (1976) non-accounting style of management. There were few controls of any kind. Systems such as Debtors Control operated poorly. The Managing Director relied on the computer system to solve all of the business's control problems but did not provide sufficient support such that the computer system was effectively developed. In other words, the Managing Director was most concerned with marketing and logistics matters and strategic and financial matters were either illogically thought through or ignored as far as possible. Despite this, the Managing Director held a fascination for strategic and financial issues and addressed such matters enthusiastically when forced to do so.

During the time that the problem was being explored, a Financial Director was appointed. The Financial Director was a graduate, although he was not a qualified accountant. His appointment was based on his reputation as a small business accountant in the timber industry. He was previously known to the Management Director and was effectively "head hunted". The Financial Director quickly formed an opinion, based partly on a visit to Canada. The Financial Director became convinced that the alternative which involved selling the business to the Canadians was the right choice. He justified this decision in only two ways during the time that the author was involved with the company:

1 The Canadians could gain access to the necessary resources for Company C to expand. The Financial Director expressed the need for the Managing Director to understand that a 50% share in a business which is 3 times the size of the existing business is beneficial in comparison with a 100% share in the existing business.

2 The Canadian company was considered to be one of two suitable prospective purchasers known to the Financial Director. The Canadian company had the advantage that they had access to funds: 'The Canadian people are good, but we might do a deal with X, if he can find the money, because he is better. X can source more timber before breakfast than the Canadians can manage in a day. But he hasn't got the backers.'

The Financial Director spent his first six months in post resolving the funding problem and investigating the effects of the lack of controls on the business. He discovered that a significant proportion of the sales for the preceding three years had not been invoiced and claimed that he could "make more money sweeping up behind the Managing Director" than the Managing Director could make in forming deals with customers.

Solution adopted

The Managing Director increasingly relied on the advice of his Financial Director as it became clear that the alternatives on offer were equally acceptable and not acceptable. The decision was made to sell the business to the Canadian company. This decision was maintained through lengthy negotiations during which the Managing Director often stated that he would have walked away from the negotiating table but for his Financial Director's faith in the correctness of the decision.

Problems encountered

Essentially, the problem was not resolveable in a structured, analytical manner because all of the alternatives were equally good (or, increasingly, bad) from the point of view of the Managing Director. Each of the solutions had particular advantages but each had features which were entirely unacceptable to the Managing Director in rational terms. Each met the quantitative, financial requirements of the problem and each failed on the basis of a qualitative issue which was an essential part of the decision making process.

Appendix C

Preface

Appendix C brings together the working papers that were produced at the time that the standard costing expert system was developed. It has not been possible to print these working papers out in a standard format and page numbering is manual.

The appendix is developed in approximately chronological order to give the following contents which have been structured into the logical stages followed during the project.

ESAC 1
Expert Systems in Accounting Education
Questionnaire: Student attitudes to lecturing.

Objectives

To determine students opinions on lecturing in order to define the nature of lecturing expertise.

Methodology/Timetable

Questionnaire design completed by end February, 1987. Informed by the view that professional students are examination orientated. Questions of roughly three types: exam orientation, education orientated, research/academic orientation. Questions set out desirable lecturing attributes to which students respond using a Likert scale.

Administered to Professional students by Easter, 1987, based on availability at Derbyshire College of Higher Education. Target of 100 responses set (rule of thumb provided by questionnaire expert at Loughborough University of Technology).

Results

107 responses from 4 seperate groups of students, out of 128 questionnaires issued (84% response rate since students were effectively a tied audience; loss mostly accounted for by absence) and 6 potential full-time groups (CIMA 4 and CACA 3 omitted because of time pressure on student groups at available times).

Data processed via Minitab. Verified and final results processed October, 1988. Desirable attributes ranked according to mean score (given in brackets):

A good lecturer in accounting subjects (Financial accounting, Cost accounting, Management accounting, Financial Management):

1. Discusses examination technique (4.4393).
2. Can answer examination questions and explain clearly the way in which specific questions should be answered (4.3551).
3.Provides a clear explanation of relevant concepts and relates these concepts to the topic being lectured (4.3458).
4. Provides clear examples of practical situations within which the subject matter of the topic can be relevant (4.3084).
5. Sets students problems/questions during class time to allow each student to think through a topic for himself/herself (4.1121).
6. Uses a variety of teaching techniques (lecture, discussion, practical work, case studies, debate, etc.) (4.0).
7. Provides good handouts using articles or parts of

articles taken from accounting journals (3.8411).
8. Provides alternative ways of approaching a topic and allows a student to choose an approach which suits himself/herself (3.841).
9. Relates ideas to the direct experience of the student (3.4673).
10. Refers to current academic research in each topic area (3.3551).
11. Shows the "one best way" of tackling a topic and proves that the method demonstrated is best by applying it to examination questions (3.2987).
12. Expects students to take notes in class and allows each student to arrange his/her own study schedule to meet the objectives of passing the examination (3.271).
13. Avoids discussion of controversial areas in order to make a topic easy to understand for the student (2.907).
14. Sets students problems/questions during class time to allow each student to think through a topic for himself/herself (2.495).
15. Shows a good understanding of the subject area but has difficulty in answering examination questions (1.841).

Conclusions

1. Confirmation that professional students could be considered to be examination orientated (1,2,15).
2. Potential for a system which has the ability to answer and explain examination questions to have high utility value for students demonstrated (1,2,3,15).
3. Some surprises: 14 is standard work-shop/seminar strategy; ?exploit Expert System capability to allow student to reinforce material during personal study time, 11 and 13 should have been more attractive viz. "the one best way to pass exams" may be a lecturers dream? students may be more sophisticated in their approaches than imagined?
4. Students'priorities: examinations first, good teaching practice second, research/academic interest last??
5. Ranges were majority 1-5, otherwise 2-5, therefore wide divergence of opinion, probably expected.
6. Quartile information seems to support mean ranking: Rank 1-6 Q1 = 4, Rank 7 - 10 Q1 = 3, Rank 11 - 13 Q1 = 2, Rank 14,15 Q1 = 1. Items 1-6 could then be thought to be significant in drawing solid support? Standard deviation information is less clear if a low standard deviation is taken to reflect consensus HOWEVER, presumably standard deviation information is inappropriate in view of skewed distributions?
7. Comparison with a response from University students???

3

		N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN	RANK, MEAN	Q1	RANK, STDEV
C1		107	4.3458	5.0000	4.4227	0.7903	0.0764	3	4	2
C2	+1/107 4.3084	107	4.2771	4.0000	4.3918	0.8602	0.0832	4	4	4
C3		107	4.3551	5.0000	4.4536	0.9034	0.0873	2	4	6
C4	+1/107 4.0000	107	3.9907	4.0000	4.0412	0.8522	0.0824	6	4	3
C5	−1/107 3.2787	107	3.308	3.000	3.340	1.306	0.126	11	2	14
C6		107	3.8411	4.0000	3.8763	0.9727	0.0940	7	3	7
C7		107	3.4673	4.0000	3.4845	0.9935	0.0960	9	3	8
C8		107	1.841	1.000	1.732	1.100	0.106	15	1	11
C9		107	3.841	4.000	3.897	1.038	0.100	8	3	10
C10		107	3.3551	3.0000	3.3402	0.8606	0.0832	10	3	5
C11		107	2.907	3.000	2.897	1.217	0.118	13	2	13
C12		107	4.4393	5.0000	4.5258	0.7291	0.0705	1	4	1
C13		107	2.495	2.000	2.443	1.327	0.128	14	1	15
C14		107	4.1121	4.0000	4.1356	1.0031	0.0970	5	4	9
C15		107	3.271	3.000	3.299	1.202	0.116	12	2	12

	MIN	MAX	Q1	Q3
C1	2.0000	5.0000	4.0000	5.0000
C2	1.0000	5.0000	4.0000	5.0000
C3	1.0000	5.0000	4.0000	5.0000
C4	2.0000	5.0000	4.0000	5.0000
C5	1.000	5.000	2.000	4.000
C6	2.0000	5.0000	3.0000	5.0000
C7	1.0000	5.0000	3.0000	4.0000
C8	1.000	5.000	1.000	2.000
C9	1.000	5.000	3.000	5.000
C10	2.0000	5.0000	3.0000	4.0000
C11	1.000	5.000	2.000	4.000
C12	2.0000	5.0000	4.0000	5.0000
C13	1.000	5.000	1.000	4.000
C14	1.0000	5.0000	4.0000	5.0000
C15	1.000	5.000	2.000	4.000

MTB > stop

[illegible] Minitab Release [illegible] Minitab [illegible]

Storage available 50000

[illegible] written the file "PRINTER LIS" [illegible] spool

[illegible] PRINTER LIS" (r = remove).

[illegible] PRINTER LIS" on System [illegible]

Kedleston Road, Derby DE3 1GB telephone Derby (0332) 47181

DERBYSHIRE COLLEGE OF HIGHER EDUCATION
Director: Jonathan May TD MEd PhD

Our ref LMcA/JT

Faculty of Accountancy
Business and Management

School of Accountancy

11 March 1987

Dear Student

I am currently conducting research with the objective of developing a computerised system to teach a specific area of the accounting syllabus and would like to incorporate your views in my work. Since the system will aim to represent the "best possible" teaching approaches, I wish to carry out a questionnaire based appraisal to determine "best practice" in accounting teaching from a student's point of view. I therefore request that you complete the attached questionnaire on a confidential basis, returning the completed questionnaire to me in E206.

Yours faithfully

L McAulay
School of Accountancy

EXPERT SYSTEMS IN ACCOUNTING EDUCATION

STUDENT QUESTIONNAIRE

SPRING 1987

Please tick the appropriate box below to represent your opinion. A tick in column 1 signifies that you violently disagree with the statement presented, 2 that you disagree, 3 that you have no opinion, 4 that you agree and 5 signifies that you strongly agree.

COURSE	← DISAGREE 1	2	3	4	AGREE → 5
A good lecturer in accounting subjects (Financial accounting, Costing, Management Accounting, Financial Management):					
1. Provides a clear explanation of relevant concepts and relates these concepts to the topic being lectured.					
2. Provides clear examples of practical situations within which the subject matter of the topic can be relevant.					
3. Can answer examination questions and explain clearly the way in which specific questions should be answered.					
4. Uses a variety of teaching techniques (lecture, discussion, practical work, case studies, debate etc).					
5. Shows the "one best way" of tackling a topic and proves that the method demonstrated is best by applying it to examination questions.					
6. Provides good handouts using articles or parts of articles taken from accounting journals.					

	1	2	3	4	5
7. Relates ideas to the direct experience of the student.					
8. Shows a good understanding of the subject area but has difficulty in answering examination questions.					
9. Provides alternative ways of approaching a topic and allows a student to choose an approach which suits himself/herself.					
10. Refers to current academic research in each topic area.					
11. Avoids discussion of controversial areas in order to make a topic easy to understand for the student.					
12. Discusses examination technique.					
13. Provides the minimum of notes and handouts to reduce the student's work for revision and general examination preparation.					
14. Sets students problems/questions during class time to allow each student to think through a topic for himself/herself.					
15. Expects students to take notes in class and allows each student to arrange his/her own study schedule to meet the objective of passing the examination.					

In the space below, please list any approaches adopted by lecturers in accounting subjects whom you consider to be poor.

In the space below, please note any additional points which you consider to be relevant to the quality of accounting lecturing which have not been raised in other parts of the questionnaire.

ESAC 2
Expert systems in accounting education
Standard costing system
Prolog based, question answering system.

Objectives

To learn prolog programming;
To assess feasibility of a Prolog programme capable of assisting in the process of answering examination questions;
To produce an end product suitable for testing research ideas through formative testing.

Methodology and timing

Product: Prolog-i.
June 1987: Prolog programming expertise gained through:
i) simple programme written, involving recursion, similar to standard textbook ancestor problem;
ii) solution to "the digits" problem attempted (find a three digit number which can decompose to a single digit through five multiplications of individual digits). Solution 1 made use of the list structure but was inefficient (one and a quarter hours to find solution, on Olivetti M24 machines).
Four further solutions generated, using the cut and, eventually, heuristics, in order to reduce the running time to less than five minutes. (This sequence of programmes has subsequently been used to demonstrate backtracking to classes studying expert systems).
iii) solution to a standard routing question attempted and solved quickly (subsequently used to illustrate the difference between third and fifth generation languages to classes studying expert systems).

July to August 1987: Design and writing of standard costing system, with emphasis on I/O and number manipulation because these are known weaknesses of Prolog and further developmental work planned to incorporate skills developed throughout the June to August period.

September - December 1987: Testing of standard costing system on groups of professional students (Prototypel):
i) in class, lecturer operated. Transview used to display PC output via OHP screen. Students given question material and asked to check their answers against those produced by the system. CIMA stage 4, PTD and Sandwich groups.
ii) system loaded onto library PC and group of students issued with pack of five questions and invited to check their own answers. No coercion applied. A single A4 page of instructions provided (cd,plg-i,load stdcost), students instructed to refer any operational problems to lecturers.

Description

Design aims:

Prototypel: Assists the lecturer to capture data from standard costing examination questions so that the data can be stored for later variance calculation and explanation for use by students;

Provides an answer service for use by students. The system is intended to be used by novice students and therefore is designed to be easy to access and operate. Variance analysis is data driven i.e. the structure of data base records fire relevant calculations. As far as possible, the calculations should be generalised expressions i.e. a price type variance calculation should fire for material usage variance and labour efficiency variance calculations;

Provides an elementary explanation facility which is independant of teaching method. The explanation facility should use numbers stored in the data base and should be data driven. The student is left with the problem of maintaining/updating his/her inference mechanisms based on neutral evidence provided by the explanation facility.

Rationale for this design strategy is provided by the desirability of aiming for a flexible, general system which is independant of a single lecturing/text book approach and independant of a single problem domain (i.e. question). With such independance as a goal, the system may gain acceptance by lecturers and may be expandable to practical problem domains i.e. may form a sound basis for the implementation of useful systems.

Implementation:

Class room: Series 1: CIMA Stage 4 sandwich course, four sessions (one and a half hours per session) devoted to variance calculation revision. Number of students: 8. Room E204.
The presence of the micro and transview in session 1 caused considerable interest and the session was on the whole received uncritically. Students produced answers to one of the questions in the pack of examination questions which had previously been loaded into the Prototypel system. Use of Prototypel allowed the answer to be displayed quickly once most of the students had completed their answers. Most notable was the ability to present explanations which were readily understood and generated a deeper level of questioning than customary (function of the group or of the software?). A normal explanation (personal experience and evidence of blackboards when entering classes after other lecturers have conducted standard costing classes) involves writing the key figures onto a blackboard or OHP transparency and building up the explanation as the figures unroll. A Prototypel approach allows the students to compare the key data with their own calculations and then to ask questions. A Prototypel explanation typically lasted

could that five to fifteen minutes.a conventional explanation

From session two onwards, the limitations of the transview became something of an issue. Problems of definition and print size made the task of seeing Prototypel output, especially in bright sunshine, somewhat difficult. On the whole, students were positive and the benefits of the first session continued but with the passing of the "seduction of technology" factor, students were less excited at the presence of the equipment. An interesting feature of these later sessions was the student comment "But you did not explain that variance in that way during the last session". Group discussion resolved this point as a problem of student participation rather than lecturer confusion, but the existance of the question reveals a potential advantage of Prototypel. Given the efficiency advantages claimed already for the system, does the question reveal a greater degree of internalisation by the student under the Prototypel pedagogic style?

On the whole, the experience proved encouraging:
formal assessment at the end of the course did not reveal any significant differences between this group and groups taught previously. Given the number of variables to account for, this statement alone is not significant but important is the fact that this group spent significantly fewer hours in class than did previous groups (six, compared to up to twenty for previos groups, due to syllabus changes). It could be fairly claimed therefore that the Prototypel approach shows efficiency advantages whilst maintaining effectiveness.
positive reaction of the group and implications for the staff/student relationship
conclusions that can be safely drawn are limited, due to group size and the large number of variables to account for; further evaluation is called for i.e. pre-testing and post-testing, different types of groups.

Class room: Series 2: CIMA Stage 4 day release course, four sessions (one and a half hours per session) devoted to variance calculation revision. Number of students: 15. Room E211.

Problems in viewing the transview, given group size and room characteristics, negated any attempt to add to the formative evaluation given above. The interesting feature of this experience was the unexpectedly negative attitude of some members of the group to computers. Later in the course it became clear that some group members, whilst being active computer users in their day to day work as accountants, were highly sceptical of the value of computers. This attitude did not appear to be present in younger day release groups. Attitude, coupled with technical problems led to attempts to use the Prototypel system after the first session.

Personal student use: Series 3: CACA Stage 2, full time course: Number of students: 38. Library facilities used.

Informal feedback showed that approximately half the student group made use of the Prototypel facility and approximately three quarters responded positively to the system. Formal feedback was not possible due to the proximity of examinations (time could not be made available in any effective way). Stated reasons for not using the system included fear of computing. A curious advantage of using the system was that exposure to computers would increase personal computing skills, an unexpected by-product. The group had previously completed a spreadsheet/wordprocessor assignment so that some reactions were odd.

No student referred any problems in using the system to any of the lecturers on the team.

The most notable evidence is anecdotal and concerns a particularly weak student. This student sought tutorial guidance, seeking answers to a single question attempted, at a non scheduled time. The lecturer soon realised that the students answers revealed a complete absence of understanding of the problems posed by variance analysis and spent one hour explaining an answer to the question. The student then asked for assistance on the next question. Rather than spend further time on explanations, the lecturer showed the student how to use Prototypel in the library and asked that the student seek further lecturer assistance either at the end of the day or when problems arose. The student returned to see the lecturer at the end of the day, having successfully completed all of the exercises set, apparently by means of Prototypel.

Again, in the lack of pre and post testing and with an inability to control the many variables, it is not easy to form conclusions. However, further evidence of increased efficiency would appear to have been collected and the potential for the Prototypel concept appears to have been established.

Evaluation

System arguably cost effective:
Cost - £100 plus up to about 200 hours programming (difficulty of splitting learning and programming hours; experienced programmer probably less than 100 hours work).
Programme about 10K in size.
Benefits - generalised programme, therefore possibility of multiple usage:
saves time: lecturers' time: in calculating variances when formats change (CACA question used for CIMA students or vice versa)

in dealing with the time consuming process of explaining fundamentally procedural appraoches, where the explanations are a repetition of previous lecture material, applied to a specific problem domain

students' time: in receiving explanations.The alternative of transferring explanations relevant to specific problem domains would appear to be to create OHP transparencies (suggested by one student arguing against Prototypel); expensive of lecturers' time and relatively less flexible.

Improved efficiency.

Greater flexibility than other mechanised approaches.

Problems of generalisation. Loading the system requires some considerable skill because of the diversity inherent in the alternative problem domains. Knowledge of the way in which the system is operating are therefore necessary, and therefore another drawback is:

The system cannot effectively operate and be transparent from the point of view of the lecturer.

Efficiency remarkably good:

loading prolog-i less than 5 sec.

loading the programme into prolog-i 10 sec., 6 MHz clock.

no discernable time delay responding to the user i.e. generating questions, producing calculations, providing explanations.

Poor loading of the data base; user must use calculator to carry out calculations to meet the needs of the problem domain. Clearly, the system must be refined/reconceived in order to respond more completely and with greater integrity to prospective problem domains; its ability to diagnose problem types must be extended by some suitable means.

Input/output poor; prolog does not readily lend itself to I/O since it was not designed to operate in the way envisaged by the research objectives, specifically; numbers greater than around 32767 are unreliably read by the system, necessitating entry as real numbers (Plg-i fortunately does not constrain the handling of reals), which is unnatural from the point of view of the user; read requires a terminating full stop (Plg-i fortunately provides the pre-defined predicate ratom which avoids this restriction at the cost of a loss in portability), error recovery requires the development of not so obvious prolog routines, write is acceptable but not very exciting from the point of view of the user.

Number handling acceptable, once format statements provided, for the manipulation of reals.

Reception from students: encouraging.

Reception from lecturers: encouraging. One lecturer, with no discernable prior interest in computers, asked to be able to use the system for his own group of students (declined due to lack of robustness in the system and drawbacks given above; decided to provide a better system at a later date in order to ensure a smooth transition through the indeterminate region of the success/failure plain for the implementation of IT; motivating factor - reliability in its fullest sense).

Conclusions

Feasibility established.

Cost benefit neither proved nor disproved.

If the research is to be justified, it must be on grounds of generality. Building a knowledge base to respond to a restrictive problem domain makes little sense due to the cost of inputs BUT a knowledge base for a set of problem domains appears to open up exciting possibilities; the possibility of applications software for management accounting areas, for instance.

Potential problem domains: class 1: examination questions, teaching exercises, text book problems, case study problems, class 2: practical situations (subsets?). The two areas appear intuitively to offer different problems to the systems designer (why should this be so?).

Knowledge is made explicit and, presumably, the potential for research into the nature and characterictics of different forms of knowledge therefore become researchable in a way not possible before. e.g. efficiency of alternative approaches to the processing of information (compiled vs articulated knowledge), effectiveness of alternative explanation styles; the degree to which lecturers and practitioners should make their own inferences explicit as opposed to allowing the users of accounting information to form and articulate their own inferences based on gapped explanations (an invented term: gapped explanations - explanations which seek to leave a gap between a full, explicit explanation based on the transmitter's level and style of compiled knowledge and the receiver; the receiver is forced to fill the gap but in Prototypel is given a number of exercises in order to test the reliability of the bridging process, hence the students statement regarding the inconsistency of the lecturer's explanation).

```
qlist([]).

declare([]).
declare([First|Rest]):-
        write(First),
        tab(10),
        declare(Rest).

instruct_1(Q):-
        nl,
        write("Select your question from those written above by"),
        nl,
        write("typing in the exact reference."),
        nl,
        write("If your question does not appear in the above list, type in"),
        nl,
        write("a reference. You will then be asked to provide some information."),
        nl,
        write("It is important that your reference begins with a lower case letter."
        nl,
        nl,
        write("Press carriage return to continue."),
        nl,
        ratom(Q).

check:-
        write("Have you correctly typed in your answer? (Y/N)"),
        ratom(R),
        R=y.

nextaction(Q,Qlist):-
        member(Q,Qlist),
        cls,
        answer(Q).
nextaction(Q,Qlist):-
        not(member(Q,Qlist)),
        retractall(qlist(_)),
        asserta(qlist([Q|Qlist])),
        cls,
        enquire(Q).

questionknown:-
        repeat,
        cls,
        qlist(Qlist),
        declare(Qlist),
        nl,
        instruct_1(Q),
        check,
        !,
        nextaction(Q,Qlist).

answer(Q):-
        materials(Q,AP,AQ,SP,SQ),
        production(Q,N),
        write("1. Materials price variance: "),
```

```
        pricevariance(AP,AQ,SP),
        write("2. Materials usage variance: "),
        qtyvariance(N,AQ,SP,SQ).
answer(Q):-
        materials(Q,AP,PQ,IQ,SP,SQ),
        production(Q,N),
        write("1. Materials price variance: "),
        pricevariance(AP,PQ,SP),
        write("2. Materials usage variance: "),
        qtyvariance(N,IQ,SP,SQ).
answer(Q):-
        labour(Q,AR,AH,SR,SHU),
        production(Q,N),
        write("3. Labour rate variance: "),
        pricevariance(AR,AH,SR),
        write("4. Labour efficiency variance: "),
        qtyvariance(N,AH,SR,SHU).
answer(Q):-
        varoverheads(Q,AR,AH,SR,SHU),
        production(Q,N),
        write("5. Variable overhead rate variance: "),
        pricevariance(AR,AH,SR),
        write("6. Variable overhead efficiency variance: "),
        qtyvariance(N,AH,SR,SHU).
answer(Q):-
        overheads(Q,E,FB,SOAR,AH,SHU),
        production(Q,N),
        write("7. Overhead expenditure variance: "),
        expvariance(E,FB),
        write("8. Overhead volume (CIMA) or capacity variance: "),
        capvariance(FB,SOAR,AH),
        write("9. Overhead efficiency or productivity variance: "),
        qtyvariance(N,AH,SOAR,SHU),
        write("10. Overhead volume variance (non CIMA): "),
        volvariance(N,FB,SOAR,SHU).

answer(Q):-
        write("Do you wish to see explanations of any of these variances? (Y/N)"),
        ratom(R),
        R=y,
        write("Input the number (1-10) of the variance to be explained: "),
        ratom(N),
        explanation(N,Q).

pricevariance(AP,AQ,SP):-
        Pricevariance is AQ*(AP-SP),
        write(Pricevariance),
        test(Pricevariance).

qtyvariance(N,AQ,SP,SQ):-
        Qtyvariance is SP*(AQ-(N*SQ)),
        write(Qtyvariance),
        test(Qtyvariance).

expvariance(E,FB):-
        Expvariance is E-FB,
```

```
        write(Expvariance),
        test(Expvariance).

capvariance(FB,SOAR,AH):-
        Capvariance is FB-(AH*SOAR),
        write(Capvariance),
        test(Capvariance).

volvariance(N,FB,SOAR,SHU):-
        Volvariance is FB-(N*SHU*SOAR),
        write(Volvariance),
        test(Volvariance),
        nl.

test(Variance):-
        Variance < 0,
        write(" favourable"),
        nl,
        !.
test(Variance):-
        Variance > 0,
        write(" adverse"),
        nl,
        !.
test(Variance):-
        write(" i.e. nil variance"),
        nl.


member(X,[X|_]).
member(X,[_|Y]):-member(X,Y).


enquire(Q):-
        production(Q),
        cls,
        materials(Q),
        cls,
        labour(Q),
        cls,
        overhead(Q),
        cls,
        answer(Q).

production(Q):-
        repeat,
        write("Input actual number of production units (one dec.place min.): "),
        ratom(N),
        check,
        !,
        asserta(production(Q,N)).

materials(Q):-
        write("Does the question state that materials price variance is to be "),
        nl,
        write("based on purchases? (Y/N): "),
```

```
        ratom(R),
        R=y,
        purchbasis(Q),
        !.
materials(Q):-
        write("Does the question show materials stock valued at standard? (Y/N)"),
        ratom(R),
        R=y,
        purchbasis(Q),
        !.
materials(Q):- issuesbasis(Q).

purchbasis(Q):-
        write("Is the total purchases figure given without a unit cost? (Y/N):"),
        ratom(R),
        R=y,
        ask_1(Q),
        !.
purchbasis(Q):- ask_2(Q).

ask_1(Q):-
        repeat,
        write("Input total purchases value (one dec.place min):"),
        ratom(PV),
        write("Input quantity purchased (one dec.place min):"),
        ratom(PQ),
        write("Input quantity issued (one dec.place min):"),
        ratom(IQ),
        standard(SP,SQ),
        AP is PV/PQ,
        check,
        !,
        asserta(materials(Q,PV,PQ,AP)),
        asserta(materials(Q,AP,PQ,IQ,SP,SQ)).

ask_2(Q):-
        repeat,
        write("Input the raw materials price (per kg, metre, etc):"),
        ratom(AP),
        write("Input quantity purchased (one dec.place min):"),
        ratom(PQ),
        write("Input quantity issued (one dec.place min):"),
        ratom(IQ),
        standard(SP,SQ),
        check,
        !,
        asserta(materials(Q,AP,PQ,IQ,SP,SQ)).

standard(SP,SQ):-
        write("Input standard price per unit (k.g, metres, hours, etc.):"),
        ratom(SP),
        write("Input standard usage per unit of production:"),
        ratom(SQ).

issuesbasis(Q):- ask_11(Q).
```

```
ask_11(Q):-
        repeat,
        write("Input the raw materials price (per kg, metre, etc):"),
        ratom(AP),
        write("Input the quantity of materials used (one dec.place min):"),
        ratom(AQ),
        standard(SP,SQ),
        check,
        !,
        asserta(materials(Q,AP,AQ,SP,SQ)).

labour(Q):-
        write("Is the total labour figure given without rate per hour? (Y/N)"),
        ratom(R),
        R=y,
        ask_21(Q),
        !.
labour(Q):-ask_22(Q).

ask_21(Q):-
        repeat,
        write("Input total wages cost (one dec.place min): "),
        ratom(AW),
        write("Input total hours worked (one dec.place min): "),
        ratom(AH),
        standard(SR,SHU),
        AR is AW/AH,
        check,
        !,
        asserta(labour(Q,AW,AH,AR)),
        asserta(labour(Q,AR,AH,SR,SHU)).

ask_22(Q):-
        repeat,
        write("Input hourly rate paid: "),
        ratom(AR),
        write("Input total hours worked (one dec.place min): "),
        ratom(AH),
        standard(SR,SHU),
        check,
        !,
        asserta(labour(Q,AR,AH,SR,SHU)).

overhead(Q):-
        write("Does the question include fixed overheads? (Y/N)"),
        ratom(R),
        R=n,
        !.
overhead(Q):-
        write("Does the question include variable overheads? (Y/N)"),
        ratom(R),
        R=n,
        write("FOR FIXED OVERHEADS:"),
        nl,
        ask_41(Q),
        !.
```

```
overhead(Q):-
        write("Should the answer comply with current CIMA terminlolgy? (Y/N)"),
        ratom(R),
        R=y,
        write("FOR TOTAL OVERHEADS"),
        ask_41(Q),
        !.
overhead(Q):-
        ask_31(Q),
        nl,
        write("FOR FIXED OVERHEADS:"),
        nl,
        ask_41(Q).

ask_31(Q):-
        write("FOR VARIABLE OVERHEADS:"),
        nl,
        repeat,
        write("Input the actual cost per hour: "),
        ratom(AR),
        write("Input the actual hours (one dec.place min): "),
        ratom(AH),
        write("Input the standard cost per hour: "),
        ratom(SR),
        write("Input the standard hours per unit: "),
        ratom(SHU),
        check,
        !,
        fwidth("10.10"),
        asserta(varoverheads(Q,AR,AH,SR,SHU)),
        fwidth("10.2").

ask_41(Q):-
        repeat,
        write("Input the actual expenditure (one dec.place min) : "),
        ratom(E),
        write("Input the actual hours worked (one dec.place min): "),
        ratom(AH),
        write("Input the flexed budgeted (one dec place min)    : "),
        ratom(FB),
        write("Input the standard overhead absorption rate      : "),
        ratom(SOAR),
        write("Input the standard hours per unit                : "),
        ratom(SHU),
        check,
        !,
        fwidth("10.10"),
        asserta(overheads(Q,E,FB,SOAR,AH,SHU)),
        fwidth("10.2").

exlpanation(1,Q):-
        materials(Q,PV,PQ,AP),
        genexp_1(Q,PV,PQ,AP).
explanation(1,Q):-
        materials(Q,AP,AQ,SP,SQ),
        nl,
```

```
        genexp_2(Q,AP,SP,AQ).
explanation(1,Q):-
        materials(Q,AP,PQ,IQ,SP,SQ),
        nl,
        write("The price variance is based on purchases, usage variance on issues.")
        nl,
        genexp_2(Q,AP,SP,PQ).
explanation(2,Q):-
        materials(Q,AP,AQ,SP,SQ),
        production(Q,N),
        nl,
        genexp_11(Q,AQ,N,SQ,SP).
explanation(2,Q):-
        materials(Q,AP,PQ,IQ,SP,SQ),
        production(Q,N),
        nl,
        genexp_11(Q,IQ,N,SQ,SP).
explanation(3,Q):-
        labour(Q,AW,AH,AR),
        genexp_1(Q,AW,AH,AR).
explanation(3,Q):-
        labour(Q,AR,AH,SR,SHU),
        nl,
        genexp_2(Q,AR,SR,AH).
explanation(4,Q):-
        labour(Q,AR,AH,SR,SHU),
        production(Q,N),
        nl,
        genexp_11(Q,AH,N,SHU,SR).
explanation(5,Q):-
        varoverheads(Q,AR,AH,SR,SHU),
        nl,
        genexp_2(Q,AR,SR,AH).
explanation(6,Q):-
        varoverheads(Q,AR,AH,SR,SHU),
        production(Q,N),
        nl,
        genexp_11(Q,AH,N,SHU,SR).
explanation(7,Q):-
        nl,
        overheads(Q,E,FB,SOAR,AH,SHU),
        write("The actual expenditure was: "),
        write(E),
        nl,
        write("The flexed budget was:      "),
        write(FB),
        retn(Q).
explanation(8,Q):-
        nl,
        overheads(Q,E,FB,SOAR,AH,SHU),
        write("The flexed budget was:                       "),
        write(FB),
        nl,
        write("Actual hours at standard absorption rate: "),
        A is AH*SOAR,
        write(A),
```

```
        nl,
        write(AH),
        write("@"),
        write(SOAR),
        retn(Q).
explanation(9,Q):-
        nl,
        overheads(Q,E,FB,SOAR,AH,SHU),
        production(Q,N),
        genexp_11(Q,AH,N,SHU,SOAR).
explanation(10,Q):-
        nl,
        write("Volume variance is the addition of variances 9 and 10."),
        retn(Q).

genexp_1(Q,PV,PQ,AP):-
        nl,
        write("Total cost was: "),
        write(PV),
        write(",for "),
        write(PQ),
        nl,
        write("Therefore, subject to decimal places,"),
        nl.

genexp_2(Q,AP,SP,AQ):-
        nl,
        write("The price/rate paid was: "),
        write(AP),
        nl,
        write("The standard price/rate is: "),
        write(SP),
        nl,
        write("This gives a difference of: "),
        V is AP-SP,
        write(V),
        test(V),
        write("The actual quantity involved was: "),
        write(AQ),
        nl,
        write("This gives the price/rate variance."),
        retn(Q).

retn(Q):-
        nl,
        write("Input any letter to continue."),
        ratom(X),
        cls,
        answer(Q).

genexp_11(Q,AQ,N,SQ,SP):-
        nl,
        write("The actual quantity/hours used was: "),
        write(AQ),
        nl,
        write("Standard usage/hours: "),
```

```
        write(N),
        write("@"),
        write(SQ),
        write(":"),
        Std is N*SQ,
        write(Std),
        nl,
        write("This gives a difference of: "),
        V is AQ-Std,
        write(V),
        test(V),
        write("The total variance is based on standard price/rate: "),
        write(SP),
        retn(Q).

continue:-
        repeat,
        write("Do you wish to consider any further questions? (Y/N)"),
        ratom(R),
        check(R),
        !.

check(n):-write("Good-bye"),!.
check(y):-questionknown,fail.

go:-noprompt,questionknown.
go:-continue.
go:-prompt.
```

2. The following are standard cost data for a company manufacturing a single product:

	Quantity	Price	£
Direct materials	50 kgs	£4·20 per kg	210
Direct labour	20 hours	£3·50 per hour	70
Variable production overhead	20 hours	£1·20 per hour	24
Fixed production overhead	20 hours	£4·50 per hour	90
			394
Standard selling price			£600

Budgeted production for the month of April was 260 units and this figure was used in calculating the fixed overhead absorption rate. Overhead is absorbed into production on the basis of units produced but the variable overhead is deemed to vary with hours worked.

An abridged trading and profit statement prepared in the conventional way shows the following:

	£	£
Sales		165,000
Materials used	50,200	
Direct wages	22,400	
Production overhead—variable	6,600	
Production overhead—fixed	23,500	
		102,700
Gross profit		62,300
Selling and administration		29,300
Net profit		£33,000

Additional information appropriate to April:

Sales and production 250 units

There was no work-in-progress.

Actual hours worked by direct labour 5,600

Materials used cost £4·00 per kilogramme.

You are required:

(a) to calculate the following variances:

(i) due to selling prices;

(ii) direct materials price;

(iii) direct materials usage;

(iv) direct wages rate;

(v) direct labour efficiency;

(vi) variable production overhead expenditure;

(vii) variable production overhead efficiency;

(viii) fixed production overhead expenditure;

(ix) fixed production overhead volume;

(b) to present a profit statement utilising standard costs and showing the variances:

(c) (i) to comment on two possible reasons for each of the variances you show for **(a)** (ii) and **(a)** (v) and to state who (job title) is responsible for the variance;

(ii) to state what ought to be done by the appropriate executive responsible for the direct labour efficiency variance.

(35 marks)

24 FOUNDAT
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5. For a product the following data are given:

Standards per unit of product:

Direct material	4 kilogrammes at	£0·75 per kilogramme
Direct labour	2 hours at	£1·60 per hour

Actual details for given financial period:

Output produced in units		38,000
Direct materials:		£
purchased	180,000 kilogrammes for	126,000
issued to production	154,000 kilogrammes	
Direct labour	78,000 hours worked for	136,500

There was no work-in-progress at the beginning or end of the period.

You are required to:

(a) calculate the following variances:

(i) direct materials cost;

(ii) direct materials price, based on issues to production;

(iii) direct materials usage;

(iv) direct wages cost;

(v) direct wages rate;

(vi) direct labour efficiency;

(b) state whether in each of the following cases, the comment given and suggested as the possible reason for the variance, is **consistent** or **inconsistent** with the variance you have calculated in your answer to **(a)** above, supporting each of your conclusions with a brief explanatory comment.

Item in
(a)

(ii) direct materials price variance: the procurement manager has ignored the economic order quantity and, by obtaining bulk quantities, has purchased material at less than the standard price;

(iii) direct materials usage variance: material losses in production were less than had been allowed for in the standard;

(v) direct wages rate variance: the union negotiated wage increase was £0·15 per hour lower than expected;

(vi) direct labour efficiency variance: the efficiency of labour was commendable.

(25 marks)

4. B Limited operates an integral accounting system. From the data given below you are required to:

(a) show the ledger accounts for the month of April, 1981;

(b) prepare:

(i) the cumulative profit and loss account for the period ended 30th April, 1981;

(ii) the balance sheet as at 30th April, 1981.

On 31st March, 1981 the balances in the ledger were as follows:

	£000	£000
Issued share capital		500
Reserves		220
10% Debentures		480
Buildings	650	
Plant and machinery	600	
Provision for depreciation of plant and machinery		220
Raw material stock, at standard cost	300	
Work-in-progress, at standard cost	50	
Finished goods stock, at standard cost	80	
Debtors	100	
Creditors		60
Expense creditors		20
Debenture interest	8	
Wages payable		40
Bank	52	
Administrative overhead	25	
Selling and distribution overhead	15	
Direct material: price variance		20
usage variance	5	
Direct labour: rate variance	25	
efficiency variance		15
Production overhead: expenditure variance		5
volume variance		30
Cost of sales	400	
Sales		700
	2,310	2,310

	£000
Relevant budgeted data	
Production overhead (including depreciation) per annum	2,160
Output, per annum 72,000 units	
Standard cost per unit of product:	
Direct material 5 kilogrammes at £2 per kilogramme	
Direct wages 10 hours at £4 per hour	
Production overhead 10 hours at £3 per hour	
Actual data for April 1981	
Direct material:	
Purchased from suppliers 30,000 kilogrammes	66
Issued to production 29,500 kilogrammes	
Direct wages:	
Incurred .. 60,000 hours	252
Paid	238
Production overhead	185
Administration overhead	20
Selling and distribution overhead	15
Creditors paid	76
Expense creditors paid	205
Finished goods stock, at 30th April	120
Sales	742
Debtors, cash received	767
Depreciation of plant and machinery is 20% per annum on cost	
Output 5,800 units	

(30 marks)

ICMA COST ACCTG

N84 II 1

1. Exe operates an integrated accounting system and prepares its final accounts monthly.

Balances as at 1st October

	£000
Issued share capital	1,500
Profit and loss balance	460
Freehold buildings	1,000
Plant and machinery, at cost	500
Plant and machinery: depreciation provision	300
Motor vehicles, at cost	240
Motor vehicles: depreciation provision	80
10% Debentures	240
Creditors (materials)	144
Creditors (expenses)	36
Stock—raw materials	520
Wages payable	40
Debtors	246
Bank	162
Stock—finished goods	132

Data for the month of October

Materials purchased—400,000 units at £4·90 per unit
Issued to production—328,000 units
Paid to creditors—£1,800,000
Direct wages incurred—225,000 hours at £4·20 per hour
Direct wages paid—£920,000
Production overhead incurred on credit—£1,490,000
Expense creditors paid—£1,900,000
Cash received from debtors—£4,800,000
Sales—£4,875,000
Plant and machinery purchased for cash on 1st October—£100,000
Administration and selling overhead incurred on credit—£895,000
Production and sales—39,000 units

Additional data

Debenture interest—payable monthly
Depreciation provision—plant and machinery, 20% p.a. on cost
—motor vehicles, 25% p.a. on cost
Stocks of raw materials and finished goods are maintained at standard
There are four working weeks in the month of October
The operation of motor vehicles is regarded as a cost of selling

Standard data

Direct material price—£5·00 per unit
Direct material usage—8 units per product
Direct wages—£4·00 per hour
Direct labour—6 hours per product
Production overhead—absorbed at 150% of direct wages
Gross profit—calculated at 16⅔% of selling price
Budgeted output—10,000 units per week.

You are required to:

(a) calculate the appropriate variances for October;

(16 marks)

(b) show the accounts for October as they would be expected to appear in the ledger;

(16 marks)

(c) prepare a profit and loss statement for October, together with a balance sheet as at the end of that month.

(8 marks)

(Total: 40 marks)

ICMA MAN ACCTG 27

N83 II 4.

4. A company operates a standard cost system. All material, labour, overhead, work-in-progress and finished goods are accounted for at standard. Variances are extracted at the earliest identifiable point.

Data are given below for Product A for the month of October 1983.

You are required to:

(a) show in a diagrammatical form the flow of financial data and the control points at which the variances may be extracted;

(b) (i) calculate the actual profit achieved for the month against the standard profit expected, with the variances identified;

(ii) state the quantity and value of materials and goods in stock at the month-end;

(iii) give a brief management report on the results achieved in the month compared with the standard planned.

Data

Standard cost

Production	Requirement per item of product
Direct material	20 units at £1·50 per unit
Direct wages	30 hours at £2·10 per hour

	per month
Overhead—fixed	£40,000
—variable (based on units)	£160,000
Normal capacity	120,000 hours

Marketing

	per month
Sales	4,000 items at £175 each

Actual for the month of October 1983		Cost £000
Production		
Direct material—purchased	80,000 units	128
—issued	78,000 units	
Direct wages	116,000 hours	232
Overhead—fixed		42
—variable		150
Output	3,800 items	
		Value £000
Marketing		
Sales	3,500 items	623

There was no stock at the beginning of the month.

(30 marks)

ESAC 3
Expert Systems in accounting
PrototypeA1
VP Expert based interpretation of variances system

Aims:

To investigate the operation of an inexpensive expert systems shell (cost circa £100);
To build a system within a conventional expert systems domain i.e. interpretation/diagnosis/classification.
To consider the ease of translating from a prolog system to a shell.

Methodology/timing

One week, part time, during the Autumn of 1987 was allowed. This turned out to be roughly two full days work.

A subset of Prototypel was selected (materials analysis) and translated into production rules directly i.e. without recourse to and/or graphs. Once tested, rules were added to provide a complete (though not reliable) interpretation. Following testing, the system was evaluated in two ways: through demonstration and discussion with colleagues (alongside Prototypel), and through demonstration to students in expert systems classes (in order to show the operation and limitations of expert systems). The interpretation incorporated heuristic limits and a limited exploration for the interdependancy of the calculated variances. Output is in the form of a statement showing the variances and text providing advice for the investigation of variance decision (at the time of producing the system the theory surrounding the investigation of variance decision is thought not to have included an expert systems approach, which is either a claim for originality or a test of the feasibility of using expert systems to implement existing theory in an area where practice lags theory for one of many possible reasons).

Evaluation

The system performed well within the limitation that the knowledge base for interpretation was not reliable (need to write more rules, but in student demonstrations useful for stating the closed world principle).

Lecturers unimpressed. The complete lack of interest in the approach has proved a barrier to further work. I had felt that the system might have been useful as an aid to weak and (weak and strong) overseas students, who had commonly asked me how I managed to arrive at interpretations; the rule based answer may not be a particularly relevant answer (I do not fully understand how I arrive at interpretations and why should my interpretation tend to concur with the stronger UK students; are there cultural and intellectual/cognitive issues?) but does at least have a potential for providing an answer which could satisfy this class of student. Why were lecturers SO unmoved?; the system is so trivial as to be pointless, the lecturers involved were so confused by what was going on (Prototypel output is pretty standard and the procedures involved could be guessed by the lecturers involved i.e they could form an internal (incorrect) model of what the computer was doing inside the black box) that indifference masked incomprehension, lecturers have not perceived the usefulness of the system because their relationships with students have not revealed the same issues as mine, ...

Reliable interpretation evidenced the problem of combinatorial explosion (interdependancy: two variables create 4 permutations, three variables 8 permutations; Prototypel had potentially seven variances and nine is a common full reconciliation of budgeted and actual profit).

Feedback from student demonstrations was neutral; the impact cannot be ascertained. One CIMA student produced a one page, excellent standard of answer to a five (!!!!!!!) mark question on expert systems, but this level of interest and quality can be attributed to so many factors.

Conclusion

Not seen as a useful way forward, but still demonstrated in its unacceptable present form.

Possibility of further research under the investigation of variances (as opposed to ICAL) heading????

```
RUNTIME;
ENDOFF;
ACTIONS
    FIND pricevariance
    FIND usagevariance
    FIND pricevariancetype
    FIND usagevariancetype
    FIND interpretation
    DISPLAY "The materials price variance is {pricevariance} {pricevariancetype}"
    DISPLAY "The materials usage variance is {usagevariance} {usagevariancetype}";

RULE 1
    IF production > 0
    THEN P = (production)
    BECAUSE "Actual production forms the basis for the calculation
of standard cost which is used in quantity type variance calculations";

RULE 2
    IF Qinstruction = purchases
    THEN purchbasis = yes
    BECAUSE "Materials price variance can be based on purchases or issues;
some questions specify the basis explicitly";

RULE 3
    IF Qinstruction <> issues OR
       Qinstruction = UNKNOWN AND
       stockatstandard = yes
    THEN purchbasis = yes
    BECAUSE "Where materials price variance is based on purchases, the raw
materials stock is valued at standard. Considering the stock value used in
the question can often reveal whether the price variance should be calculated
on a purchases or issues basis.";

RULE 4
    IF purchbasis <> yes
    THEN issuesbasis = yes
    BECAUSE "Where the price variance is not based on purchases, it will be
based on issues";

RULE 5
    IF purchbasis = yes AND
       purchasefigure = given AND
       PURCH > 0 AND
       PQ > 0 AND
       SP > 0
    THEN pricevariance = (PURCH - (PQ * SP))
    BECAUSE "Price variances represent the difference between the standard
and actual prices for raw materials, based on actual quantities; in this case,
the actual quantity purchased.";

RULE 6
    IF purchbasis = yes AND
       purchasefigure = given AND
       SP > 0 AND
       IQ > 0 AND
       SQ > 0 AND
```

```
    P > 0
    THEN usagevariance = ((IQ - P * SQ)* SP)
    BECAUSE "Usage variances represent the difference between quantities used
and the standard quantity for the actual production, based on standard prices
for materials. In this case, stocks are also valued at standard prices.";

RULE 7
    IF purchbasis = yes AND
       purchasefigure = not_given AND
       RMP > 0 AND
       QP > 0 AND
       SP > 0
    THEN pricevariance = (QP *(RMP - SP))
    BECAUSE "Price variances represent the difference between standard and
actual prices paid for materials, multiplied by the quantity purchased, in
this case.";

RULE 8
    IF purchbasis = yes AND
       purchasefigure = not_given AND
       IQ > 0 AND
       SQ > 0 AND
       P > 0 AND
       SP > 0
    THEN usagevariance = ((IQ - P * SQ)* SP)
    BECAUSE "Usage variances represent the difference between the quantity
of materials issued and the standard usage based on production, multiplied
by the standard price of the materials";

RULE 9
    IF issuesbasis = yes AND
       RMP > 0 AND
       IQ > 0 AND
       SP > 0
    THEN pricevariance = ((RMP - SP) * IQ)
    BECAUSE "Price variances represent the difference between standard and
actual prices of materials, multiplied by the quantity issued, in this case.";

RULE 10
    IF issuesbasis = yes AND
       IQ > 0 AND
       SP > 0 AND
       SQ > 0 AND
       P > 0
    THEN usagevariance = ((IQ - P * SQ)*SP)
    BECAUSE "Usage variances represent the difference between material issued
and the standard usage of material in creating the actual level of production,
based on standard prices.";

RULE 11
    IF pricevariance > 1000
    THEN interpretation = complete
    DISPLAY "The price variance should be investigated. Possible areas of
investigation include raw materials buying policies, the incidence
of stock-outs during the period and general levels of price increase.";
```

```
RULE 12
     IF pricevariance_size < -0.05 AND
        usagevariance_size > 0.05
     THEN interpretation = complete
     DISPLAY "Purchasing policy should be reviewed with regard to quality.
It is possible that a favourable price variance through the
purchase of sub-standard goods is related to an adverse usage
variance representing excessive scrap.";

RULE 13
     IF PURCH > 0
     THEN pricevariance_size = (pricevariance/PURCH);

RULE 14
     IF IQ > 0
     THEN usagevariance_size = (usagevariance/(IQ * SP));

RULE 15
     IF pricevariance > 0
     THEN pricevariancetype = adverse;

RULE 16
     IF pricevariance < 0
     THEN pricevariancetype = favourable;

RULE 17
     IF usagevariance > 0
     THEN usagevariancetype = adverse;

RULE 18
     IF usagevariance < 0
     THEN usagevariancetype = favourable;

ASK production: "Input the actual number of units produced:";
ASK Qinstruction: "State the basis for calculating the price variance as given
in the question. Type a question mark if the question does not provide any
instuctions on this matter.";
CHOICES Qinstruction: purchases, issues;
ASK stockatstandard: "Does the question state that the materials stock is
valued at standard?";
CHOICES stockatstandard: yes, no;
ASK purchasefigure: "Is the purchases value given in total?";
CHOICES purchasefigure: given, not_given;
ASK PURCH: "Input total purchases value:";
ASK PQ: "Input the quantity of materials purchased:";
ASK SP: "Input the standard price per unit of purchases:";
ASK IQ: "Input the quantity of materials issued:";
ASK SQ: "Input the standard quantity of materials required for each unit of producti
ASK RMP: "Input the raw materials price paid per unit:";
ASK QP: "Input the quantity of materials purchased:";
```

ESAC 4
Expert Systems in Accountancy
PrototypeA2
Translation of VP system into Savoir, Version 1.3

Aims

To check translatability in order to test the portability of expert systems between shells

To check for Value for Money from a system at £3000+

Methodology/Timing

One week, part time, during Autumn term 1987, taking into account copyright restrictions imposed by supplier (final product is not available for general consideration, although text file IS attached).

Take a subset of PrototypeA1 (interpretation not complete i.e. system will only produce output for a restricted input),
implement in Savoir

Evaluation

Personal comments:

cf. VP Expert:

Some input control provided (range restriction); of some, minor utility.

I/O appalling; 6MHz clock, a discernable pause occurs between input and processing which allows the user to feel that the input has not been accepted and to attempt a fresh input. Knowledge of Savoir's single letter instructions necessary (as opposed to VP's Lotus clone I/O menu structure which is relatively easy even for non-Lotus afficianados).

Problem domain mismatch: Savoir apparently good for stochastic modelling, target problem domain determinate; therefore the best of Savoir not exploited whilst VP possibly operating flat out. For the target domain, the superiority of VP in terms of ease of programming (the one error message provided by Savoir was not listed in the manual), efficiency (despite the fact that Savoir ran as a compiled system) and I/O is beyond debate.

Conclusion

Further work on Savoir abandoned on cost grounds and adequacy of VP to meet needs.
Only if movement into stochastic models required at some

future date will investigation of the £500+ shells be attempted.

```
DISPLAY 'Program to calculate price variance #13#'
INVESTIGATE pricevariance
ASSOONAS AT_START

NUMBER pricevariance 'The value of the price variance'
         purchases * (actualprice - stdprice)
       IF purchasebasis
       ELSE issues * (actualprice - stdprice)

QUESTION purchasebasis 'Is the variance based on purchases?#13#'
       YESNO
QUESTION purchases 'Input the purchase quantity:#13#'
       NUMERIC 0 100000
QUESTION issues 'Input the issues quantity:#13#'
       NUMERIC 0 100000
QUESTION actualprice 'Input the actual price pais:#13#'
       NUMERIC 0 1000
QUESTION stdprice 'Input the standard price:#13#'
       NUMERIC 0 1000

DISPLAY 'The price variance was #pricevariance,13#'
       STOP pricevariance
       ASSOONAS pricevariance > 0
```

ESAC 5
Expert Systems in Accountancy
LPA Prolog

Aims

To take advantage of LPA I/O facilities and possibility of compiling finished systems.

To explore the issue of portability by loading and running Prototypel under LPA Prolog.

To explore the advisability of adopting LPA for future developmental work.

Methods/Timetable

Two months, part time, were set aside in Summer, 1988.

An initial attempt to load Prototypel failed due to the inability of LPA to interpret write statements. The problem of ratom would have been understandable since it is a non standard predicate and time was allowed to prepare the necessary LPA procedures to run non standard Prolog-1 pre-defined predicates. The problem of write came as a surprise and from the initial exposure to the end of the sub project, time was entirely devoted to trying to understand LPA I/O.

Results

By the end of the period, the mysteries of LPA windows and write instructions had been mastered but, whilst some progress had been made, sensible read actions had not been created.

Conclusions

Subsequent reading has revealed

ESAC 6
Expert Systems in Accounting
Prototype2: VP Expert extension of Prototypel

Objectives

To round off the work of the first phase of the research by producing a demonstration version pulling together ideas and expertise gained to date and based on Prototype2, using Prototypel as a base

Methodology/Timing

Two weeks, full time, were allowed in October 1988. Building on the experience of previous prototypes, a systematic approach to building the system was attempted:
i) initial exploration with a small subset of the final version envisioned in order to explore alternative approaches. This was basically a study of feasibility of translating ideas into final code. The basic idea was that the selected subset should contain all of the requirements of the final version. Ascertaining that the subset works should guarantee the operation of the final version; Prototypel had already provided assurance that a relatively small number of types of procedure could be trivially exploded to create larger systems. In the initial phase, data base handling (reading/writing operations), modularisation of knowledge bases, processing multiple responses from users and the use of autonomous text files as means of allowing users the opportunity to write their own explanations were explored with regard to feasibility and efficiency. Suitable procedural types were written, debugged and made to work together.
ii) a compiled version of the knowledge base was created by means of and/or graphs and algorithms. These diagrams were produced in the rough.
iii) extensive use was made of the editor copy facility to construct a product based on the primary procedural building blocks. The initial subset of the knowledge base was exploded by refining procedures which were known to be successful. Refinement basically involved changing the procedural building blocks to reflect localities within and/or graphs or algorithms (changing "materials" to "labour", re-defining formulae to match problem domain models).
iv) program code was used to produce and/or graphs and algorithmic diagrams using the expert system code. This formed the first stage in coding and de-bugging and led to detailed code revisions.
v) testing and de-bugging. Since procedural building blocks had all been previously tested, this stage only involved detailed code revision; spelling inconsistencies, errors in particular formulae, ommission of variables from the left hand side of arguments. Testing was carried out using the five Prototypel problem domains i.e. full reliability cannot yet be guaranteed.

vi) the system was extended and refined in the light of shortcomings exposed by the testing process. This involved: the addition of branches, extensively through copying and localised revision; the addition of rules to replace questions so as to enhance the ability of the system to match the problem domain characteristics. This process of tuning the system to meet specific circumstances tested the adaptability of the system, conceived as a generalised model, to respond to local conditions. The "ultimate" system must be able to engage upon a process of learning to be able to adapt to localised cultures (technical languages, specific articulations of knowledge). Tuning appears to be the only expert system facility to meet this requirement (note the ability of lecturers to amend text files themselves to aid this process of adaptability). Extending brought with it memory problems. The initial system was contained within one module in order to explore the memory constraint problem, despite knowledge of and testing of chaining. Extension led to two modules. Refinements should have led to three modules (not yet carried out because of time; testing necessary to iron out minor problems but could be time consuming).
vii) final testing, de-bugging, copying to floppy and preparation for demonstration purposes.

Note:
Explanation styles were varied to create debate. A final product would standardise explanations at the top level and allow lecturers to write their own text files for the bottom level of explanation. This would require some evaluation of explanation styles for the top level and a degree of documentation for access to the bottom level. Some code revision desirable so that explanation files would link directly to explanations at the top level (use of small number of generalised files in Prototype2 to meet time constraints).

Description

Three modules as in Prototype1 enacted by two modules because of a chance aspect of the fact that numeric variables must be instantiated before a formula will work (therefore data base questioning for data and calculations run off the same rules).

System:
loads data base by determining the question type and then calling for data to load a data base file.
once system knows about a question, variances are calculated on the basis of data base data and presented. Previously stored question data is immediately available (stored in dbase file)
explanation facility available. Answer illustrated by use of values taken from the data base.

Conclusions

Some issues begin to gell:

compiled vs articulated knowledge

expert systems must provide generalised models; management accountancy is so procedurally based that 3GLs make most sense for coding the specific requirements of a specific company.

expert systems may beat 3GLs for rapid prototyping (but where does this really get us?)

expert systems may beat 3GLs for GAOs but NOT algorithmic situations; the facilities of pattern matching and backtracking must be needed or otherwise the inherent IF THEN ELSE of expert systems cannot compete with IF THEN ELSE in 3GLs other than for rapid prototyping, where VP I/O is OK. NOT OK for a finished product.

Control of I/O not good; the coder is restricted heavily to VPs conventions and writing routines to control (e.g. file reading for lecturer explanations) are unnatural and depend upon artificial means to strip out operations offered.

Modules big, therefore loading time discernable. Once loaded, efficiency not an issue. Possibility of running out of memory suspected as more questions loaded to data-base but re-designation over three modules probably sufficient (need for "destructive" testing?)

Lecturer/student needs some time to learn VP cf Prototypel which was entirely transparent to the user from an operational point of view.

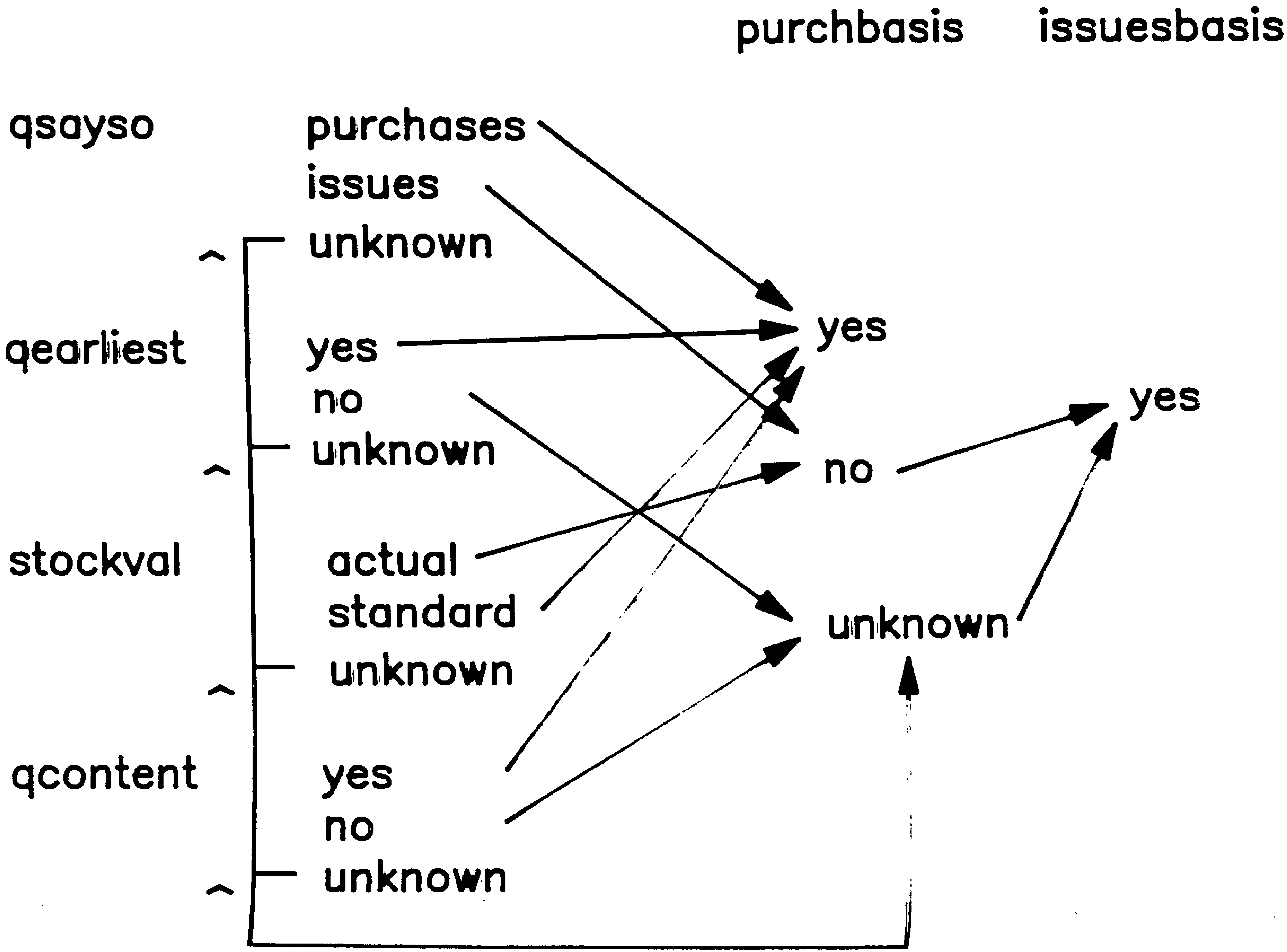
Some questions contain knowledge assumptions which are untenable and questionable; therefore loading such knowledge explicitly undesirable, but otherwise requirement on lecturer to load a question in such a way that it conforms to the knowledge model. i.e. drawback of Prototypel; level of lecturer knowledge of the system.

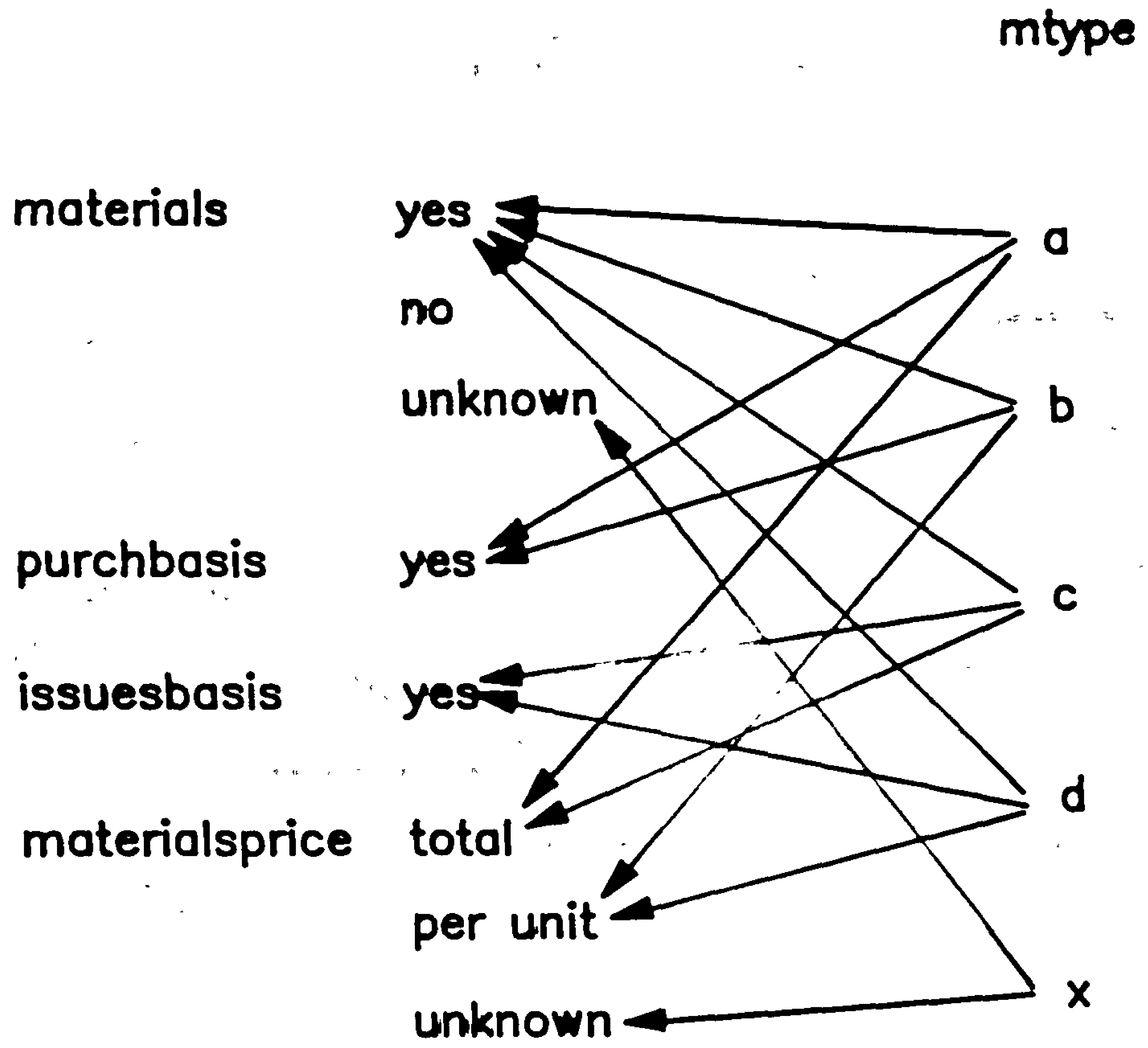
Transparency vs opaqueness.

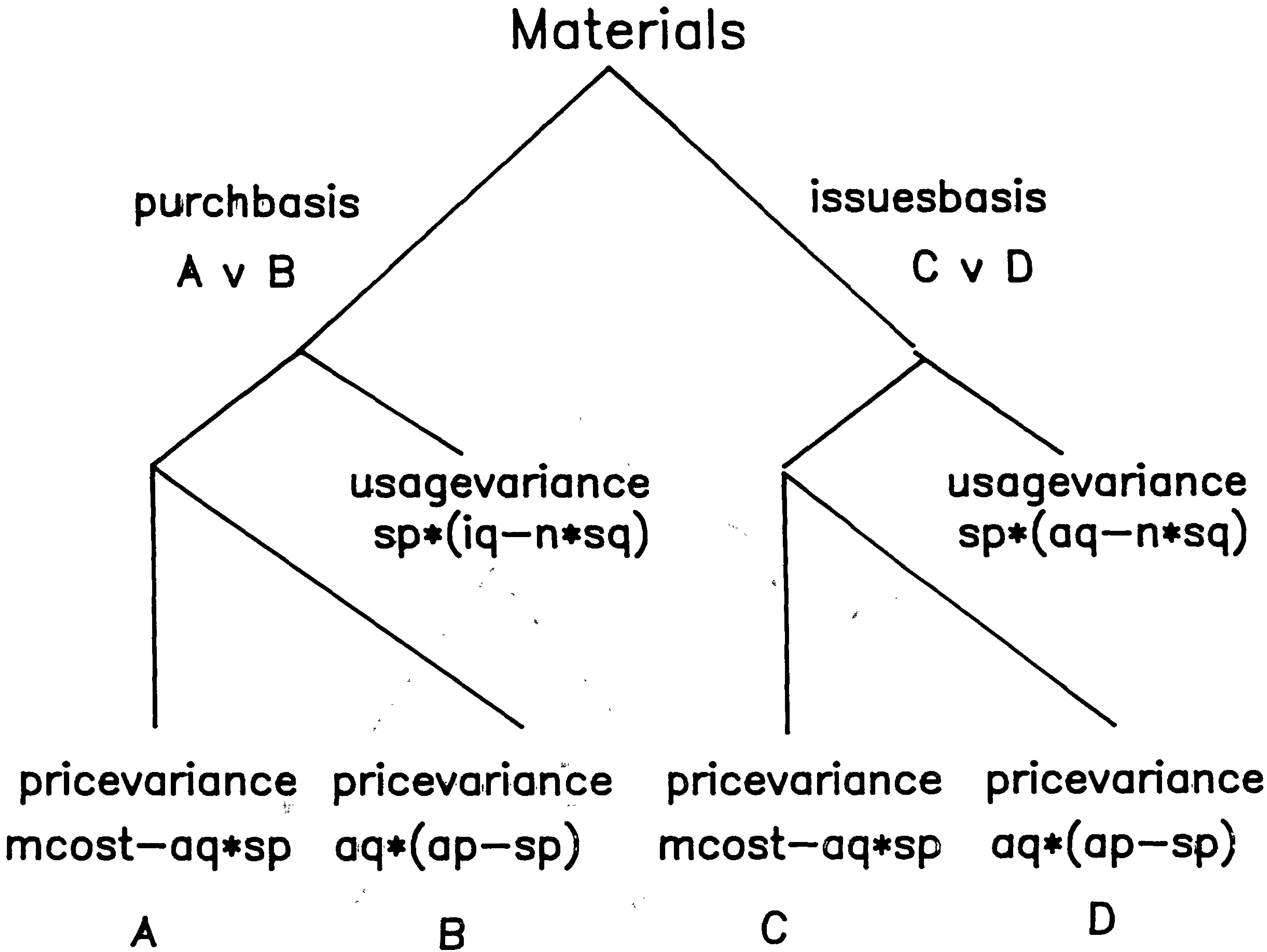
Expert systems conventionally supposed to be visible. I want to create systems for which the articulated knowledge is acceptable to lecturers and understandable by students but which rely on (my) articulated knowledge to operate with satisfactory (not optimal) efficiency within the constraints of PC memory and only own up to articulated knowledge in a form acceptable or useful to the user. This implies making my system invisible to the user (lecturer or student) because they may not like or understand my system, allowing it to learn how to respond in particular situations (problem domains, user cultures), allowing it to make available compiled knowledge in a form useful to the user. This means a different approach to explanations and why questions than customarily expected.

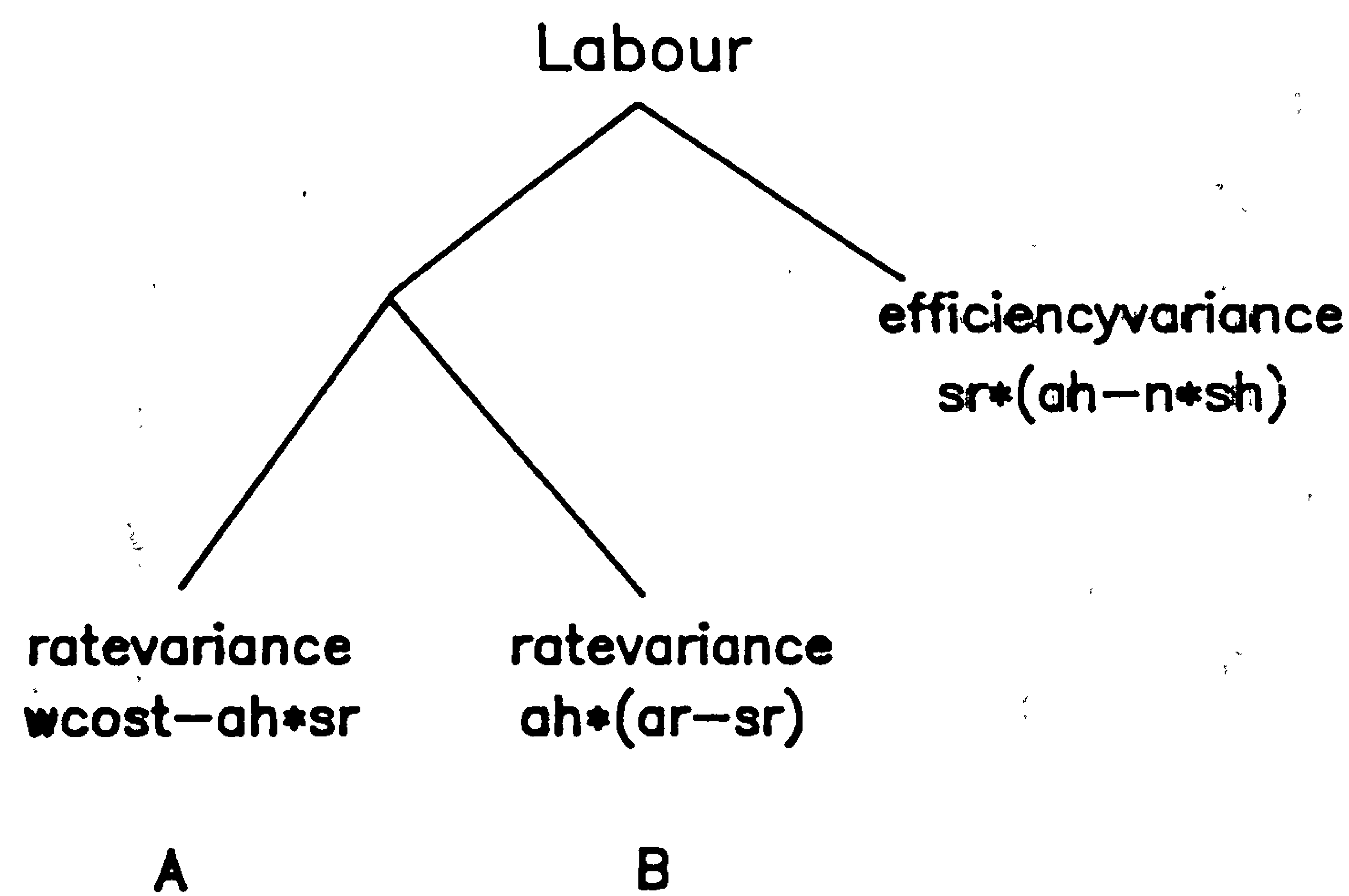
Parts of the system conform. Determining the question type is an example of an expert system which classifies/diagnoses. Calculations may be thought to follow accounting procedures. Explanations are textual and the expert systems rules are procedurally based. System is deterministic. Is this a para or quasi expert system? What are the implications for coding in a 3GL?

Useful product vs protype. Do we keep on saying that an idea can be converted easily into something useful?


purchbasis
issuesbasis
qsayso
purchases
issues
unknown
qearliest
yes
no
unknown
stockval
actual
standard
unknown
qcontent
yes
no
unknown
yes
no
unknown
yes

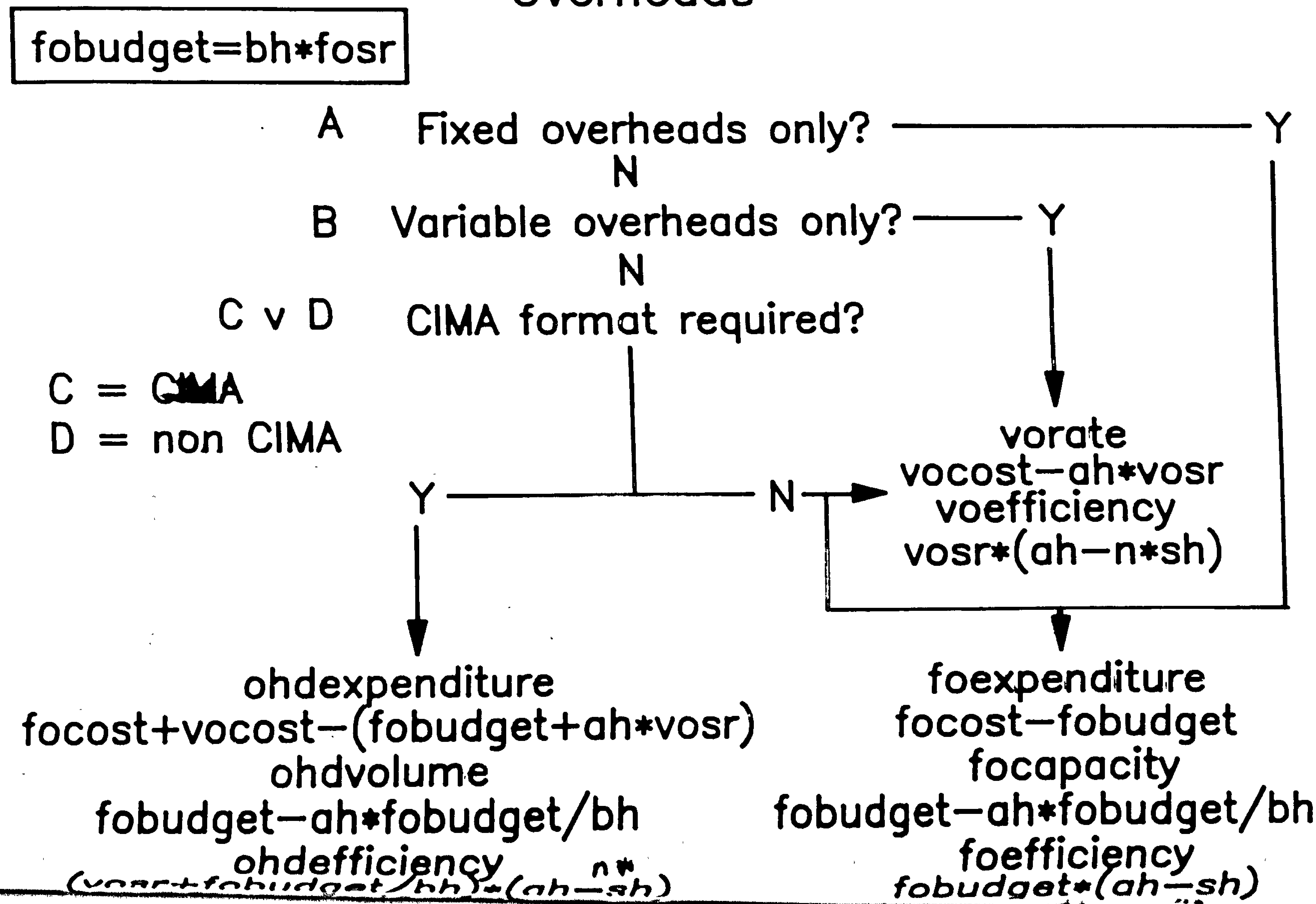

mtype
materials
yes
no
unknown
purchbasis
yes
issuesbasis
yes
materialsprice
total
per unit
unknown
a
b
c
d
x


Materials
purchbasis
A v B
issuesbasis
C v D
usagevariance
sp*(iq−n*sq)
usagevariance
sp*(aq−n*sq)
pricevariance
mcost−aq*sp
pricevariance
aq*(ap−sp)
pricevariance
mcost−aq*sp
pricevariance
aq*(ap−sp)
A
B
C
D


Labour
efficiencyvariance
sr*(ah−n*sh)
ratevariance
wcost−ah*sr
ratevariance
ah*(ar−sr)
A
B

TEXT CUT OFF IN ORIGINAL

Overheads


fobudget=bh*fosr
A Fixed overheads only?
Y
N
B Variable overheads only?
Y
N
C v D CIMA format required?
C = CIMA
D = non CIMA
Y
N
vorate
vocost−ah*vosr
voefficiency
vosr*(ah−n*sh)
ohdexpenditure
focost+vocost−(fobudget+ah*vosr)
ohdvolume
fobudget−ah*fobudget/bh
ohdefficiency
(vosr+fobudget/bh)*(ah−n*sh)
foexpenditure
focost−fobudget
focapacity
fobudget−ah*fobudget/bh
foefficiency
fobudget*(ah−sh)

Price type variances comprise the materials price variance, the labour rate variance, the variable overhead rate variance, the CIMA overhead expenditure variance and the fixed overhead expenditure variance. The final two variances must be thought of as adaptations to the fundamental principle, which will be explained first.

A standard price or rate represents the predetermined cost per unit of input. It can be determined by:
a) knowledge of the market, as in the case of materials price, where the buyer or supplier supplies information from which the standard is established;
b) extrapolation of past trends, where the present input cost and knowledge of the past inform the standard setting decision making process. In the case of labour rates, the present rate of pay may be increased by a rate determined by past trends, or, alternatively, by a rate known to be acceptabe to the market place, the latter being closer to the situation given in a) above.
A variance arises when the actual cost per unit of input varies from this standard.
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The quantity type variances are the materials price variance, the labour efficiency variance, the variable overhead efficiency variance and the fixed overhead efficiency variance. At present, the CIMA overhead efficiency variance includes both variable and fixed elements. For all of these variances, the actual time taken or quantity of materials used, in effect, the quantity relevant to the input, is compared with the time or quantity which should have been consumed in achieving the attained output. This prescribed quantity is known as the standard hours achieved, in the case of labour or overhead variances.

For wages, the standard hours achieved are determined by multiplying the production for the period by the standard hour for one unit of production. The standard hour can be predetermined from past statistics, ad hoc trials, management experience or work study timings. Overheads may be based on the same figure or can be based on the standard hour relevant to the machinery, in capital intensive situations. Materials are similar, but use the standard quantity of materials per unit of output as their basis.
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The overhead capacity variance, otherwise called the volume variance by CIMA's current Terminology, represents the quantification of the difference between the planned and actual plant capacity utilisation, measured in hours relevant to the input. This comes down to taking the difference between the budgeted and actual hours worked and multiplying the difference by the fixed overhead absorption rate. A rationale for this is given by the fact that working longer hours than budgeted implies a reduction in the fixed cost per unit of output, assuming that the extra hours translate into a greater quantity of output, which would be the case where standard efficiency is achieved.
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Materials variances calculation depend upon the way in which the system implemented values quantities of material stocks, inputs and outputs. The most straightforward case involves the calculation of price and usage variances based upon the quantities of materials issued from store. Both the price and usage elements use the issues quantity and stocks are valued on an actual basis as a mechanical corollary of the processing of data. Since the price variance is based upon the issue of stock, in cases where the material stocks are at a significant level, a substantial time period may elapse between the time of purchase and the time at which the variance is presented. Since this breaches the principle of designing systems to motivate through rapid feedback, this particular variance measurement strategy may be felt to be sub-optimal. The alternative approach is to base price variances on purchase quantities and usage variances on issues quantities. This overcomes the shortcoming described above but is not without problems. Since this approach forces stocks to be valued at standard, there may be a problem in gaining audit acceptance to the use of this valuation basis for external reporting. This may lead to a need to revalue stocks on an actual basis of some kind reducing the cost-benefit administrative advantages normally associated with standard costing systems.

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Variances may be either favourable, adverse or zero.
For price type variances, a favourable variance implies that the cost of inputs was lower than anticipated at the time that the standard was finalised. For quantity type variances, a favourable variance implies that the quantity of input required to complete the output was lower than anticipated at the time that standard quantities or standard hours were established. Favourable price type variances imply greater economy whilst favourable quantity type variances imply greater efficiency in comparison with the targets planned by way of standards.

The unusual case is given by the capacity or volume (CIMA) variance, where a greater number of hours worked than planned gives rise to a favourable variance. The rationale for this treatment is given under the explanation for quantity type variances. Rather than being an economy or efficiency situation, the variance is concerned with opportunity costs, where working fewer hours than planned represents the loss of the opportunity to absorb fixed overhead (i.e. to reduce the cost per unit of output) and is thus an adverse variance.
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execute;
runtime;
endoff;

actions
menu the_q,all,std,q
find the_q
find solution
display " "
display "Press any key to load the explanation facility.
The screen will go blank for a few seconds~"
savefacts stdata
chain stdexp;

ask the_q:"Select a question from those listed above or
type a ? to consult the system about a new question.";

rule 1
if the_q <> unknown
then solution = found
get the_q = q,std,all
find variance
else solution = findmore
find questionnumber
find variance
q = (questionnumber)
the_q = (q)
append std;

rule 2
if solution <> unknown
then variance = to_be_determined
find pricevariance
find usagevariance
find ratevariance
find efficiencyvariance
find vorate
find voefficiency
find foexpenditure
find focapacity
find foefficiency
find ohdexpenditure
find ohdvolume
find ohdefficiency;

ask questionnumber: "Provide a reference number for the new
question. You will be asked a series of questions.";

rule 101
if mtype = a
or mtype = c
and mcost > 0
and aq > 0
and sp > 0
then pricevariance = (mcost - aq * sp)
variance = (pricevariance)
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find variancetype
format pricevariance, 8.0
display "Material price variance: {pricevariance} {variancetype}"
reset variancetype
because " Data is being collected to determine the price variance";

rule 102
if mtype = b
or mtype = d
and aq > 0
and ap> 0
and sp > 0
then pricevariance = (aq * (ap -sp))
variance = (pricevariance)
find variancetype
format pricevariance, 8.0
display "Material price variance: {pricevariance} {variancetype}"
reset variancetype
because " Data is being collected to determine the price variance";

rule 103
if mtype = a or
   mtype = aa or
   mtype = b
and sp > 0
and iq > 0
and n > 0
and sq > 0
then usagevariance = (sp * (iq - n * sq))
variance = (usagevariance)
find variancetype
format usagevariance, 8.0
display "Material usage variance: {usagevariance} {variancetype}"
reset variancetype
because "Data is being collected to calculate the usage variance";

rule 104
if mtype = c
or mtype = cc
or mtype = d
and sp > 0
and aq > 0
and n > 0
and sq > 0
then usagevariance = (sp * (aq - n * sq))
variance = (usagevariance)
find variancetype
format usagevariance, 8.0
display "Material usage variance: {usagevariance} {variancetype}"
reset variancetype
because "Data is being collected to determine the usage variance";

rule 111
if mtype = aa
or mtype = cc
and mcost > 0
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and ap > 0
and sp > 0
then pricevariance = (mcost - mcost / ap * sp)
aq = (mcost / ap)
variance = (pricevariance)
find variancetype
format pricevariance, 8.0
display "Material price variance: (pricevariance) (variancetype)"
reset variancetype
because "Data is being collected to calculate the price variance";

rule 201
if ltype = a
and wcost > 0
and ah > 0
and sr > 0
then ratevariance = (wcost - ah * sr)
variance = (ratevariance)
find variancetype
format ratevariance, 8.0
display "Wages rate variance: (ratevariance) (variancetype)"
reset variancetype
because "Data is being collected to determine the rate variance";

rule 202
if ltype = b
and ah > 0
and ar > 0
and sr > 0
then ratevariance = (ah * (ar - sr))
variance = (ratevariance)
find variancetype
format ratevariance, 8.0
display "Wages rate variance: (ratevariance) (variancetype)"
reset variancetype
because "Data is being collected to determine the rate variance";

rule 203
if ltype = a or
   ltype = aa or
   ltype = b
and sr > 0
and ah > 0
and n > 0
and sh > 0
then efficiencyvariance = (sr * (ah - n * sh))
variance = (efficiencyvariance)
find variancetype
format efficiencyvariance, 8.0
display "Wages efficiency variance: (efficiencyvariance) (variancetype)"
reset variancetype
because "Data is being collected so that the efficiency variance can be;
calculated";

rule 211
if ltype = aa
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and wcost > 0
and ar > 0
and sr > 0
then ratevariance = (wcost - wcost / ar * sr)
ah = (wcost / ar)
variance = (ratevariance)
find variancetype
format ratevariance, 8.0
display "Wages rate variance: {ratevariance} {variancetype}"
reset variancetype
because "Data is being collected for the rate variance calculation";


rule 501
if otype = b
or otype = d
and vocost > 0
and ah > 0
and vosr > 0
then vorate = (vocost - ah * vosr)
variance = (vorate)
find variancetype
format vorate, 8.0
display "Variable overhead rate variance: {vorate} {variancetype}"
reset variancetype
because "Data is being collected for the variable overhead rate variance
calculation";

rule 502
if otype = b
or otype = d
and vosr > 0
and ah > 0
and n > 0
and sh > 0
then voefficiency = (vosr * (ah - n * sh))
variance = (voefficiency)
find variancetype
format voefficiency, 8.0
display "Variable overhead efficiency variance: {voefficiency} {variancetype}"
reset variancetype
because "Data is being collected for the
variable overhead efficiency calculation";

rule 601
if otype = a
or otype = d
and focost > 0
and fobudget > 0
then foexpenditure = (focost - fobudget)
variance = (foexpenditure)
find variancetype
format foexpenditure, 8.0
display "Fixed overhead expenditure variance: {foexpenditure} {variancetype}"
reset variancetype
because "Data is being collected for the overhead expenditure variance
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calculation";

rule 602
if otype = a
or otype = d
and fobudget > 0
and ah > 0
and bh > 0
then focapacity = (fobudget - ah * fobudget / bh)
variance = (focapacity)
find variancetype
format focapacity, 8.0
display "Fixed overhead capacity variance: {focapacity} {variancetype}"
reset variancetype
because "Data is being collected for the capacity variance calculation";

rule 603
if otype = a
or otype = d
and fobudget >0
and bh > 0
and ah > 0
and sh > 0
and n > 0
then foefficiency = (fobudget / bh * (ah - n * sh))
variance = (foefficiency)
find variancetype
format foefficiency, 8.0
display "Fixed overhead efficiency variance: {foefficiency} {variancetype}"
reset variancetype
because "Data is being collected for the fixed overhead
efficiency variance calculation";

rule 611
if otype = aa
or otype = dd
and focost > 0
and bh > 0
and fosr > 0
then foexpenditure = (focost - bh * fosr)
variance = (foexpenditure)
find variancetype
format foexpenditure, 8.0
display "Fixed overhead expenditure variance: {foexpenditure} {variancetype}"
reset variancetype
because "Data is being collected for the expenditure variance calculation";

rule 612
if otype = aa
or otype = dd
and fosr> 0
and ah > 0
and bh > 0
then focapacity = (fosr * (bh - ah))
variance = (focapacity)
find variancetype
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format focapacity, 8.0
display "Fixed overhead capacity variance: {focapacity} {variancetype}"
reset variancetype
because "Data is being assembled from which the capacity variance
can be calculated";

rule 613
if otype = aa
or otype = dd
and fosr >0
and ah > 0
and sh > 0
and n > 0
then foefficiency = (fosr * (ah - n * sh))
variance = (foefficiency)
find variancetype
format foefficiency, 8.0
display "Fixed overhead efficiency variance: {foefficiency} {variancetype}"
reset variancetype
because "Data is being collected from which the fixed overhead
efficiency variance can be calculated";

rule 701
if otype = c
and focost > 0
and vocost > 0
and fobudget > 0
and ah > 0
and vosr > 0
then ohdexpenditure = (focost + vocost - (fobudget + ah * vosr))
variance = (ohdexpenditure)
find variancetype
format ohdexpenditure, 8.0
display "Overhead expenditure variance: {ohdexpenditure} {variancetype}"
reset variancetype
because "Data is being collected for the expenditure variance calculation";

rule 702
if otype = c
and fobudget > 0
and ah > 0
and bh > 0
then ohdvolume = (fobudget - ah * fobudget / bh)
variance = (ohdvolume)
find variancetype
format ohdvolume, 8.0
display "Overhead volume variance: {ohdvolume} {variancetype}"
reset variancetype
because "Data is being collected for the CIMA volume variance calculation";

rule 703
if otype = c
and vosr > 0
and fobudget > 0
and bh > 0
and ah > 0
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```
and sh > 0
and n > 0
then ohdefficiency = ((vosr + fobudget / bh) * (ah - n * sh))
variance = (ohdefficiency)
find variancetype
format ohdefficiency, 8.0
display "Overhead efficiency variance: {ohdefficiency} {variancetype}"
reset variancetype
because "Data is being calculated for the overhead efficiency calculation";

rule 711
if otype = cc
and focost > 0
and vocost > 0
and bh > 0
and fosr > 0
and ah > 0
and vosr > 0
then ohdexpenditure = (focost + vocost - (bh * fosr + ah * vosr))
variance = (ohdexpenditure)
find variancetype
format ohdexpenditure, 8.0
display "Overhead expenditure variance: {ohdexpenditure} {variancetype}"
reset variancetype
because "Data is being collected for the expenditure variance calculation";

rule 712
if otype = cc
and fosr> 0
and ah > 0
and bh > 0
then ohdvolume = (fosr * (bh - ah))
variance = (ohdvolume)
find variancetype
format ohdvolume, 8.0
display "Overhead volume variance: {ohdvolume} {variancetype}"
reset variancetype
because "Data is being collected for the CIMA volume variance";

rule 713
if otype = cc
and vosr > 0
and fosr > 0
and ah > 0
and sh > 0
and n > 0
then ohdefficiency = ((vosr + fosr) * (ah - n * sh))
variance = (ohdefficiency)
find variancetype
format ohdefficiency, 8.0
display "Overhead efficiency variance: {ohdefficiency} {variancetype}"
reset variancetype
because "Data is being collected for the overhead efficiency ;
variance calculation";

rule 997
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if variance = 0
then variancetype = nil_variance;

rule 998
if variance < 0
then variancetype = favourable;

rule 999
if variance > 0
then variancetype = adverse;

ask n: "Type in the number of units of production manufactured
for the period.";
ask mcost: "What was the total cost of materials for the period?";
ask aq: "Provide the materials quantity for the period.";
ask sp: "What is the standard price for each unit of materials?";
ask ap: "How much was paid for each unit of raw materials purchased
or used during the period?";
ask iq: "Provide the quantity of materials issued during the period:";
ask sq: "What is the standard quantity of materials to be used to make each
unit of production?";
ask wcost: "What was the cost of wages for the period?";
ask ah: "How many hours were worked in total for the period?";
ask sr: "What is the standard rate of pay for the workforce?";
ask ar: "How much was paid for each hour worked during the period?";
ask sh: "What is the standard time allowed for each unit of
production, given in hours?";
ask vocost: "Provide the total cost of variable overheads:";
ask vosr: "What is the standard rate per hour for variable overheads?";
ask focost: "Provide the total cost of fixed overheads:";

!rule 1001
!if otype = aa
!or otype = bb
!or otype = cc
!or otype = dd
!and budgeted_units = yes
!and budget_units > 0
!and sh > 0
!and fosr > 0
!then fobudget = (budget_units * sh * fosr)
!because "The fixed overhead budget is being determined";
!
!rule 1002
!if otype = aa
!or otype = bb
!or otype = cc
!or otype = dd
!and budgeted_units = yes
!and budget_units > 0
!and sh > 0
!then bh = (budget_units * sh)
!because "The fixed overhead budget is being determined";
!
!ask budgeted_units: "Is the budgeted number of units provided?";
!choices budgeted_units: yes,no;
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!ask budget_units: "Enter the number of units budgeted to be
!produced during the period:";
!
!rule 1003
!if otype = aa
!or otype = bb
!and ohd_abs_rate = yes
!and rec_rate > 0
!and sr > 0
!then vosr = (rec_rate / 100 * sr)
!because "The overhead rate is being determined";
!
!rule 1004
!if otype = aa
!or otype = bb
!and ohd_abs_rate = yes
!and rec_rate > 0
!and sr > 0
!then fosr = (rec_rate / 100 * sr)
!because "The overhead rate is being determined";
!
!rule 1005
!if otype = cc
!or otype = dd
!and vohd_abs_rate = yes
!and vohd_rec_rate > 0
!and sr > 0
!then vosr = (vohd_rec_rate / 100 * sr)
!because "The overhead rate is being determined";
!
!rule 1006
!if otype = cc
!or otype = dd
!and fohd_abs_rate = yes
!and fohd_rec_rate > 0
!and sr > 0
!then fosr = (fohd_rec_rate / 100 * sr)
!because "The overhead rate is being determined";
!
ask ohd_abs_rate: "Is the overhead absorption rate provided as
a particular rate per labour cost, e.g. 200% of direct wages?";
choices ohd_abs_rate: yes,no;
ask rec_rate: "Provide the overhead absorption rate, eg enter 200
if the absorption rate is 200% of direct wages:";
ask vohd_abs_rate: "Is the variable overhead absorption rate provided as
a particular rate per labour cost, e.g. 200% of direct wages?";
choices vohd_abs_rate: yes,no;
ask vohd_rec_rate: "Provide the variable overhead absorption rate, eg enter 200
if the absorption rate is 200% of direct wages:";
ask fohd_abs_rate: "Is the fixed overhead absorption rate provided as
a particular rate per labour cost, e.g. 200% of direct wages?";
choices fohd_abs_rate: yes,no;
ask fohd_rec_rate: "Provide the fixed overhead absorption rate, eg enter 200
if the absorption rate is 200% of direct wages:";

ask fobudget: "How much has been provided in the budget for fixed
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overhead expenditure?";
ask bh: "How many hours have been budgeted to be worked?";
ask fosr: "What is the standard rate per hour for fixed overheads?";

rule 5001
if materials = yes
and purchbasis = yes
and materialsprice = total
then mtype = a
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5002
if materials = yes
and purchbasis = yes
and materialsprice = per_unit
then mtype = b
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5003
if materials = yes
and issuesbasis = yes
and materialsprice = total
then mtype = c
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5004
if materials = yes
and issuesbasis = yes
and materialsprice = per_unit
then mtype = d
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5005
if materials = no
or materials = unknown
then mtype = x
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

ask materials: "Is information on materials provided?";
choices materials: yes,no;

rule 5006
if materialsprice = unknown
then mtype = x
display "I'm sorry but I cannot carry out an analysis of
materials with the information you have provided.
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Please consult your tutor."
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5011
if materials = yes
and purchbasis = yes
and materialsprice = total_&_per_unit
then mtype = aa
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5013
if materials = yes
and issuesbasis = yes
and materialsprice = total_&_per_unit
then mtype = cc
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5201
if qsayso = purchases
then purchbasis = yes
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5203
if qsayso = issues
then purchbasis = no;

rule 5204
if qearliest = yes
then purchbasis = yes
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

!rule 5205
!if qearliest = no
!then purchbasis = unknown;

rule 5206
if stockval = standard
then purchbasis = yes
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5207
if stockval = actual
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then purchbasis - no
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5208
if qcontent - yes
then purchbasis - yes
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";


!rule 5209
!if qcontent - no
!then purchbasis - unknown;


rule 5249
if qsayso - unknown
and qearliest - unknown
and stockval - unknown
and qcontent - unknown
then purchbasis - no;

rule 5299
if purchbasis - no
or purchbasis - unknown
then issuesbasis - yes;

ask qsayso: "Sometimes, there is information available
which tells you whether the materials price variance
is based on purchases or issues. If this information
is available, make the appropriate selection from
the menu below by moving the cursor and pressing enter.
If you cannot find the relevant information, press the
question mark key.";
choices qsayso: purchases,issues;
ask qearliest: "Are you told to calculate the variance at
the earliest time possible?";
choices qearliest: yes,no;
ask stockval: "Is the stock valued at standard or actual
price? If you do not know, press the question mark key.";
choices stockval: standard,actual;
ask qcontent: "Are you provided with purchase and issues
quantity information AND not instructed to calculate the
price variance at the issues stage?";
choices qcontent: yes,no;

ask materialsprice: "Information on materials cost for the period can take
three forms. It can be presented as a total material
cost of purchasing or usage (total), it can be presented as a
cost per unit of material (per unit),or both total and per_unit
figures can be given. In which form is the information
on materials cost presented?";
choices materialsprice: total,per_unit,total_&_per_unit;
```

```
rule 5300
if labour = yes
and labourate = total
then ltype = a
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5301
if labour = yes
and labourate = hourly_rate
then ltype = b
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5302
if labour = no
or labour = unknown
then ltype = x
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5303
if labourate = unknown
then ltype = x
display "I'm sorry but I cannot carry out an analysis of
labour with the information you have provided.
Please consult your tutor."
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5310
if labour = yes
and labourate = total_&_hourly_rate
then ltype = aa
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

ask labour: "Is labour information included?";
choices labour: yes,no;
ask labourate: "Information on the rate paid to employees
is normally provided in one of three ways. Is the total figure
of wages cost (total), the hourly rate of pay (hourly_rate)
or both the wages cost and the hourly rate provided?";
choices labourate: total,hourly_rate,total_&_hourly_rate;

rule 5401
if ohd = fixed_only
and fohdrate = total
then otype = a
because "It is necessary to determine the characteristics of the
```

```
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5402
if ohd - fixed_only
and fohdrate - hourly_rate
then otype - aa
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5403
if ohd - variable_only
then otype - b
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5404
if ohd - fixed_and_variable
and fohdrate - total
and cima - yes
then otype - c
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5405
if ohd - fixed_and_variable
and fohdrate - hourly_rate
and cima - yes
then otype - cc
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5405
if ohd - fixed_and_variable
and fohdrate - total
and cima - no
or cima - unknown
then otype - d
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5406
if ohd - fixed_and_variable
and fohdrate - hourly_rate
and cima - no
or cima - unknown
then otype - dd
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";
```

```
rule 5407
if ohd = no_overhead
or ohd = unknown
then otype = x
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

rule 5408
if fohdrate = unknown
then otype = x
display "I'm sorry, but I cannot carry out an analysis of
fixed overheads with the information you have provided.
Please consult your tutor."
because "It is necessary to determine the characteristics of the
situation before carrying out the variance analysis since much of the
detailed analysis depends on the way in which data is provided.";

ask ohd: "Overhead analysis may not be required (no_overhead),
the situation may contain only fixed overhead (fixed only)
or variable overhead (variable only) or both fixed and variable
overhead (fixed and variable). If you are not sure which option
is correct and overhead information is present and must be
analysed, request an analysis of fixed overhead only (fixed only).
If you are absolutely unsure, type in a question mark (?) and see
your tutor; no analysis of overhead will be undertaken.";
choices ohd: no_overhead,fixed_only,variable_only,fixed_and_variable;
ask cima: "Do you wish the answer to be presented in accordance with
the terminology of the Chartered Institute of Management Accountants,
which is somewhat different to the usual text-book approach?";
choices cima: yes,no;
ask fohdrate: "Can you provide either the total budgeted fixed overhead
or the fixed overhead rate per labour hour?";
choices fohdrate: total,hourly_rate;
```

```
execute;
runtime;
endoff;

actions
line_count = 1
loadfacts stdata
find exp
whileknown explain
  reset explain
  pop exp,explain
  find explanation
  reset explanation
end
display "Press any key to load the variance data.
The screen will go blank for a few seconds~"
chain std;

ask exp: "Make a selection from the menu below.
Press the End key once your selection is complete.

If you wish to see an explanation for any
of the variances given below, use the cursor to make
your selection and then press enter. If you do not wish
to see an explanation, select 'not required'.
In this part of the system, you may choose more than
one item from each menu. The system will process all
of your choices, in reverse order, once you press the End key";
choices exp: not_required,materials_price,materials_usage,
labour_rate,labour_efficiency,
variable_ohd_rate,var_ohd_efficiency,
overhead_expenditure,overhead_volume,overhead_capacity,overhead_efficiency;
plural: exp;

rule 1001
if explain = not_required
then explanation = done;

rule 1101
if explain = materials_price
and mtype = a
or mtype = c
then explanation = done
pricevariance = (mcost - aq * sp)
cls
display "The materials price variance is found by comparing
the cost of materials for the period in question, {mcost},
with the quantity of purchases valued at standard price, {aq} @ {sp}.
This gives {mcost} - {aq} * {sp} = {pricevariance}.

Press any key to continue~"
find furtherexp
whileknown furtherexplain
  reset furtherexplain
  pop furtherexp,furtherexplain
  find furtherexplanation
```

```
  reset furtherexplanation
end;

rule 1102
if explain = materials_price
and mtype = b
or mtype = d
then explanation = done
pvariance = (ap - sp)
pricevariance = (aq * (ap - sp))
cls
display "The materials price variance is found by comparing
the price paid for the raw materials purchased, (ap), and the
standard price, representing the price which should have been
paid, (sp). The difference, (pvariance), is converted into a
price variance by multiplying (pvariance) by the quantity of
materials purchased, (aq), to give (pricevariance).

Press any key to continue~"
find furtherexp
  whileknown furtherexplain
  reset furtherexplain
  pop furtherexp,furtherexplain
  find furtherexplanation
  reset furtherexplanation
end;

rule 1103
if explain = materials_price
and mtype = aa
or mtype = cc
then explanation = done
scost = (mcost / ap * sp)
pricevariance = (mcost - mcost / ap * sp)
cls
display "The materials price variance is found by comparing
the cost of materials for the period with the standard cost.
Since the normal calculation of standard cost of materials
requires knowledge of the quantity of materials used or purchased
during the period, this is first found by dividing the total cost,
(mcost), by the price paid for materials, (ap). This quantity is
multiplied by the standard price, (sp), to give standard cost.
The price variance , (pricevariance) is then given by cost of materials,
(mcost), less standard cost, (scost).

Press any key to continue~"
find furtherexp
  whileknown furtherexplain
  reset furtherexplain
  pop furtherexp,furtherexplain
  find furtherexplanation
  reset furtherexplanation
end;

rule 1201
if explain = materials_usage
```

```
and mtype = a
or mtype =aa
or mtype = b
then explanation = done
usagevariance = (sp * (iq - n * sq))
qvar = (n * sq)
cls
display "The materials usage variance is found by comparing
the quantity of materials issued, {iq}, with the standard quantity,
found by multiplying the standard quantity of raw materials required
for each unit of production, {sq}, by the actual quantity of production,
{n}. This difference, {qvar} is then valued at standard price, {sp}.

Press any key to continue~"
find furtherexpl
  whileknown furtherexplainl
  reset furtherexplainl
  pop furtherexpl,furtherexplainl
  find furtherexplanationl
  reset furtherexplanationl
end;

rule 1202
if explain = materials_usage
and mtype = c
or mtype =cc
or mtype = d
then explanation = done
usagevariance = (sp * (aq - n * sq))
qvar = (n * sq)
cls
display "The materials usage variance is found by comparing
the quantity of materials used, {aq}, with the standard quantity,
found by multiplying the standard quantity of raw materials required
for each unit of production, {sq}, by the actual quantity of production,
{n}. This difference, {qvar} is then valued at standard price, {sp}.

Press any key to continue~"
find furtherexpl
  whileknown furtherexplainl
  reset furtherexplainl
  pop furtherexpl,furtherexplainl
  find furtherexplanationl
  reset furtherexplanationl
end;

rule 1301
if explain = labour_rate
and ltype = a
then explanation = done
ratevariance = (wcost - ah * sr)
cls
display "Hours worked: {ah}
Standard rate per hour: {sr}
Wages should have cost: {ah} * {sr}
Wages did cost:         {wcost}
```

```
Comparison of these gives: {ratevariance}

Press any key to continue~"
find furtherexp2
  whileknown furtherexplain2
  reset furtherexplain2
  pop furtherexp2,furtherexplain2
  find furtherexplanation2
  reset furtherexplanation2
end;

rule 1302
if explain = labour_rate
and ltype = b
then explanation = done
ratevariance = (ah * (ar - sr))
cls
display "Rate paid: {ar}
Should have been: {sr}
The difference is multiplied by the hours worked, {ah}, giving {ratevariance}

Press any key to continue~"
find furtherexp2
  whileknown furtherexplain2
  reset furtherexplain2
  pop furtherexp2,furtherexplain2
  find furtherexplanation2
  reset furtherexplanation2
end;

rule 1303
if explain = labour_rate
and ltype = aa
then explanation = done
ratevariance = (wcost - wcost / ar * sr)
cls
display "Cost of wages: {wcost}
Rate paid for the period: {ar}
Hours worked during the period: {wcost} / {ar}
The hours worked during the period, multiplied by the standard rate
of pay, {sr}, is compared with the cost of wages for the period to
give the rate variance, {ratevariance}.

Press any key to continue~"
find furtherexp2
  whileknown furtherexplain2
  reset furtherexplain2
  pop furtherexp2,furtherexplain2
  find furtherexplanation2
  reset furtherexplanation2
end;

rule 1401
if explain = labour_efficiency
and ltype = a
or ltype = aa
```

```
or ltype = b
then explanation = done
efficiencyvariance = (sr * (ah - n * sh))
stdh = (n * sh)
cls
display "Hours worked: {ah}
Standard hours: {n} * {sh}, {stdh}
Hours worked to acheive those standard hours: {ah}
The difference, {ah} - {stdh} is valued at the standard rate of pay, {sr}.
This gives the efficiency variance of {efficiencyvariance}

Press any key to continue~"
find furtherexp3
  whileknown furtherexplain3
  reset furtherexplain3
  pop furtherexp3,furtherexplain3
  find furtherexplanation3
  reset furtherexplanation3
end;

rule 1501
if explain = variable_ohd_rate
and otype = b
or otype = d
then explanation = done
vorate = (vocost - ah * vosr)
cls
display "Hours worked: {ah}
Variable overhead standard rate per hour: {vosr}
The hours worked should, therefore, have cost: {ah} * {vosr}
They did cost: {vocost}.
The variable overhead rate variance is: {vorate}

Press any key to continue~"
find furtherexp4
  whileknown furtherexplain4
  reset furtherexplain4
  pop furtherexp4,furtherexplain4
  find furtherexplanation4
  reset furtherexplanation4
end;

rule 1502
if explain = var_ohd_efficiency
and otype = b
or otype = d
then explanation = done
voefficiency = (vosr * (ah - n * sh))
stdh = (n * sh)
cls
display "Hours worked: {ah}
Standard hours: {n} * {sh}, {stdh}
Hours worked to acheive those standard hours: {ah}
The difference, {ah} - {stdh} is valued at the standard rate of pay, {vosr}.
This gives the efficiency variance of {voefficiency}.
Note how similar the variable overhead and wages efficiency variances are.
```

```
Press any key to continue~"
find furtherexp5
  whileknown furtherexplain5
  reset furtherexplain5
  pop furtherexp5,furtherexplain5
  find furtherexplanation5
  reset furtherexplanation5
end;

rule 1601
if explain = overhead_expenditure
and otype = a
or otype = d
then explanation = done
foexpenditure = (focost - fobudget)
cls
display "Fixed overhead cost for the period: {focost}
Fixed overhead budgeted for the period: {fobudget}
The expenditure variance is the difference: {foexpenditure}

Press any key to continue~"
find furtherexp6
  whileknown furtherexplain6
  reset furtherexplain6
  pop furtherexp6,furtherexplain6
  find furtherexplanation6
  reset furtherexplanation6
end;

rule 1602
if explain = overhead_capacity
and otype = a
or otype = d
then explanation = done
frate = (fobudget / bh)
focapacity = (fobudget - ah * fobudget / bh)
cls
display "Fixed overhead budget for the period: {fobudget}
This is compared with the hours worked, {ah}, valued at the
fixed overhead absorption rate, in this case calculated by
dividing the budget, {fobudget}, by the budgeted hours, {bh}.
Basically, the variance measures the difference between the
hours planned, i.e. budgeted and the hours worked and it can be
explained as {bh} - {ah} * {frate}, where {frate} is the
fixed overhead absorption rate, giving {focapacity}.

Press any key to continue~"
find furtherexp7
  whileknown furtherexplain7
  reset furtherexplain7
  pop furtherexp7,furtherexplain7
  find furtherexplanation7
  reset furtherexplanation7
end;
```

```
rule 1603
if explain = overhead_efficiency
and otype = a
or otype = d
then explanation = done
foefficiency = (fobudget / bh * (ah - n * sh))
cls
display "Fixed overhead absorption rate: (fobudget) / (bh)
Actual hours: (ah)
Standard hours: (n) * (sh)
The overhead efficiency variance is basically the same as
the labour efficiency variance, i.e. a comparison of standard
and actual hours, valued at the standard hourly rate,
giving: (foefficiency)

Press any key to continue~"
find furtherexp9
  whileknown furtherexplain9
  reset furtherexplain9
  pop furtherexp9,furtherexplain9
  find furtherexplanation9
  reset furtherexplanation9
end;

rule 1611
if explain = overhead_expenditure
and otype = aa
or otype = dd
then explanation = done
foexpenditure = (focost - bh * fosr)
cls
display "Fixed overhead cost for the period: (focost)
Fixed overhead budgeted for the period: (bh) * (fosr)
The expenditure variance is the difference: (foexpenditure)

Press any key to continue~"
find furtherexp6
  whileknown furtherexplain6
  reset furtherexplain6
  pop furtherexp6,furtherexplain6
  find furtherexplanation6
  reset furtherexplanation6
end;

rule 1612
if explain = overhead_capacity
and otype = aa
or otype = dd
then explanation = done
focapacity = (fosr * (bh - ah))
cls
display "The capacity variance measures the difference between the
hours planned, i.e. budgeted, (bh) and the hours worked, (ah).
This difference is valued at the fixed overhead absorption rate, (fosr),
to give: (focapacity).
```

```
Press any key to continue~"
find furtherexp7
  whileknown furtherexplain7
  reset furtherexplain7
  pop furtherexp7,furtherexplain7
  find furtherexplanation7
  reset furtherexplanation7
end;

rule 1613
if explain = overhead_efficiency
and otype = aa
or otype = dd
then explanation = done
foefficiency = (fosr * (ah - n * sh))
cls
display "Fixed overhead absorption rate: {fosr}
Actual hours: {ah}
Standard hours: {n} * {sh}
The overhead efficiency variance is basically the same as
the labour efficiency variance, i.e. a comparison of standard
and actual hours, valued at the standard hourly rate,
giving: {foefficiency}

Press any key to continue~"
find furtherexp9
  whileknown furtherexplain9
  reset furtherexplain9
  pop furtherexp9,furtherexplain9
  find furtherexplanation9
  reset furtherexplanation9
end;

rule 1701
if explain = overhead_expenditure
and otype = c
then explanation = done
ohdexpenditure = (focost + vocost - (fobudget + ah * vosr))
cls
display "Overhead cost for the period: {focost} + {vocost}
Overhead flexed budgeted for the period: {fobudget} + ({ah} * {fosr})
That is, the total of fixed and variable elements. The budget for
variable overheads must be flexed on the basis of hours in order
that the capacity variance can be interpreted.
The expenditure variance is the difference between the
flexed budget and actual expenditure: {ohdexpenditure}

Press any key to continue~"
find furtherexp6
  whileknown furtherexplain6
  reset furtherexplain6
  pop furtherexp6,furtherexplain6
  find furtherexplanation6
  reset furtherexplanation6
end;
```

```
rule 1702
if explain = overhead_volume
and otype = c
then explanation = done
frate = (fobudget / bh)
ohdvolume = (fobudget - ah * fobudget / bh)
cls
display "Fixed overhead budget for the period: {fobudget}
This is compared with the hours worked, {ah}, valued at the
fixed overhead absorption rate, in this case calculated by
dividing the budget, {fobudget}, by the budgeted hours, {bh}.
Basically, the variance measures the difference between the
hours planned, i.e. budgeted and the hours worked and it can be
explained as {bh} - {ah} * {frate}, where {frate} is the
fixed overhead absorption rate, giving {ohdvolume}.

Press any key to continue~"
find furtherexp8
  whileknown furtherexplain8
  reset furtherexplain8
  pop furtherexp8,furtherexplain8
  find furtherexplanation8
  reset furtherexplanation8
end;

rule 1703
if explain = overhead_efficiency
and otype = c
then explanation = done
tabs = (fobudget / bh + vosr)
ohdefficiency = ((vosr + fobudget / bh) * (ah - n * sh))
cls
display "Fixed overhead absorption rate: {fobudget} / {bh}
Variable overhead absorption rate: {vosr}
The total of these gives the total absorption rate: {tabs}
Actual hours: {ah}
Standard hours: {n} * {sh}
The overhead efficiency variance is basically the same as
the labour efficiency variance, i.e. a comparison of standard
and actual hours, valued at the standard hourly rate, or absorption rate
giving: {ohdefficiency}

Press any key to continue~"
find furtherexp9
  whileknown furtherexplain9
  reset furtherexplain9
  pop furtherexp9,furtherexplain9
  find furtherexplanation9
  reset furtherexplanation9
end;

rule 1711
if explain = overhead_expenditure
and otype = cc
then explanation = done
totalohd = (bh * fosr + ah * vosr)
```

```
ohdexpenditure = (focost + vocost - (bh * fosr + ah * vosr))
cls
display "Overhead cost for the period: {focost} + {vocost}
Overhead flexed budgeted for the period:
                              Fixed: {bh} * {fosr}
                           Variable: {ah} * {vosr}
                              Total: {totalohd}
That is, the total of fixed and variable elements. The budget for
variable overheads must be flexed on the basis of hours in order
that the capacity variance can be interpreted.
The expenditure variance is the difference between the
overhead flexed budget and actual expenditure: {foexpenditure}

Press any key to continue~"
find furtherexp6
  whileknown furtherexplain6
  reset furtherexplain6
  pop furtherexp6,furtherexplain6
  find furtherexplanation6
  reset furtherexplanation6
end;

rule 1712
if explain = overhead_volume
and otype = cc
then explanation = done
ohdvolume = (fosr * (bh - ah))
cls
display "The capacity variance measures the difference between the
hours planned, i.e. budgeted, {bh} and the hours worked, {ah}.
This difference is valued at the fixed overhead absorption rate, {fosr},
to give: {ohdvolume}. Most texts on standard costing call this the
capacity variance.

Press any key to continue~"
find furtherexp8
  whileknown furtherexplain8
  reset furtherexplain8
  pop furtherexp8,furtherexplain8
  find furtherexplanation8
  reset furtherexplanation8
end;

rule 1713
if explain = overhead_efficiency
and otype = cc
then explanation = done
tabs = (fosr + vosr)
ohdefficiency = ((vosr + fosr) * (ah - n * sh))
cls
display "Fixed overhead absorption rate: {fosr}
Variable overhead absorption rate: {vosr}
The total of these gives the total absorption rate: {tabs}
Actual hours: {ah}
Standard hours: {n} * {sh}
The overhead efficiency variance is basically the same as
```

```
the labour efficiency variance, i.e. a comparison of standard
and actual hours, valued at the standard hourly rate, or absorption rate
giving: {ohdefficiency}

Press any key to continue~"
find furtherexp9
  whileknown furtherexplain9
  reset furtherexplain9
  pop furtherexp9,furtherexplain9
  find furtherexplanation9
  reset furtherexplanation9
end;



rule 2501
if furtherexplain = continue
then furtherexplanation = done;

rule 2502
if furtherexplain = quantity
then furtherexplanation = done
whileknown qexp
  receive mqty,qexp
  display "{qexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2503
if furtherexplain = variance_type
then furtherexplanation = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2504
if furtherexplain = general
then furtherexplanation = done
whileknown gexp
  receive pgen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2501
if furtherexplain1 = continue
then furtherexplanation1 = done;

rule 2502
if furtherexplain1 = quantity
then furtherexplanation1 = done
```

```
whileknown qexp
  receive mqty,qexp
  display "{qexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2503
if furtherexplain1 = variance_type
then furtherexplanation1 = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2504
if furtherexplain1 = general
then furtherexplanation1 = done
whileknown gexp
  receive qgen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2505
if furtherexplain1 = prod_units
then furtherexplanation1 = done
whileknown pexp
  receive pu,pexp
  display "{pexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2601
if furtherexplain2 = continue
then furtherexplanation2 = done;

rule 2602
if furtherexplain2 = variance_type
then furtherexplanation2 = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 2603
if furtherexplain2 = general
then furtherexplanation2 = done
whileknown gexp
  receive pgen,gexp
```

```
  display "(gexp)"
  find control reset control
end
display "Press any key to continue.~";

rule 2701
if furtherexplain3 = continue
then furtherexplanation3 = done;

rule 2702
if furtherexplain3 = prod_units
then furtherexplanation3 = done
whileknown qexp
  receive pu,qexp
  display "(qexp)"
  find control reset control
end
display "Press any key to continue.~";

rule 2703
if furtherexplain3 = variance_type
then furtherexplanation3 = done
whileknown vexp
  receive type,vexp
  display "(vexp)"
  find control reset control
end
display "Press any key to continue.~";

rule 2704
if furtherexplain3 = general
then furtherexplanation3 = done
whileknown gexp
  receive qgen,gexp
  display "(gexp)"
  find control reset control
end
display "Press any key to continue.~";

rule 2801
if furtherexplain4 = continue
then furtherexplanation4 = done;

rule 2802
if furtherexplain4 = variance_type
then furtherexplanation4 = done
whileknown vexp
  receive type,vexp
  display "(vexp)"
  find control reset control
end
display "Press any key to continue.~";

rule 2803
if furtherexplain4 = general
then furtherexplanation4 = done
```

```
whileknown gexp
   receive pgen,gexp
   display "{gexp}"
   find control reset control
end
display "Press any key to continue.~";

rule 2901
if furtherexplain5 = continue
then furtherexplanation5 = done;

rule 2902
if furtherexplain5 = prod_units
then furtherexplanation5 = done
whileknown qexp
   receive pu,qexp
   display "{qexp}"
   find control reset control
end
display "Press any key to continue.~";

rule 2903
if furtherexplain5 = variance_type
then furtherexplanation5 = done
whileknown vexp
   receive type,vexp
   display "{vexp}"
   find control reset control
end
display "Press any key to continue.~";

rule 2904
if furtherexplain5 = general
then furtherexplanation5 = done
whileknown gexp
   receive qgen,gexp
   display "{gexp}"
   find control reset control
end
display "Press any key to continue.~";

rule 3001
if furtherexplain6 = continue
then furtherexplanation6 = done;

rule 3002
if furtherexplain6 = variance_type
then furtherexplanation6 = done
whileknown vexp
   receive type,vexp
   display "{vexp}"
   find control reset control
end
display "Press any key to continue.~";

rule 3003
```

```
if furtherexplain6 = general
then furtherexplanation6 = done
whileknown gexp
  receive pgen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3101
if furtherexplain7 = continue
then furtherexplanation7 = done;

rule 3102
if furtherexplain7 = prod_units
then furtherexplanation7 = done
whileknown qexp
  receive pu,qexp
  display "{qexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3103
if furtherexplain7 = variance_type
then furtherexplanation7 = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3104
if furtherexplain7 = general
then furtherexplanation7 = done
whileknown gexp
  receive ogen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3201
if furtherexplain8 = continue
then furtherexplanation8 = done;

rule 3202
if furtherexplain8 = prod_units
then furtherexplanation8 = done
whileknown qexp
  receive pu,qexp
  display "{qexp}"
  find control reset control
end
display "Press any key to continue.~";
```

```
rule 3203
if furtherexplain8 = variance_type
then furtherexplanation8 = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3204
if furtherexplain8 = general
then furtherexplanation8 = done
whileknown gexp
  receive ogen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3301
if furtherexplain9 = continue
then furtherexplanation9 = done;

rule 3302
if furtherexplain9 = prod_units
then furtherexplanation9 = done
whileknown qexp
  receive pu,qexp
  display "{qexp}"
find control reset control
end
display "Press any key to continue.~";

rule 3303
if furtherexplain9 = variance_type
then furtherexplanation9 = done
whileknown vexp
  receive type,vexp
  display "{vexp}"
  find control reset control
end
display "Press any key to continue.~";

rule 3304
if furtherexplain9 = general
then furtherexplanation9 = done
whileknown gexp
  receive qgen,gexp
  display "{gexp}"
  find control reset control
end
display "Press any key to continue.~";

ask furtherexp: "If you wish to see an explanation on
```

```
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp: general,quantity,variance_type,continue;
plural: furtherexp;

ask furtherexp1: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp1: general,quantity,prod_units,variance_type,continue;
plural: furtherexp1;

ask furtherexp2: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp2: general,variance_type,continue;
plural: furtherexp2;

ask furtherexp3: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp3: general,prod_units,variance_type,continue;
plural: furtherexp3;

ask furtherexp4: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp4: general,variance_type,continue;
plural: furtherexp4;

ask furtherexp5: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp5: general,prod_units,variance_type,continue;
plural: furtherexp5;

ask furtherexp6: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp6: general,variance_type,continue;
plural: furtherexp6;

ask furtherexp7: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp7: general,variance_type,prod_units,continue;
plural: furtherexp7;

ask furtherexp8: "If you wish to see an explanation on
```

```
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp8: general,variance_type,prod_units,continue;
plural: furtherexp8;

ask furtherexp9: "If you wish to see an explanation on
any matters of detail, select from the menu provided
below. To continue without seeing the more detailed
explanations, select 'continue'";
choices furtherexp9: general,prod_units,variance_type,continue;
plural: furtherexp9;

rule 10001
if line_count > 0
and line_count < 12
then control = found
line_count = (line_count + 1);

rule 10002
if line_count = 12
then control = found
display "Press any key to continue~"
line_count = 1;
```

ESAC 7
Expert systems in accounting

Prolog vs shells

For the purpose of this discussion, it is assumed that VP in general is a fair reflection of shells for the limited purpose defined by this particular piece of research. For stochastic models, for instance, other comments and conclusions would be appropriate.

Portability

Prolog is not genuinely portable unless Closksin and Mellish syntax is slavishly adhered to. The cause of this problem is the availability of pre-defined predicates which make considerable sense (e.g. ratom). Portability is a possibility for prolog, especially where predicates are defined to form a translation from one prolog version to another. For expert system shells, portability does not even appear to be remotely possible; the nearest to portability would be to define knowledge bases in pseudo code and call upon suppliers to offer a translation/testing/debugging service.

Efficiency and memory

Efficiency is only a problem from the point of view of loading program code and there does not seem to be any reason to differentiate expert system shells from prolog in respect of this problem. Memory constraints are overcome by modularity in design, with a consequent efficiency problem. Prolog ought to be inherently better than expert system shells but the issue is not so easy: prolog does not consume memory space for built in I/O but does consume space for data base manipulation. More work needed. Not a crucial problem for the work so far but of potential importance for future work.

Flexibility

Prolog offers a lesser constraint on the data structures which can be manipulated and is thus more flexible. Built in data base capabilities, the ability to create recursive generalised procedures, the potential for frame and slot systems answering problems raised and learning potential make prolog the more likely candidate for success in meeting specifications suggested by the research to date. Knowledge capture appears to be at a greater degree of compilation for expert system shells

I/O

More in built code offered by shells with implication that a system can be built faster. Neither expert system shell or prolog considered to be satisfactory beyond the prototype stage. Error recovery needs attention in both. Some learning required by user for operation of expert system shells.

Ease of learning

Prolog offers some challenges (the cut, order of arguments within recursive statements). Expert system shells relatively easier (to the point of boredom?).

Conclusion

For a quick, small system; the expert system shell is the obvious candidate.
Where production rules can be used to reliably and completely describe the knowledge space; the expert system shell is the obvious candidate. Assumed to be the highly compiled knowledge medium.
Where flexibility and generality are the order of the day; prolog offers advantages. Assumed to be the articulated knowledge medium.

Mix and Yield

$$\Delta mc = \sum_i \left(q \left(p_i' u' m_i' - p_i u m_i \right) \right)$$

$$= \sum_i \left(q \left((p_i - \Delta p_i) u' m_i' - p_i u m_i \right) \right)$$

$$= \sum_i \left(q \left(p_i u' m_i' - \Delta p_i u' m_i' - p_i u m_i \right) \right)$$

$$= \underline{\underline{\sum_i \left(-q (\Delta p_i u m_i) \right)}} + \sum_i \left(q (p_i u' m_i' - p_i u m_i) \right)$$

Price Variance

$$= \sum_i \left(q \left(p_i u' (m_i - \Delta m_i) - p_i u m_i \right) \right)$$

$$= \underline{\underline{\sum_i \left(-q (p_i u' \Delta m_i) \right.}} + q \left. (p_i u' m_i - p_i u m_i) \right)$$

Mix Variance

$$= \sum_i \left(q \left(p_i m_i (u - \Delta u) - p_i u m_i \right) \right)$$

$$= \sum_i \left(q \left(p_i u m_i - p_i \Delta u m_i - p_i u m_i \right) \right)$$

$$= \underline{\underline{\sum_i \left(-q (p_i \Delta u m_i) \right)}}$$

Yield Variance

Marginal costing

$$\Delta fc = q'h'c' - qhc$$

Absorption costing

Input $q'h'c'$
Output $q'hc$

$$\Delta fc = q'h'c' - q'hc$$
$$= q'h'c' - (q - \Delta q)(hc)$$
$$= \underline{\underline{q'h'c - qhc}} + \Delta qhc \quad \text{Expenditure variance}$$
$$= \Delta q(h' + \Delta h)(c' + \Delta c)$$
$$= \Delta qh'c' + \Delta qh'\Delta c + \Delta q\Delta hc' + \Delta q\Delta h\Delta c$$
$$= \Delta qh'c' + \Delta qh'\Delta c + (q - q')\Delta hc' + \Delta q\Delta h\Delta c$$
$$= \Delta qh'c' + \Delta qh'\Delta c + q\Delta hc' - q'\Delta hc' + \Delta q\Delta h\Delta c$$
$$= \Delta qh'c' + \Delta qh'\Delta c + q\Delta hc' - q'\Delta hc + q'\Delta h\Delta c + \Delta q\Delta h\Delta c$$

since $-q'\Delta hc' = q'\Delta h(c - \Delta c)$

remove $\underline{\underline{-q'\Delta hc}}$ Efficiency variance

$$= \Delta qh'(c' + \Delta c) + q\Delta hc' + \Delta h\Delta c(q' + \Delta q)$$
$$= \Delta qh'c + q\Delta hc' + \Delta h\Delta cq$$
$$= \Delta qh'c + \Delta hq(c' + \Delta c)$$
$$= \Delta qh'c + \Delta hqc$$
$$= c(h'(q - q') + q(h - h'))$$
$$= c(h'q - h'q' + qh - qh')$$
$$= \underline{\underline{cqh - ch'q'}} \quad \text{Capacity variance}$$

	Normal, budget, standard		Variance		Actual
Cost per hour	c	$-$	Δc	$=$	c'
Hours per unit of output	h	$-$	Δh	$=$	h'
Output quantity	q	$-$	Δq	$=$	q'

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Professor I L Mangham
Professor R E Thomas
Professor C R Tomkins

Dear Malcolm,

Welcome to the wonderful world of knowledge elicitation! Notice how the expert reveals more and more of his/her knowledge as the knowledge engineer just about gets on top of the last crop of ideas.

The fundamental problem is this. We started out to explain the conventional wisdom. This is compiled knowledge. Additionally, for standard costing, the knowledge is modularised and academics, working in the isolated compartments of individual modules, have not resolved the full implications of their analysis (partly, I suspect, because they do not want to. See also my comments on the Gee chapter I sent you. Gee <u>is</u> mathematically inclined. His chapter is saying something I used to teach, before I worked out the fuller implications) Your analysis is moving towards articulation ∴ issues arise which the conventional wisdom avoids (see additional notes sheet, 5-7).

We have two choices.

1) We go for a complete analysis. I can do this

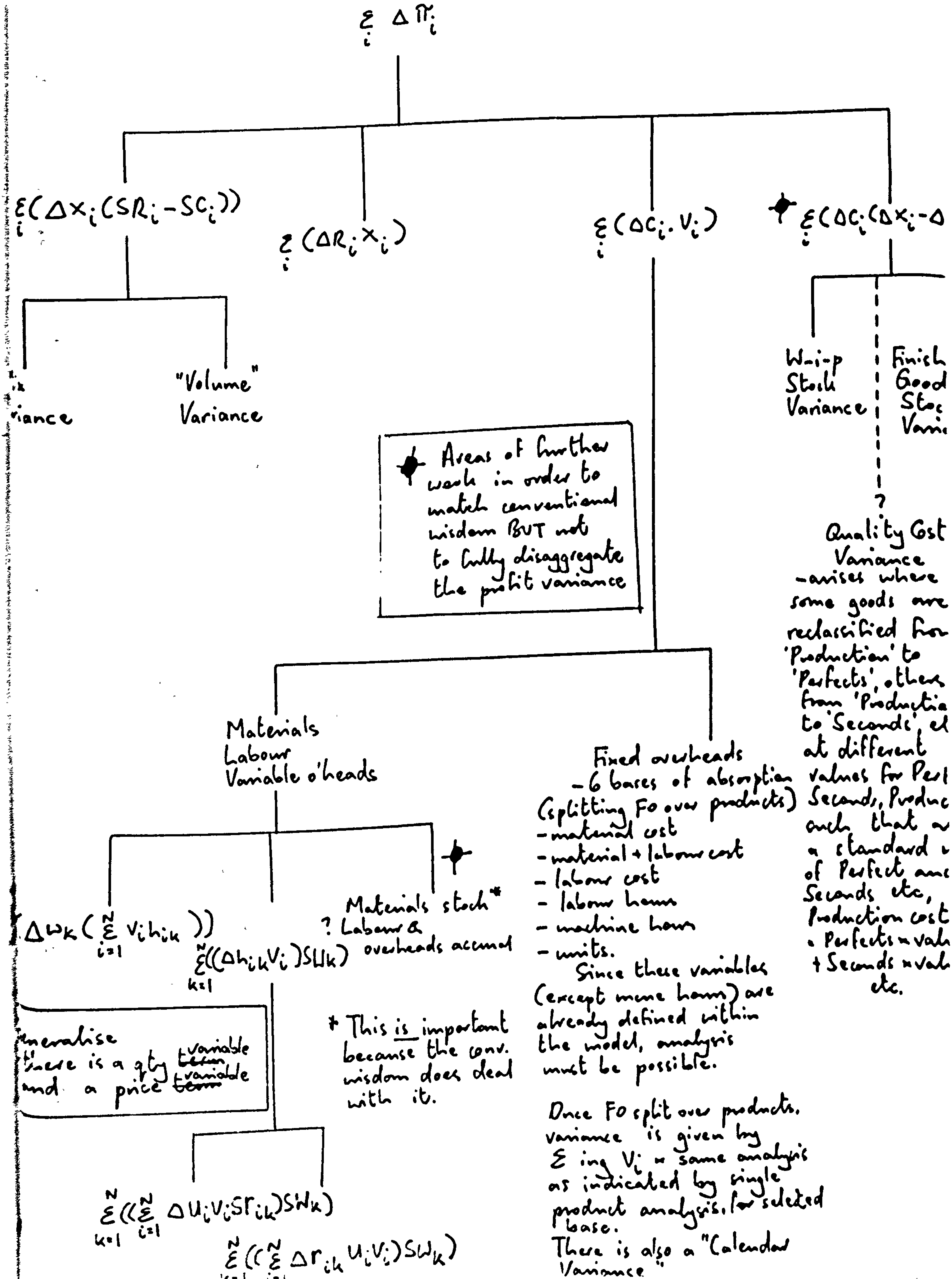
but it is clear that I handle the mathematics inefficiently. If I do the analysis, I must be the knowledge engineer re. your maths knowledge. Alternatively, if you do the maths, you have to knowledge engineer from me because the books do not help any more. I am combining practical experience of 10 years of standard costing with eight years of making sense of text-books and that practical experience. I enclose an exercise/case study I devised with the intention of showing the distillation of about 70% of the mechanical, numerical analysis knowledge I possess. No other lecturer has understood the exercise. One group of students spent a whole week arriving at an answer. Only two students have completed the exercise in less than three hours (incidentally, 2 LUT graduates, after 12 hours of standard costing lectures from me + what they knew from LUT).

2) We explain only the conventional wisdom, but discuss terms such as $\sum_i (\Delta C_i (\Delta X_i - \Delta V_i))$ in general terms, without trying to resolve them. For this analysis, we have virtually completed the analysis -

a) Multi-product profit variance needs rewriting. I have provided the input and output terms. Can you do the analysis?

b) Cost analysis with [illegible]

Variance Tree



Additional notes.

Towards a generalised representation of variance analysis

1. Single product is a trivial example of the multiple product situation ∴ only describe the multiple product

2. As 1, for multiple inputs (raw materials, labour categories....)

3. 'Materials' is the same as 'Labour' and 'Variable overhead' ∴ only need to analyse for a generalised input.

4. Lemma 3 is the two factor variance analysis, applicable to sales or any of the cost categories. (Traditional analysis reveals the joint-factor A-factor B variance and explicitly deals with this term. The justifications for the treatment might be interesting to report).

5. Conventional wisdom treats W-i-p stock variance and Finished Goods Stock Variance as:

a) Within Standard Costing "theory" – £nil ∴ Debate stock value

b) Within Integrated/Interlocking "theory" as a factor which is necessary to reconcile ~~Sta~~ Management Accounts and Financial Accounts. ∴ No need to debate stock values!

Does the left hand know what the right hand is doing?

* Stock values are debated. Raw materials provide the focus, because of 6

6. Conventional wisdom treats movement of work-in-progress as nil. Interestingly (?) CACA Stage 1 (!) has examined the implications of W-i-p. The students did not do very well. There isn't much on finish goods, either.

7. The conventional wisdom ignores the Quality Cost Variance.

8. Cost variances – I talk of stock movement, which is applicable to materials. The equivalent for labour and overheads may be 'accruals'. I think that accountants may find this analogy odd

but, in fact, both find their roots in timing differences, which is a consistent theme is financial accounting viz.

Cost input (Invoice) → Stocks → Cost in accounts

Cost input (Invoice) → Accruals → Cost in accounts.
(Wage payment) (Wages cost incurred)

Stocks and accruals reverse from period to period so that over the full life of an organisation their effect is nil.

This is not an unnecessary detail, incidentally. I am consistently chasing articulated knowledge. So far, we might have:

i) The accountant manipulates problem spaces

ii) In manipulating those problem spaces, the underlying resolution given by convention reflects:

a) the need to be consistent (see Article)

b) timing

etc.?

The exciting (impossible) implication of this is:

i) We give Prolog the term $\Delta\pi$

ii) We tell Prolog how to resolve this term, including lemmas to improve efficiency (equivalent to heuristics)

iii) We tell Prolog about principles of accounting

- i) is this a function of learning? I think so.
- ii) or are there underlying concepts which can be specified

iv) We provide heuristics.

∴ Prolog invents variance analysis.

I am not yet making a high priority of this but the implications for designing applications software are important.

Illustrate importance of stocks, in general terms

Company A begins operations on 1.1.88. ie no. stocks.

Sales 5000 units of teddy bears @ £5/bear £25,000

Purchases £20,000 of stuffing, fabric, etc.

Production 6000 units of teddy bears @ cost ??? No Work in Progr

Stocks of stuffing, fabric, etc at end of period £2,000.

Profit is not £25,000 - £20,000 £5000

BUT is

Raw materials	Opening stock	nil	
	Purchases	£20,000	
	Closing stock	£2,000	£18,000

No Work in Progress ∴ 6000 bears cost £18,000, £3 each

∴ Profit from sales of 5000 bears = 5000(5-3) = £10,000

Financial accountant would show this as

Sales		£25000
Raw materials		
O/S	-	
Purchases	20,000	
C/S	2,000	
	18,000	
Finished Goods		
O/S	-	
Cost of goods produced	18,000	
C/S (1,000 @ £3)	3,000	
Cost of goods sold		£ 15,000
Profit		£ 10,000

unit from accountant, units counted.

VARIANCE LEMMAS

For any variable X, SX is standard values

and $SX = X + \Delta X$

we interpret the sign of ΔX to suit the context, i.e. to suit X.

Lemma 1 ~~S(SA+B) = SA + SB~~

$\Delta(A+B) = \Delta A + \Delta B$

Proof:- $\Delta(A+B) = S(A+B) - (A+B) = SA + SB - A - B$

$= (SA - A) + (SB - B)$

$= \Delta A + \Delta B$.

Lemma 2 $\Delta(\sum_i A_i) = \sum_i \Delta A_i$

Proof by repeated application of lemma 1

Lemma 3 : $\Delta(A.B) = \Delta A.SB + \Delta B.A$

Proof: $\Delta(AB) = S(AB) - AB$

$= SA.SB - A.B$

$= (A + \Delta A).SB - AB$

$= \Delta A.SB + A(SB - B)$

$= \Delta A.SB + \Delta B\, A$

$$\Delta(\sum_i A_i B_i) = \sum_i (\Delta A_i SB_i + \Delta B_i A_i)$$

27/11/88

Multi-Product Profit Variance

Amend for stocks

Let π be total profit generated by N products in a period

& π_i = profit generated by product i, in a period.

X_i = Sales volume of product i, in a period

…ers to goods (…tion) R_i = Unit Revenue for sales of product i,

V_i = Volume of units of product i in the period

C_i = ~~marginal~~ cost of unit of product i . (Marginal or absorption cost)

…ment in …Progress M_i = Movement in stock for the period, units

Then $\pi = \sum_i \pi_i$

and $\pi_i = X_i.R_i - (V_i.C_i + M_iC_i)$ ~~~~

$M_iC_i = (x_i - V_i)C_i$

Now $\Delta\pi = \sum_i \Delta\pi_i$ by lemma 2

$\Delta\pi_i = \Delta(x_i R_i) - \Delta(V_i c_i + M_i C_i)$ lemma 1

$= \Delta x_i . sR_i + \Delta R_i x_i - \Delta V_i . sc_i - \Delta c_i . V_i$ } lemma 3

$= \Delta x_i (sR_i - sc_i) + sc_i(\Delta x_i - \Delta V_i) - \Delta R_i x_i - \Delta c_i$ …

$= \Delta X_i . (sR_i - sc_i)$ = Sales Margin Volume Variance

$\Delta R_i . X_i$ = Sales Margin Price Variance

$-\Delta C_i . V_i$ = Total Cost Variance.

$+ sc_i(\Delta x_i - \Delta V_i)$

Something to do with a stock variance I guess
- Correct

…is term should be $\Delta C_i(\Delta x_i - \Delta V_i)$.
…e conventional wisdom will tell you that …rk in Progress and Finished Goods are valued … Standard. This means that $C_i = SC_i$ for …ock valuation purposes $\therefore \Delta C_i$ = nil $\therefore$ …is term does not exist.

27/111/81.

Multi-Product Cost Variances

We must now expand $\Delta C_i - V_i$ = Total Cost Variance

ignoring a) Stock changes – Best not!
b) All overhead charges

$C_i = M_i + L_i + \sum M_j p_j$ where M_j is Stock movement on inputs j

M_i = Material cost of 1 unit of product i
L_i = Labour cost of 1 unit of product i

[...] necessary Cost is sum [...] inputs (Conventionally, m, l, [...]e overheads but is this an artificial convention eg. ?? applicability to Leisure Parks [...]ted for stocks of these inputs

[...] 1 $\Delta C_i = \Delta M_i + \Delta L_i$

[N]ow assume there are J different raw materials $j = 1$ to J
+ K different labour types $k = 1$ to K

[T]hen let h_{ik} = Hours of labour type k required for 1 unit of product i
ω_k = wage rate of labour type k.

u_i = Total materials used per output unit of product i
r_{ij} = fraction of material j in total materials used for product i
q_{ij} = quantity of material j used in production of 1 unit of product [i]
p_j = price per unit of ~~product~~ material j

Now $H = (h_{ik})$ is an $N \times K$ matrix

+ $R = (r_{ij})$ + $Q = (q_{ij})$ are $N \times J$ matrices

with $q_{ij} = u_i r_{ij}$

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Labour Variances   Take ~~ΔC_i~~ $= C_i = L_i + M_j P_j$ from the (3)

$$L_i = \sum_k' h_{ik} . w_k$$

ie include stock term
Stock term resolves in 3 valid poss ways. Either discuss or I will check

lemma 2 $$\Delta L_i = \sum_k' \Delta (h_{ik} w_k)$$

lemma 3 $$\Delta(h_{ik} . w_k) = \Delta h_{ik} . S w_k + \Delta w_k . h_{ik}$$ yearam

Labour component of $\Delta C_i . V_i \doteq \sum_{k=1}^{K'} (\Delta h_{ik} . S w_k + \Delta w_k . h_{ik}) V_i$

Labour component of $\Delta \pi = \sum_{i=1}^{N'} \left(V_i \sum_{k=1}^{K'} [\Delta h_{ik} S w_k + \Delta w_k . h_{ik}]\right)$

So changing the order of summation

Labour component of $\Delta \pi$ = Sum over all different labour types k (ie $\sum_{k=1}^{K'}$)

of $\left(\sum_{i=1}^{N'} \Delta h_{ik} V_i\right) . S w_k$ = labour efficiency variance of labour type k

+ $\Delta w_k \left(\sum_{i=1}^{N'} V_i h_{ik}\right)$ = wage rate variance of labour type k

---

which agrees with standard text books since

$\sum_{i=1}^{N'} V_i h_{ik}$ = total actual hours of labour type k used

~~$(\Delta h_{ik}) = \Delta\left(\sum_{i=1}^{N'} h_{ik}\right) =$ Standard - actual hours of labour type k used.~~

$\sum_{i=1}^{N} (V_i . \Delta h_{ik})$ = ? don't know what to call this ?
? Standard hours - Actual hours (I don't think there is a name)
? Variance as measured in hours

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Material Variances

These can be handled at 2 different levels

Take $M_i = \sum_{j=1}^{J} q_{ij} P_j$

Then this is identical form to Labour ∴∴ Yes! ∴ Eureka = advantage of articulated know[ledge]. Students don't seem [to] appreciate that ex[...] variance analysis comes down to 3 basic variances

So Material component of $\Delta\pi$ = Sum over all different materials j

material j component of $\Delta\pi$ =

$$= \left(\sum_{i=1}^{N} V_i \Delta q_{ij}\right) . SP_j = \text{Material j usage variance}$$

ie same as labour efficiency

+

$$\Delta P_{j_0} \left(\sum_{i=1}^{N} V_i q_{ij}\right) = \text{Material j price variance}$$

ie same as labour rate

→ Total Quantity of Material j used.

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... + yield variances fine ✓

Now take $m_i = \sum_{j=1}^{J} u_i r_{ij} p_j$ i.e. $q_{ij} =$

This is the same as before, i.e. that

$$\Delta(q_{ij} \cdot p_j) = \Delta q_{ij} \cdot Sp_j + \Delta p_j \cdot q_{ij}$$

now

$$\Delta q_{ij} = \Delta(u_i r_{ij}) = \Delta u_i . Sr_{ij} + \Delta r_{ij} . u_i$$

so material j usage variance

$$= \left(\sum_{i=1}^{N} \Delta u_i . V_i . Sr_{ij}\right) Sp_j$$ ✓ material j yield variance

$$+ \left(\sum_{i=1}^{N} \Delta r_{ij} . (u_i V_i)\right) Sp_j$$ ✓ materials j mix variance

I wonder if this only makes sense if it is summed over all j materials ✓

- I also wonder if I have this the right way round. it could be I should use

$$\Delta(r_{ij} u_i) = \Delta r_{ij} Su_i + \Delta u_i . r_{ij}$$

this would change Sr_{ij} to r_{ij} in yield variance

+ also u_i to Su_i in mix variance

caused by differences in proportions ??

caused by differences in quantity.

28/11/88

This looks fine
Inputs/Outputs checked 30/11/88

Laurie,

Please find enclosed my interpretation of what is happening with overhead costs in both the Variable case and the Absorption model.

I think I now understand what is going on in the analysis of overheads in the simple case of 1 product and only 1 set of hours, based say one key labour type.
To complete the analysis in this simple case all we need is the correct treatment of 'stocks' and 'work in progress'. This requires your expert knowledge & I believe you said you had done this. I hope this fits in with our analyses so far – I am sure it will – Because of my definition of V_i in your earlier paper, this does not apply to overheads in any significant new way.
The difference in the way the Variable and Absorption model treat the variance is interesting and I am just beginning to appreciate why and what the meaning is.

At the moment I don't see how to extend the overhead analysis to the multi product or the multi-labour-type case (or both for that matter). I need your expert knowledge to tell me what MA's actually do in these cases.

By the way, if this sort of complete analyses is not well known in books, it is probably not well known in academic circles or in journals. If that is the case, we definitely ought to publish the Maths in a refereed journal – and soon!

Cheers
Malcolm

O/H Costs – Single Product Case

Let FO = O/H's charged to production in a period

then $\pi = X.R - (V.C + FO + \text{WIP \& FG. Stock movement})$

The true profit variance $\Delta\pi$ is given by

$$\Delta\pi = \Delta(X.R - V.c) - (SFO - FO) \quad (1)$$

In the case of Absorption Costing

it is taken that

$$FO = V.HR.OR$$
$$= V.OCR \checkmark$$

where
OR = o/h cost per overhead hour
HR = o/h hour per unit produced
$H = V.HR$ = Actual ~~o/h~~ hours worked
$OCR = HR.OR$ = Overhead rate per unit produced.

Now OR, ~~HR~~ std., OCR are ~~not~~ usually known or calculated, → calculated from knowledge of the other variables.
but SOR, SHR, $SOCR$ are calculated. → Determined in advance. eg. technical studies, mgr. judgement
It is usually take that H is known.

Theoretically
$$\pi = X.P - V.c - V.OCR$$
so
$$\pi = X.P - V.c' \quad \text{where } c' = c + OCR$$

From previous work (replacing c by c')

$$\Delta\pi = \Delta X_{\&}(SR - SC')$$
$$\Delta R.X$$
$$SC'(\Delta X - \Delta V)$$
$$\Delta c'.V$$

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$\Delta\pi$ can be rewritten

$$\Delta\pi = \Delta X.(SR - SC') + \Delta R X + SC'(\Delta X - \Delta V) + \Delta C.V + \Delta OCR.V \quad (2)$$

All terms on the first line make sense with SC' the total standard marginal cost.

The problem is $\Delta OCR.V$

$\Delta OCR.V$ = Total fixed o/H variance in (2)

$= (SOCR - OCR)V$

$= V.SOCR - FO$ as per text books

Comparing (1) & (2) we see that

$\Delta OCR\ V = (SFO - FO) + SOCR.\Delta V$

i.e. $\Delta OCR.V = (SFO-FO) + (SV-V).SOCR$ = Volume Variance.

$= (SFO-FO) + (SV-V)(SHR)(SOR)$

$= (SFO-FO) + (SV.SHR - V.SHR)SOR)$

$= (SFO-FO) + \{(SV.SHR - H) + (H - V.SHR)\}SOR$

$= (SFO-FO) + (SV\,SHR - H)SOR + (H - V.SHR)SOR$

So inserting this expression of $\Delta OCR.V$ in (2), the total fixed O/H variance part is split into 3 parts viz.

$\Delta\pi = \Delta X.(SR - SC') + \Delta R.X + SC'(\Delta X - \Delta V)$

$+ \Delta CV$

$+ (SFO - FO)$ = Fixed o/H expenditure Variance

Volume Variance: $+ (SV\,SHR - H)SOR$ = Volume capacity Variance

$+ (H - V.SHR)SOR$ = Volume efficiency Variance

Which agrees with text books - although the stock part is still a mystery to me.*

This is clearly a bit more of problem for the multi-product cases. How is FO & SFO split among the products? → There 6 methods of which are the major

* We can either pull it out here OR leave it in the $\sum_i(\Delta C_i(\Delta X_i - \Delta V_i))$ term from 29/11/88.

N.B Drury has the following definitions:–

Expenditure Variance = SFO – FO

Total Fixed O/H variance = V. SHR. OR – FO

However these two gives –

Volume Variance = (V – SV). SHR SOR

This is split into:–

Volume efficiency Var = (V SHR – H). SOR

\+

Vol. capacity Var = (H – SV. SHR). SOR

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In the case of Variable Costing

it now makes sense to let $OCR = VHR.VOR$
and the awkward term in ②
can be resolved by using

$$\Delta OCR = \Delta VHR.SVOR + \Delta VOR.VHR$$

+ multiplying by V

$$\Delta OCR.V = \Delta VOR.V.VHR + \Delta VHR.V.SVOR$$

Hence now

$$\Delta OCR.V = \text{Total variable O/H variance}$$

$$= \Delta VOR.V.VHR = \text{Variable O/H expenditure variance}$$

$$+ \Delta VHR.V.SVOR = \text{Variable O/H efficiency variance}$$

where.

Var. O/H Expenditure Var = $\Delta VOR.V.VHR$

$= SVOR.(V.VHR) - VOR.V.VHR$

since $H = V.VHR$ $= SVOR.H$ — Actual Var o/h cost

+

Var. O/H efficiency Var $= \Delta VHR.V.SVOR$

$= (SVHR - VHR)V.SVOR$

$= (V.SVHR - V.VHR).SVOR$

$= (V.SVHR - H).SVOR$

This agrees with DRURY.

29/11/88.

Variance analysis: the case of stocks

In the general case:

Financial situation

Raw materials

		£
Opening stock	20kg @ £3	60
Purchases	30kg @ £4	120
Closing stock	18kg @ £4	(72)
Issued to production	32 kg	108

Finished goods

			£
: 4 kg @ £2.50]	Opening stock	5 units @ £10	50
	Production	12 units	108
: 3kg @ £3]	Closing stock	7 units @ £9	(63)
	Cost of Sales		95

		£
Sales	10 units @ £20	200
Cost of Sales		95
Gross Profit		105

Standard

		£/unit
Standard cost	3kg @ £5/kg	15
Standard selling price		20
Standard Profit	10 units @ £5/unit	50

Profit Variance (£105-£50) £ 55 fav.

Analysis

	Price variance taken at: Purchase Stage	Usage Stage
Price Variance	£30 fav	£52 fav
Usage Variance	£20 fav	£20 fav
Raw materials stock variance	£22 fav	nil
Finished goods stock variance	£17 adv	£17 adv
	£55 fav	£55 fav

Stock movement: Rm −2kg Actual +£12 Standard −£10 Variance £22 fav.
Fg +2units Actual +£13 Standard +£30 Variance £17 adv.

Stock variance analysis

			Actual	Std	Price Variance	Usage Variance
Raw materials	o/s	20kg	60	100	+40	
	c/s	(18kg)	(72)	(90)	−18	
					+22	
Finished goods	o/s	5 units	50	75	+50	−25
	c/s	(7 units)	(63)	(105)	−42	nil
					+ 8	−25

Mathematical exposition

	Actual	Standard	Varia…
Input quantity per output unit	aQ	sQ	vQ
Input price per input unit	aP	sP	vP
Units of output	U		
Stock level	L		

os Opening stock cs Closing stoc…
rm Raw materials fg Finished good…
p Period

Actual (Financial cost)

$U(aQaP)$ But how do we define U, aQ and aP ?

Analysis:

…al	(U) Unit	kg Total	(aQ) kg/unit	(aP) £/kg	£	Standard (sP)	(sQ)	Variance (UaQ.vP) Price type	(sP.U.vQ) Quantity type
…w materials								$12 \times 2\frac{2}{3}$(3·375−5) £52 fav.	
…s		20		3	60	5		20(3−5) £40 fav.	
…ch		30		4	120	5		30(4−5) £30 fav.	
/s		(18)		4	(72)	5		18(4−5) £18 adv.	
								£22 fav.	
		32		3·375	108	5		32(3·375−5) £52 fav.	
…shed goods									
/s	5	20	4	2·50	50	5	3	5×4(2·5−5) £50 fav.	£5(5×(4−3)) £25 adv.
	12	32	2⅔	3·375	108		3		£5(12×(2⅔−3)) £2…
/s	(7)	(21)	3	3	(63)	5	3	7×3(3−5) £42 adv.	£5(7×(3−3)) nil
								£8 fav.	£25…
…es	10				95				

Notes

a) <u>Units.</u> For raw materials, the concept of "equivalent units for raw material quantities" would seem to be necessary to provide a unified scheme. Assuming quantities of raw materials are sensibly convertible to Units, which is doubtful, the conversion must be made in terms of average actual quantities of input per unit,

$U.aQ.vP$ becomes $12.\ 2^{2}/_{3}.(3{\cdot}375-5)$
where $U.aQ$ = Issues from raw material stock

This decomposes to

① $L_{os}.aQ.vP - L_{cs}.aQ.vP$
② + a silly term which is $U - L_{os} + L_{cs}\ (aQvP)$
where $(U - L_{os} + L_{cs})(aQ)$ = Purchases of raw materials.

② The silly term is a mechanical term in the conventional wisdom of budgeting.
① i) In the case where the variance is calculated at the usage stage, vP = nil ∴ This term must disappear.
ii) In the case where the variance is calculated at the purchases stage, the conventional wisdom states that $aP = sP$ ∴ vP = nil and this term is ignored, effectively.
iii) In practical cases, there is no reason why this term should not be analysed. The conventional wisdom deals with the analysis under the section on Integrated / Interlocking accounts.

Note that for this analysis, U is the Production units. In the case of Work-in-Progress stocks, U would be Production units adjusted for work-in-progress (assuming Production is synonomous with output rather than work done).

For finished goods, production and sales units could be defined as U. There logical course of action is to define U = sales. The full analysis then becomes:

Standard Profit = $U.sP.sQ$
Actual Profit = ? because what do aQ and aP mean?

An input approach is necessary, perhaps based on $U - L_{os} + L_{cs}$ as a definition of production (this is again known to the conventional wisdom of budgeting).

However. "Actual Profit = $(U - L_{FGOS} + L_{FGCS})(aQaP)$" does not work, because in the general case, L_{FGOS} and L_{FGCS} can be valued at different values, ie aQ and aP may differ.

∴ U must be Production
Further, U must be Production = Work done in the case including Work-in-Progress since W-i-p. valuation is carried out on same basis as Finished goods.

∴ $\text{Actual Profit} = U.aQ_p.aP_p - L_{FGOS}.aQ_{FGOS}.aP_{FGOS} + L_{FGCS}.aQ_{FGCS}.aP_{FGCS}$

where $U.aQ_p.aP_p$ gives Usage and Price variances, as earlier and lemma 3

The conventional wisdom states that stocks must be valued at standard so the Stock level terms reduce to zero.
Stock variances can be calculated in practice and are described by the conventional wisdom under Integrated/Interlocking accounts.

Conclusions

From the general case, illustrated by the example above:

(i) A full analysis can be generated and explained in terms of the combined conventional wisdom of standard costing, budgeting and integrated/interlocking accounts.
Discussion: Is the conventional wisdom a sensible way of breaking down complexity into modules for teaching purposes? Why is the conventional wisdom taken to be best practice? Why is the conventional wisdom of standard costing not related to other areas, eg. in the debate over valuation of stock at standard and the impact on the point at which the price variance is taken?

(ii) The mathematics reduces to applying lemma 3 to individual terms within the definition of Financial profit. The conventional wisdom states that stocks of Work in Progress and Finished Goods are to be valued at standard, which reduces the stock terms to nil.

(iii) Raw materials gives rise to 3 alternative analyses based on a) point at which price variance is taken, b) stock valuation basis. The first is an organisational consideration, the second a function of organisational and auditing considerations.

- Price variance extracted at Purchase stage, Stocks valued at standard
- " " " " Issues " , " " " actual
- " " " " Purchase " , " " " "

The fourth combination could be said to be the worst of both worlds but is clearly technically feasible.

The analysis of raw materials is artificial in the sense that the U term is not a physical reality. Raw material stocks make sense in terms of U.Q. and (U+L)Q combinations.

iv) The conventional wisdom simplifies variance analysis by relaxing assumptions regarding stocks. Why? In particular, why teach that raw material stocks can be valued at actual OR standard, with a resultant implication for the price variance calculation WHILST work-in-progress and finished goods are valued at standard? Is such teaching useful?

v) Thinking in general terms is more difficult than analysing through reconciliation (the principal approach to the example). Will anyone else be interested in making the effort.

vi) The implications for computing are exciting BUT computerising compiled knowledge is trivial whilst time consuming whilst computerising articulated knowledge is a voyage into the unknown. For the above, articulated knowledge would be:

a) product cost (cost = quantity x price. This is ost theory. Note the straight line assumption and the possibility in practice of defining more sophisticated functions)

b) definition of (actual) financial profit

c) lemma 3

d) application of lemma 3 to individual variables in product cost

e) stock valuation basis

f) point at which to take price variance.

a) and b) are definitions. e) and f) could be the basis for expert systems.